GEOTECHNICAL REPORT

SR-90

MP 2.54 to 9.28

I90 Two Way Transit & HOV Operations

Geotechnical Recommendations for W 80th Line Ramp Bridge XL-2423

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10/27/05

October 27, 2005

Washington State
Department of Transportation
Douglas B. MacDonald
Secretary of Transportation

Environmental & Engineering
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Contents

1. Project Location and Description

This project will provide Two-Way Transit and HOV lanes between Seattle and Bellevue. HOV lanes will be added to the left of the general purpose lanes on the eastbound and westbound mainline roadways. Where existing reversible lanes exist, they will be maintained in their current configuration.

As part of this project, a direct access ramp will be added to connect the proposed westbound HOV lane to the existing 80th Ave. SE undercrossing on Mercer Island. The proposed bridge will be a 3 span structure. The west abutment will be a non-structural connection between the existing bridge and the proposed ramp bridge. An existing tunnel providing access from SE Island Crest Way to westbound SR 90 is within 10 feet of pier 1 of the proposed ramp bridge. Figure 2 shows a layout of the proposed bridge and the existing bridge and tunnel structures.

2. Regional Geology

The project site is located in the central portion of the Puget Sound Lowland geomorphic province. The Puget Sound Lowland is an elongated topographic and structural depression bordered by the Cascade Mountains to the east and the Olympic Mountains to the west. The Puget Lowland owes its present-day geomorphology to the most recent glacial advance and retreat, known as the Vashon Stade of the Fraser Glaciation. This ice sheet filled the Puget Lowlands with as much as 3,000 to 5,000 feet of ice at least four different times during this period.

The Puget Sound area is underlain by a thick, complex sequence of glacial and interglacial sediments. Meltwater flowing from the advancing ice sheet transported a variety of sediment that built a broad outwash plain. Coarse sediment such as sand and gravel was deposited in the high-energy environment near the advancing glacier. Finer sediment such as silt and clay was deposited in the low-energy environment further from the glacier and in ponds and lakes that were formed as the advancing ice sheet blocked meltwater channels. As the ice sheet advanced, these sediments were overridden by hundreds of meters of ice and were compacted to their present condition. Following the last glacial advance and retreat, alluvial (river) and lacustrine (lake-bed) sediments were deposited by runoff from the eastern slopes of the Olympics. The more recent portions of these sediments (lower-energy) consist of fine-grained sands, silts, and clays.

A geologic map titled *Geologic Map of Surficial Deposits in the Seattle 30' x 60' Quadrangle* (James C. Yount, James P. Minard, and Glenn R Dembroff, 1993) indicates the project site is underlain by Vashon Till. This till generally ranges form gravelly, sandy sit to silty sand with varied quantities of clay, cobbles, and boulders.

3. Site Conditions

The W 80th Ramp Bridge will be constructed in an existing, landscaped median between the westbound mainline and reversible lanes on I 90. The median is raised above the traffic lanes approximately 3 feet. Traffic barriers are serving as retaining walls to provide the grade separation between the roadway and the median. The landscaping generally consists of brush and coniferous trees. The trees are generally 25 to 35 feet in height and are dense enough to provide a complete visual barrier between the westbound mainline and reversible lanes.

4. Field Exploration

Our field exploration consisted of advancing one exploratory boring at each proposed bridge pier. Each boring extended to a depth of approximately 100 feet below the existing ground surface. Piezometers were installed in each boring to monitor groundwater elevations.

5. Site Soil Conditions

Based on our test borings, there are two general soil units underlying the project site. Unit 1 consists of fill material placed during construction of I 90 and the existing tunnel structure. It appears the tunnel was constructed using cut and cover technology and an open cut, without shoring, was used. Fill was encountered to depths of 25 feet in the vicinity of the tunnel (boring BH-1-05). Away from the tunnel the fill is approximately 10 feet thick. The fill generally consists of loose to very dense poorly graded sand with silt and gravel. Underlying the fill is generally dense to very dense silt with sand and sandy silt. This unit is interpreted to be glacial till. Interbedded sand and gravel seams were encountered in the till. Stiff to very hard clay was encountered at depths of 85 to 105 feet below the existing ground surface in boring BH-1-05.

6. Groundwater

Groundwater was encountered in each of the borings performed for this project. Open standpipe piezometers were installed in each of the borings to monitor groundwater levels. Depths to groundwater vary with time of year and other factors. Due to the relatively short period of time between the drilling and preparation of this report, water level readings have only been taken during the drier summer months. We anticipate water levels will be higher during the wetter winter and spring months. We will continue to monitor the water levels up through preparation of the PS&E documents. If there is a significant change in water level that would affect the design, we will provide revisions to our recommendations. Water levels and the date of the readings are presented on the boring logs.

7. Seismological Considerations

7.1. Site Seismicity

The seismicity of the area is predominantly influenced by the oblique subduction of the Juan de Fuca Plate under the North American Plate. The convergence between the plates is estimated to be about 4 cm per year. Within this active tectonic environment, three possible sources for seismic events in the Seattle area have been identified. The first two sources are intraplate and are related to plate deformations and stress concentrations within the two plates as they are deformed by the subduction process. The first source is near surface within the continental crust of the uplifting North American Plate, and the second source is deeper within the subducting Juan de Fuca plate. The third source is off shore near the subduction line between the two plates and is related to movement along the subduction interface. This source has recently been referred to as the Cascadia Subduction Zone.

Shallow crustal seismicity within the North American plate, until recently, was thought to be limited in magnitude, less than 3 on the Richter scale, and unrelated to specific structures within the Puget Sound Lowland. Recent evidence suggests that some geologic structural control may be present and that these structures may be capable of producing shallow crustal seismic events with magnitudes greater than 6 on the Richter scale. One such structure is the inferred Seattle

Fault. Evidence suggests that relatively recent activity has occurred along this fault, approximately 1,100 years ago. One of the most recent earthquakes of record from a shallow crustal source was the Richardson Point earthquake on January 28, 1995. The earthquake was a magnitude of 5 on the Richter scale and ground accelerations of 0.07g were recorded. Minor damage and some liquefaction was evident as the result of ground shaking.

Other notable earthquakes within the region have generally been attributed to the intraplate seismicity within the Juan de Fuca plate. On April 13, 1948, a magnitude 7.0 earthquake occurred, on April 29, 1965, a magnitude 6.5 earthquake occurred, and on February 28, 2001 a magnitude 6.9 earthquake occurred. These two quakes are believed to be from this source. Both of the quakes caused damage and liquefaction within the Seattle/Olympia area.

The Cascadia Subduction Zone has not experienced a known earthquake within the last 165 years of seismic record. However, evidence suggests that at various times within the last 3,500 years many coastal estuaries have experienced rapid subsidence as the result of seismic activity related to this zone. It is generally believed that this source is capable of producing seismic events as large as magnitude 9.

7.2. Design Earthquake Parameters

Seismic activity in the Puget Sound Lowland is largely attributed to the Cascadia subduction zone, where the Juan de Fuca oceanic plate is being thrust under the North America Plate. In addition, shallow crustal faults are also considered to have caused sudden uplift and subsidence in the Puget Lowland. Recent investigations indicate a major fault is located through downtown Seattle, between Bainbridge Island and Issaquah, and is termed the "Seattle Fault." In the project vicinity, the fault is thought to roughly parallel I 90. Geologic evidence indicates a large earthquake was generated along this fault approximately 1,100 years ago.

While the seismicity of Washington is not as well understood as other areas of western North America, seismologists believe that the local subduction zone has created great interplate earthquakes in the past (Modified Mercalli Intensities up to VIII), and is capable of future earthquakes on the order of magnitude 7; however, the recurrence interval of such earthquakes is anticipated to be infrequent (i.e. thousands of years).

For seismic design, a peak bedrock acceleration coefficient of 0.32 is recommended, based on the 2002 US Geological Survey National Seismic Hazards Mapping Project. The recommended acceleration coefficient is based on expected ground motion at the project site that has a 10 percent probability of exceedence in a 50-year period (475-year return period). Design response spectra presented in the *AASHTO LRFD Bridge Design Specifications* are considered appropriate for the seismic design of this bridge. A Type II Soil Profile response spectrum, with a Site Coefficient of 1.2 is recommended for seismic design.

7.3. Liquefaction Potential

The liquefaction potential of saturated soils is evaluated mainly on soil gradation, density, and the depth of the deposit. The potential for liquefaction is highest for loose, fine to medium grained sands and silty sands. Increasing fines content (i.e., silt and clay) decreases the potential for liquefaction. Conversely, clean coarse grained granular soils are less susceptible to liquefaction due to their high permeability. The potential for liquefaction also decreases with increasing density and depth.

We have evaluated the potential for liquefaction of the project soils based on the SPT data obtained from the field explorations and the percentages of silt. Our analysis indicates that the potential for liquefaction is low.

8. Geotechnical Recommendations

8.1. Approach Slabs

Section 8.6.5.3 of the *WSDOT Geotechnical Design Manual*(M 46-03) requires the use of approach slabs where approach embankments exceed 8 feet in height. We recommend approach slabs be used at the east abutment of the W 80th ramp bridge.

8.2. Foundation Recommendations

Due to the proximity of the tunnel, drilled shafts are the preferred foundation type at Piers 1 and 2. Both drilled shafts and spread footings are suitable foundation types at the east abutment. The following sections provide design information for both drilled shafts and spread footings.

8.2.1. Drilled Shafts

Enclosed in Appendix D are ultimate capacity charts for strength, service and extreme event limit states in English units. We understand the shaft sizes at Piers 1 and 2 are controlled by the proposed column size. We have provided capacity charts for 8-foot diameter shafts based on discussions with the Bridge and Structures Office. The charts show the load that can be applied at the top of the shaft. The weight of the shaft has not been deducted from the compressive capacity in the figures and is not included in the uplift. The capacities or loads shown in the figures are those that can be applied at the top of shaft. The net weight of the shaft should be treated as a load applied to the top of the shaft. Uplift capacity can be equated to the nominal skin friction on the charts.

Separate plots for ultimate skin friction (Q_s) and ultimate end bearing (Q_b) are provided on the capacity charts. At a given depth on the figures, the factored resistance (Q′) can be determined by adding the ultimate skin friction multiplied by its resistance factor (ϕ_s) and the ultimate end bearing multiplied by its resistance factor (ϕ_b) as shown in the following equation:

$$Q' = Q_s \cdot \phi_s + Q_b \cdot \phi_b$$

For the service limit state, the settlement of the shaft foundations will be less than 1 inch. Settlement will occur as the loads are applied. Post construction settlement should be negligible.

We recommend that the following resistance factors be used when evaluating the different limit states.

Drilled Shaft Resistance Factors

Limit State	Resistance Factor ϕ		
	Skin Friction Qs	End Bearing Qb	Uplift
Strength	0.60	0.55	0.45
Service	1.00	1.00	N/A
Extreme	1.00	1.00	0.8

There are no geotechnical reasons to specify a shaft tip elevation. The shaft tip elevations should be determined by the structural engineer, as we anticipate lateral loading will govern shaft length. Soil parameters for use in lateral analysis of the shafts are included in Appendix D.

8.2.2. Special Considerations for Pier 2

The side of an 8-foot diameter drilled shaft at Pier 2 will be within 3 feet of the existing S-W ramp tunnel. During preparation of our preliminary recommendations, we were concerned that movement of the shaft and tunnel during extreme event loading could damage the structures. Our preliminary recommendation was to isolate the bridge column from the surrounding soil with a permanent casing and placing the top of shaft elevation at the same elevation as the bottom of the tunnel. The Bridge and Structures Office has analyzed this scenario, and the results indicate the column length difference between Piers 1 and 2 results in unacceptable loading conditions. One alternative would be to install the same casing at Pier 1, however this would be costly due to the increased material costs and the construction difficulties.

After further consideration, and discussions with the Bridge and Structures Office, we feel the risk of damage to either or both of the structures during extreme event loading is low if the top of shaft elevation is at or near the existing ground surface. Placing the top of shaft at the ground surface simplifies the construction and will reduce construction costs.

Figure 4 in Appendix A provides pressure distribution information for estimating the loads imposed on the tunnel by the shaft during an extreme event. We are recommending the pressure on the tunnel be approximated by using a triangular distribution vertically, and a 2 to 1 horizontal distribution as shown on Figure 4. The magnitude of the pressure will need to be computed using L-PILE, SIL-SHAFT, or a similar analysis program. The soil springs can be developed using the soil parameters for lateral analysis provided in Appendix D. Soil Springs for shaft movement in the direction of the tunnel will need to be combined with the structure springs from the tunnel, see Figure 5.

8.3. Spread Footing Recommendations for the East Abutment

Spread footings are a suitable foundation type at the east abutment of the proposed bridge. Appendix E contains tables of bearing capacity versus footing width for service, strength, and extreme limit states for each bridge. In order to provide adequate service limit state bearing capacity, we recommend a maximum footing elevation of 65.0 feet.

Equivalent spring constants for the spread footing foundations should be determined by the method outlined in Section 7.2.4 of FHWA Report No. IP-87-6 titled: *Seismic Design and Retrofit for Highway Bridges*. The shear modulus and Poisson's ratio of the foundation soil must be estimated to calculate the equivalent spring constants using this method. Based on the results of our analysis, we have developed a range of shear modulus values for the soil units under the subject spread footing. The most critical spring constant depends on the rigidity of the superstructure. This is determined by the structural engineer. Ranges of shear modulus values are presented in Appendix E, so as to determine which is more critical, a weak or stiff spring.

We recommend the following resistance factors be used when evaluating the different limit states.

Spread Footing Resistance Factors

Limit State	Resistance Factor ϕ		
	Shear Resistance to Sliding	Passive Pressure Resistance to Sliding	Bearing
Strength	0.80	0.50	0.45
Service	N/A	N/A	1.00
Extreme	0.90	0.90	0.90

Abutment walls should be designed using the lateral earth pressure coefficients and soil parameters provided in Appendix E, in conjunction with the design methods presented in the WSDOT *Bridge Design Manual*. We recommend disregarding the upper 2 feet of soil against the front face of the abutment wall when determining passive soil resistance unless pavement is located at the toe. Per the *Bridge Design Manual*, the lateral earth pressure due to traffic surcharge loading can be calculated by using a uniformly distributed load at the ground surface of 250 psf multiplied by K_a.

9. Construction Considerations

Seepage is expected in the shaft excavations. The contractor should be prepared to use drilling slurries or casing to control groundwater and maintain sidewall stability. Temporary casing will be necessary in the man-made fills near the surface. Casing tip elevation recommendations for Pier 1 and the East Abutment are essentially for surface casing only. The casing elevations shown in the following table should be included in the Contract.

Casing Limits

Wall Name or Bridge No.	Wall Station or Bridge Pier Number	Casing Type	Elev. of Bottom of Required Casing[(1)] (ft)	Upper and Lower Elevation Limits for Concurrent Casing Placement with Excavation (ft)
W80th Ramp	Pier 2	Temporary	54	G.S.[(2)] to 54.[(3)]
W80th Ramp	Pier 1	Temporary	65	G.S.[(2)] to 65
W80th Ramp	East Abutment	Temporary	65	G.S.[(2)] to 65

(1) If the shaft tip elevation is above the limit specified, then casing is required only to the tip elevation of the shaft.
(2) G.S - Ground surface elevation or the bottom elevation of casing shoring.
(3) See report text for information regarding casing at Pier 2.

When installing the required casings between the upper and lower elevation limits specified above, the casings should be advanced prior to or concurrently with the shaft excavation. Excavation in advance of the casing tip should not exceed 2 feet.

Casing installation using vibratory methods at Pier 2 may damage the existing tunnel. We recommend casing installation methods that limit ground vibration be used at Pier 2. These methods could include placement of the casing in an open-hole excavation, or use of casing oscillators or rotators. Casings at Pier 1 and the East Abutment may be installed using vibratory or other methods.

While not specifically encountered in the borings, cobbles and boulders may be present based on the geologic nature of the soils. The shaft contractor should be prepared to remove cobbles and boulders during shaft construction.

10. Recommended Additional Services

Because the future performance and integrity of the geotechnical elements of this project will depend largely on proper PS&E preparation and diligent construction procedures, we recommend that the Geotechnical Division (GD) in conjunction with the Regional Materials Engineer (RME) provide the following post-report services:

- The GD should prepare the Summary of Geotechnical Conditions to be included in the PS&E as an appendix. The summary should be prepared as part of the PS&E review process.
- The GD/RME should review all construction plans and specifications to verify that the design criteria presented in this report have been interpreted correctly and properly integrated into the design.
- The GD/RME should attend pre-construction conferences with the Construction Project Engineer and Contractor to discuss important geotechnical related construction issues.
- The GD/RME should review Contractor submittals for all shoring walls and other geotechnical elements of this project.
- The RME should observe all exposed subgrades after completion of stripping and excavation to contract elevations. The RME should confirm that suitable soil conditions have been reached and determine appropriate subgrade compaction methods.

In addition to the aforementioned services, the Geotechnical Division can provide inspector training for construction personnel, assist in change of condition claims, and review cost reduction incentive proposals (CRIPs).

11. Intended Report Use and Limitations

This report has been prepared to assist the Washington State Department of Transportation in the engineering design and construction of the subject project. It should not be used, in part or in whole for other purposes without contacting the EEP Geotechnical Division for a review of the applicability of such reuse. This report should be made available to prospective contractors for their information or factual data only and not as a warranty of ground conditions.

The conclusions and recommendations contained in this report are based on the Geotechnical Division's understanding of the project at the time that the report was written and on site conditions that existed at the time of the field exploration. If significant changes to the nature, configuration, or scope of the project occur during the design process, the Geotechnical Division should be consulted to determine the impact of such changes on the recommendations and conclusions presented in this report.

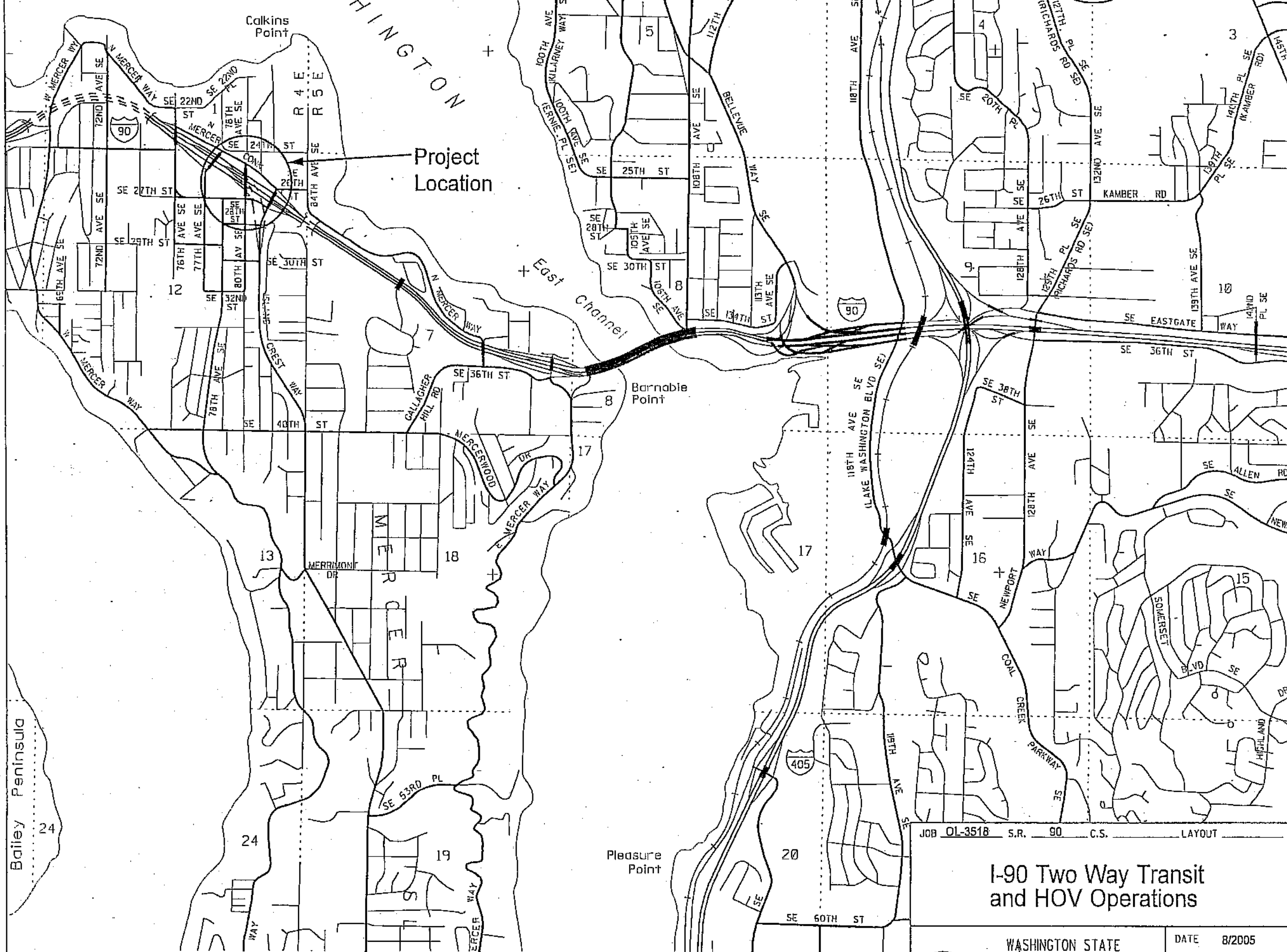
Site exploration and testing describes subsurface conditions only at the sites of subsurface exploration and at the intervals where samples are collected. These data are interpreted by members of the Geotechnical Division who then render an opinion regarding the general subsurface conditions. The distribution, continuity, thickness, and characteristics of identified (and unidentified) subsurface materials may vary considerably from that indicated by the subsurface data. While nothing can be done to prevent such variability, the Geotechnical Division is prepared to work with the Design Team to reduce the impacts of variability on project design, construction, and performance. Periodic geotechnical observation during construction may be beneficial in this respect. This ongoing involvement of the Geotechnical Division throughout the design and project development process will also help to avoid costly mistakes associated with misinterpretation of the contents of this report and resulting shortcomings of project design or contract documents.

The conclusions and recommendations presented in this report assume that surface and subsurface conditions, as observed during field exploration activities are representative of the site conditions throughout the project area. Because of this assumption, these recommendations are subject to change based on actual conditions encoutnered. Actual subsurface conditions can be discovered only during earthwork and construction operations. Accordingly, the Geotechnical Division should be involved in the construction of the project in order to make appropriate observations and recommendations for alteration in design, as appropriate.

Questions or comments regarding the contents of this report should be directed to Mark Frye at (360) 709-5469 or Tony Allen at (360) 709-5450.

Appendix A

Figures



JOB	OL-3518	S.R.	90	C.S.		LAYOUT

I-90 Two Way Transit and HOV Operations

WASHINGTON STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BRANCH
T. E. BAKER MATERIALS ENGINEER

DATE 8/2005
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Figure 1: Vicinity Map

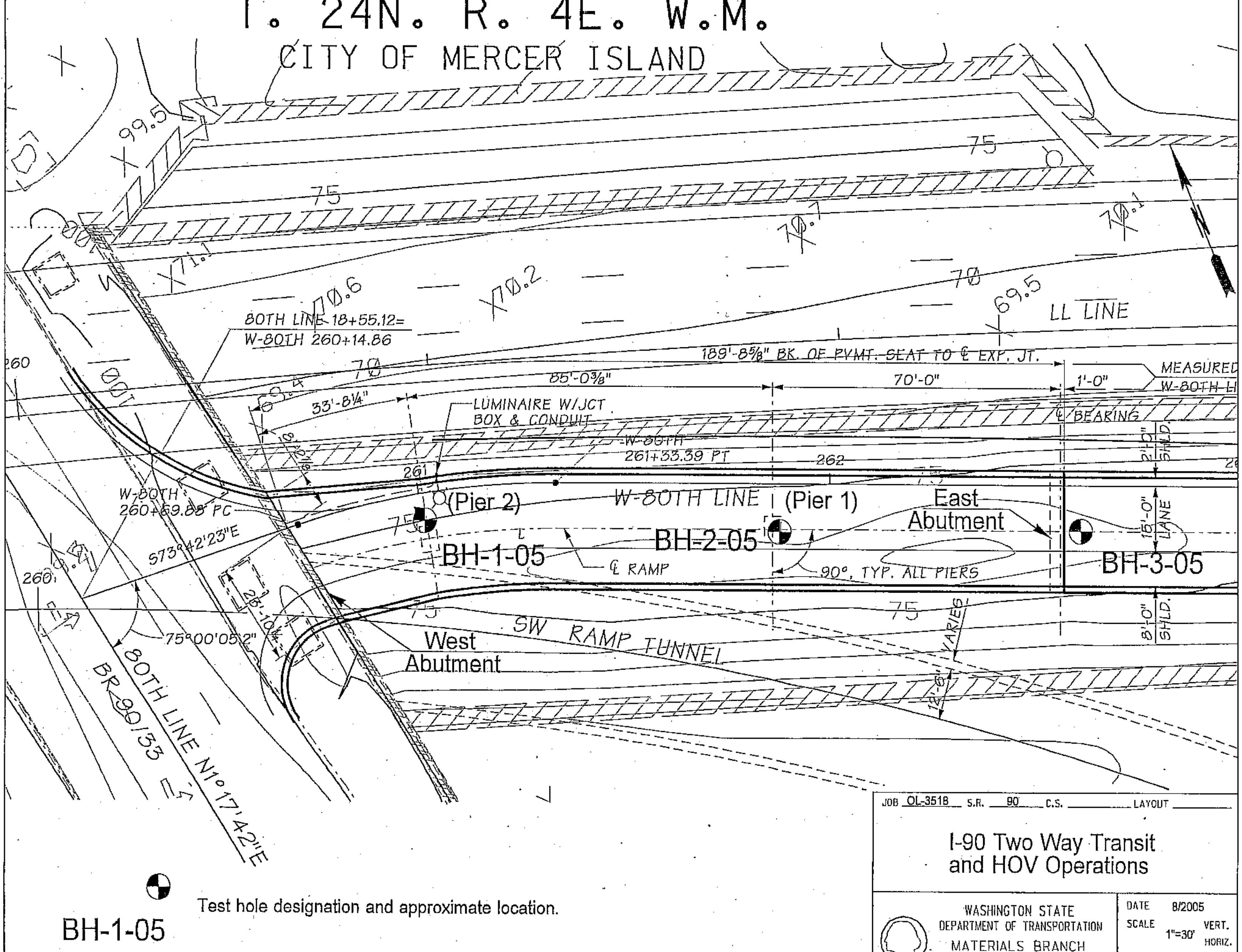

Figure 2: Site and Exploration Plan

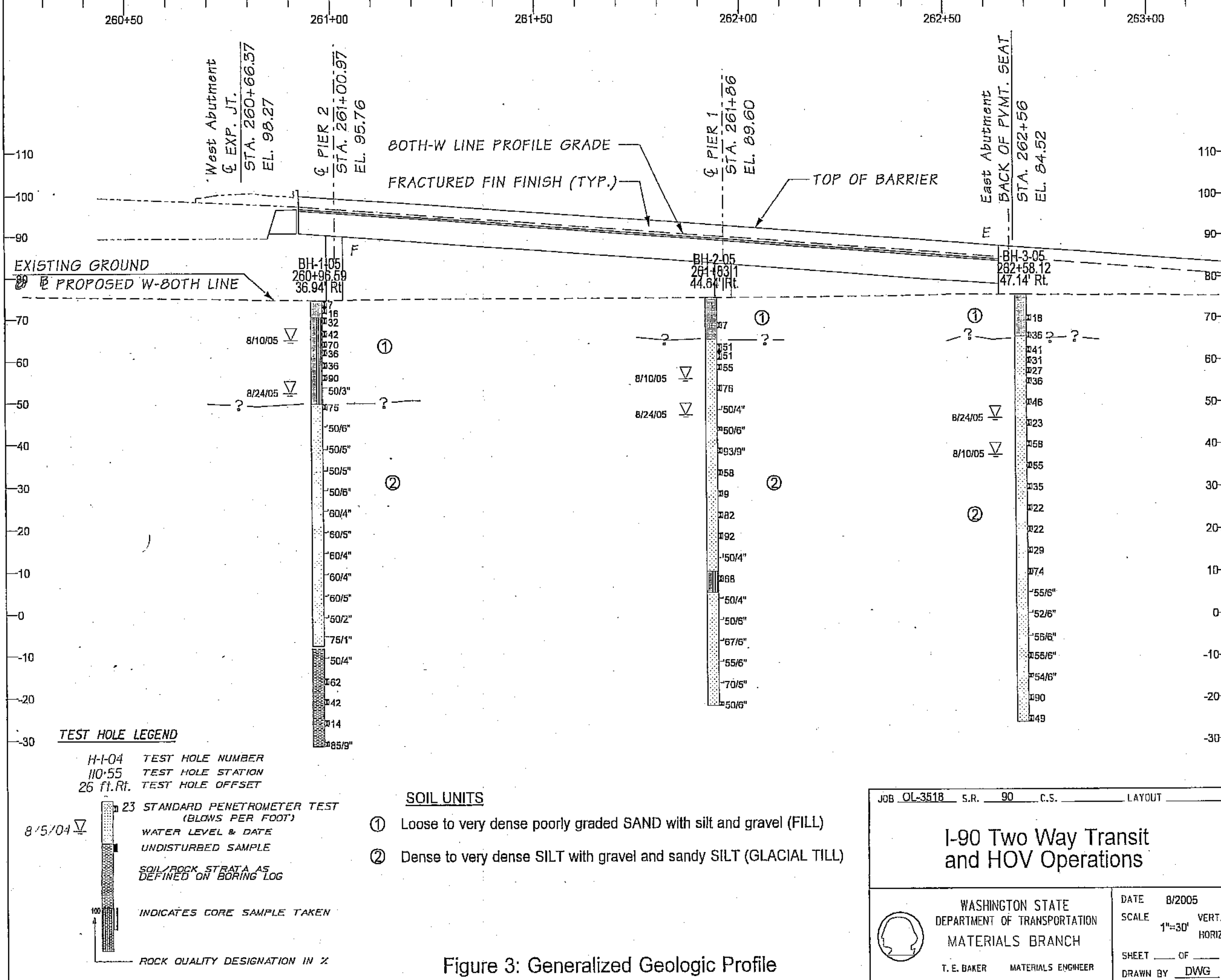

Figure 3: Generalized Geologic Profile

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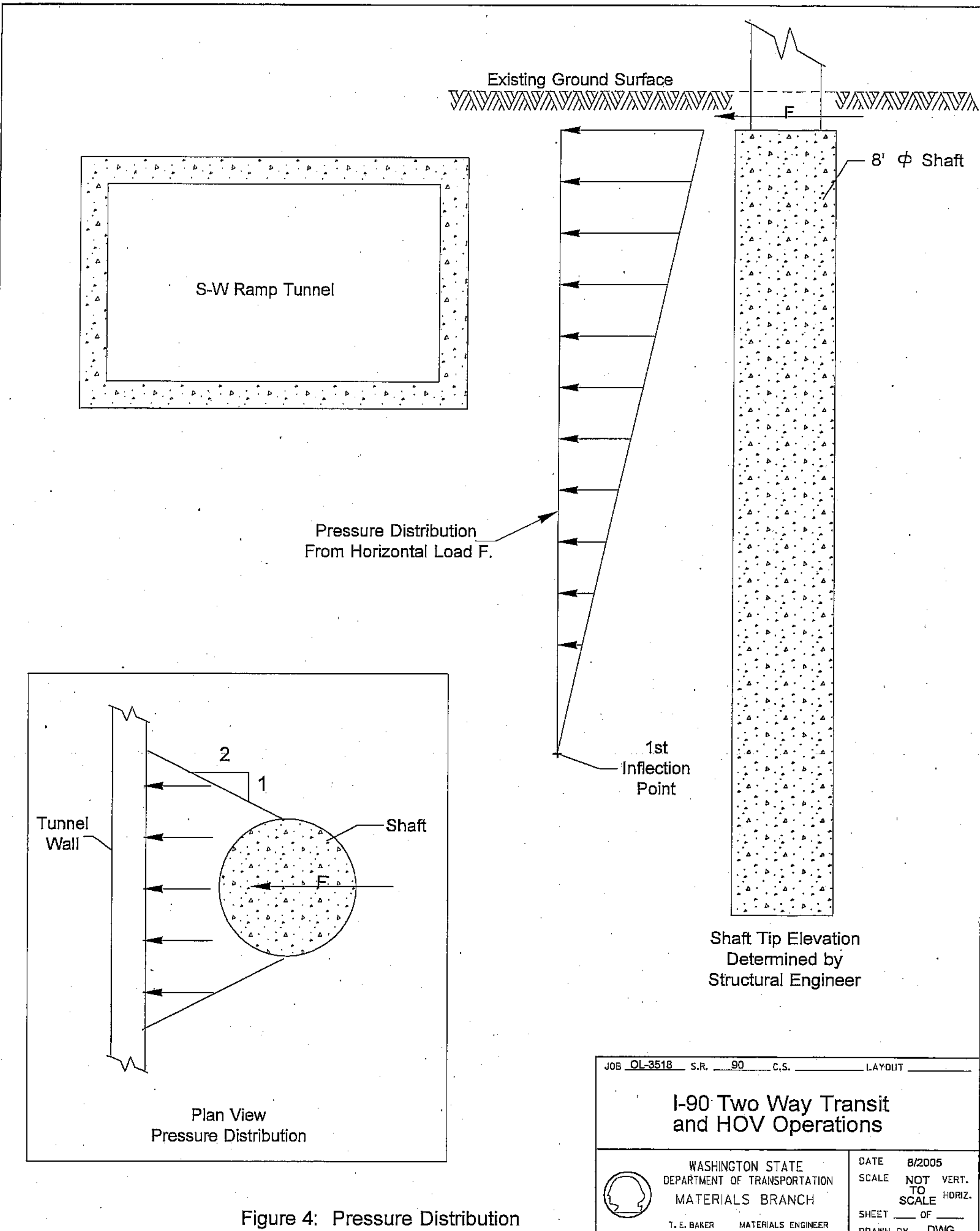

Figure 4: Pressure Distribution

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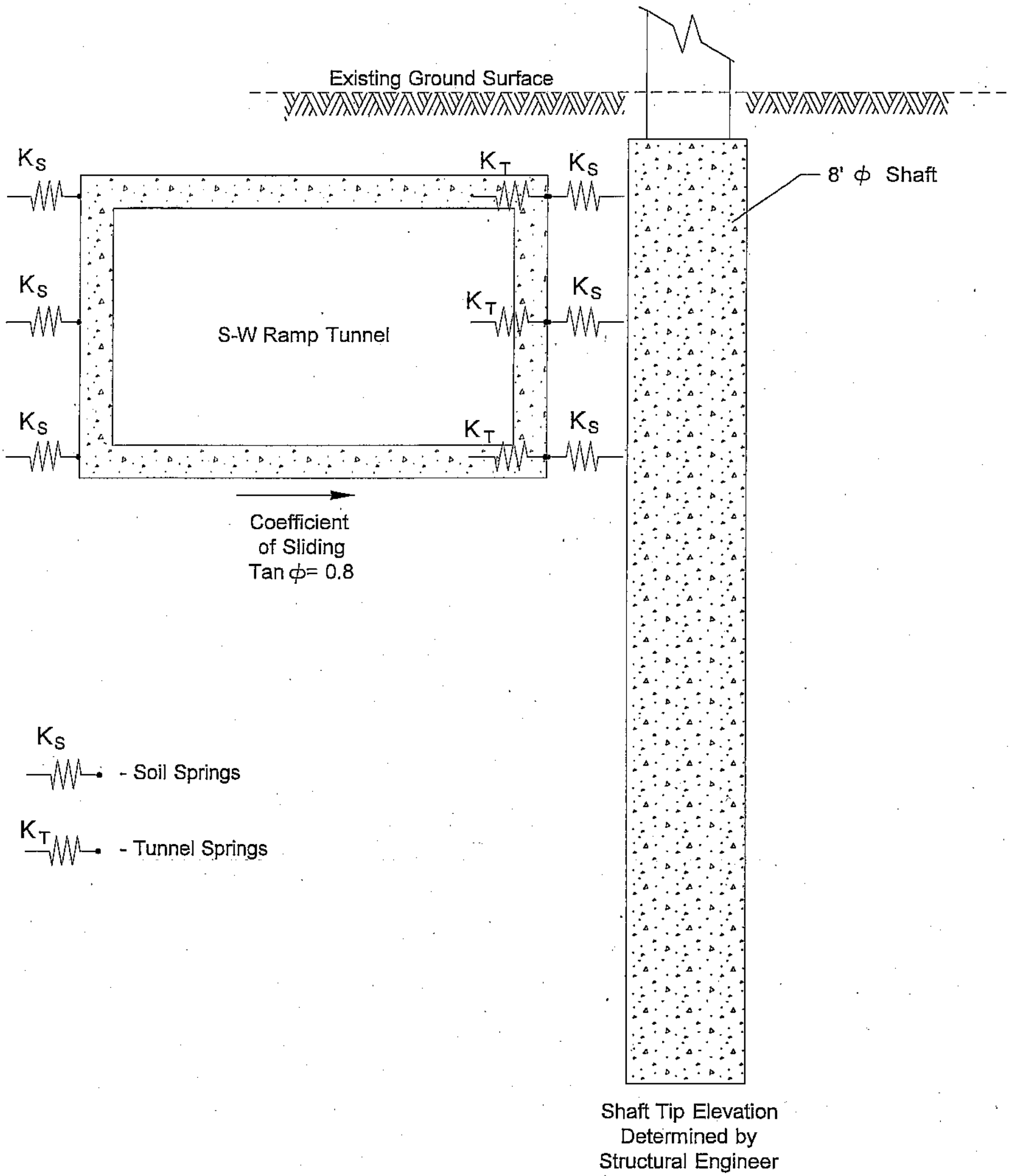

JOB OL-3518	S.R. 90	C.S.	LAYOUT

I-90 Two Way Transit and HOV Operations

WASHINGTON STATE
DEPARTMENT OF TRANSPORTATION
MATERIALS BRANCH
T. E. BAKER MATERIALS ENGINEER

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Figure 5: Soil Springs

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Appendix B

Boring Logs

Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-66049

HOLE No. BH-1-05

Sheet 1 of 5

Job No. OL-3518 SR I-90 Elevation 76.2 ft (23.2 m)

Project I-90 Two Way Transit and HOV Operations

Driller Kerry Cooper Lic# 2552

Site Address SR-90 Vicinity of 80th Ave SE

Inspector Cleo Andrews

Start August 9, 2005 Completion August 10, 2005 Well ID# AKL-170

Equipment CME 45 w/ autohammer

Station 260+96.59 Offset 36.94' Rt. Casing (HWT 4" OD x 12.0')(HQ 3" OD x 110.0') Method Wet Rotary

Northing 217524.39 Easting 1295431.69 Latitude Longitude

County King Subsection NE 1/4 of the NE 1/4 Section 12 Range 4 EWM Township 24 N

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
0		1, 3, 4, (7)	D-1		Poorly graded SAND with organics(roots), loose, brown, dry, stratified. Length Recovered 1.5 ft, Length Retained 1.0 ft
		4, 6, 10, (16)	D-2		Poorly graded SAND with gravel and organics(roots), medium dense, brown, moist, stratified. Length Recovered 1.5 ft, Length Retained 1.0 ft
	1				
5		11, 17, 15, (32)	D-3		Poorly graded SAND with silt and gravel, subrounded, dense, olive gray, moist, homogeneous. Very little drilling fluid lost starting at 4.0'. Length Recovered 0.3 ft, Length Retained 0.3 ft
	2	13, 20, 22, (42)	D-4		Poorly graded SAND with silt and gravel, subrounded, dense, olive gray, moist, homogeneous. Length Recovered 1.0 ft, Length Retained 1.0 ft
10	3	15, 30, 40, (70)	D-5		08/10/2005 A.T.D. (groundwater) Poorly graded SAND with silt and gravel, subrounded, very dense, dark brown, moist, homogeneous. Length Recovered 1.0 ft, Length Retained 1.0 ft
		14, 18, 18, (36)	D-6	GS MC	SP-SM, M.C.=9% Poorly graded SAND with silt and gravel, subrounded, dense, dark brown, moist, homogeneous. Length Recovered 1.0 ft, Length Retained 1.0 ft
	4				
15		14, 18, 18, (36)	D-7		Poorly graded SAND with silt and gravel, subrounded, dense, dark brown, moist, homogeneous. Length Recovered 1.0 ft, Length Retained 1.0 ft
	5	32, 45, 45, (90)	D-8		Poorly graded SAND with silt and gravel, subrounded, very dense, dark brown, moist, homogeneous. Length Recovered 1.2 ft, Length Retained 1.0 ft
20	6				

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card R-66049

Job No. OL-3518 SR I-90 Elevation 76.2 ft (23.2 m) HOLE No. BH-1-05

Project I-90 Two Way Transit and HOV Operations Driller Kerry Cooper Lic# 2552

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
				50/3" (50/3")		D-9		Poorly graded SAND with silt and gravel, subrounded, very dense, dark brown, moist, homogeneous. Length Recovered 0.2 ft, Length Retained 0.2 ft		
								08/24/2005	▼	
	7									
25			>>	22 30 45 (75)		D-10		Sandy SILT, with 0.2' of well graded gravel with sand, very dense, olive gray, moist, stratified (Changed at 24.7'). Length Recovered 1.2 ft, Length Retained 1.2 ft		
	8									
	9									
30				50/6" (50/6")		D-11		SILT, with horizontal fine grained sand lenses, very dense, olive gray, moist, laminated. Length Recovered 0.5 ft, Length Retained 0.5 ft		
	10									
35				13 50/5" (50/5")		D-12		SILT with sand, very dense, olive gray, moist, laminated with medium grained sand. Length Recovered 0.9 ft, Length Retained 0.9 ft		
	11									
	12									
40				50/5" (50/5")		D-13	GS MC	ML, M.C.=16% SILT with sand, very dense, olive gray, moist, homogeneous. Length Recovered 0.9 ft, Length Retained 0.9 ft		
	13									
45				50/6"		D-14	GS	ML, M.C.=21%		

Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-66049

HOLE No. BH-1-05

Sheet 3 of 5

Job No. OL-3518 SR I-90 Elevation 76.2 ft (23.2 m)

Project I-90 Two Way Transit and HOV Operations

Driller Kerry Cooper Lic# 2552

Depth (ft): 50, 55, 60, 65, 70

Meters (m): 14, 15, 16, 17, 18, 19, 20, 21

Standard Penetration Blows/ft: 10, 20, 30, 40

SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material
(50/6")			MC	SILT with sand, very dense, olive gray, moist, homogeneous. Length Recovered 0.5 ft, Length Retained 0.5 ft
60/4" (60/4")		D-15		SILT with sand, very dense, olive gray, moist, homogeneous. Sampler bouncing on gravel at 49.8' Length Recovered 0.3 ft, Length Retained 0.3 ft
60/5" (60/5")		D-16	GS MC AL	ML, M.C.=18%, LL=21, non plastic Sandy SILT with gravel, gravel are subrounded, very dense, medium dark gray, moist, homogeneous. Length Recovered 0.4 ft, Length Retained 0.4 ft with ID Califorinia sampler.
60/4" (60/4")		D-17	GS MC	ML, M.C.=22% SILT with sand, with fine grained sand lenses, very dense, olive gray, moist, laminated. Length Recovered 0.4 ft, Length Retained 0.4 ft
60/4" (60/4")		D-18		SILT with sand, very dense, olive gray, moist, homogeneous, (Sample taken with 2" ID califorinia sampler). Length Recovered 0.3 ft, Length Retained 0.3 ft
60/5"		D-19		SILT with sand, very dense, olive gray, moist,

Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-66049

HOLE No. BH-1-05

Job No. OL-3518 SR I-90 Elevation 76.2 ft (23.2 m)

Sheet 4 of 5

Project I-90 Two Way Transit and HOV Operations

Driller Kerry Cooper Lic# 2552

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
		(60/5")			homogeneous, (Sample taken with 2" ID California sampler). Length Recovered 0.4 ft, Length Retained 0.4 ft
	22				
75	23	36 50/2" (50/2")	D-20		SILT with sand and gravel, subrounded, very dense, olive gray, moist, homogeneous, (Sample taken with 2" ID California sampler). Changed at 76.0' no gravel indicated while drilling. Length Recovered 0.5 ft, Length Retained 0.5 ft
	24				
80		75/1" (75/1")	D-21		No Recovery
	25				
85	26	50/4" (50/4")	D-22		Fat CLAY, very hard, olive gray, moist, homogeneous. Length Recovered 0.3 ft, Length Retained 0.3 ft
	27				
90		21 30 37 (62)	D-23	GS MC AL	CH, MC=29%,PI=44 Fat CLAY, very hard, dark gray, moist, homogeneous. Length Recovered 1.5 ft, Length Retained 1.0 ft
	28				
95		14	D-24		Lean CLAY, hard, dark gray, moist, homogeneous.

Standard Penetration Blows/ft: 10 20 30 40

SOIL OL-3518 I-90 TWO WAY TRANSIT AND HOV OPERATIONS.GPJ SOIL.GDT 8/26/05,2:59:11 PB

Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-66049

HOLE No. BH-1-05

Sheet 5 of 5

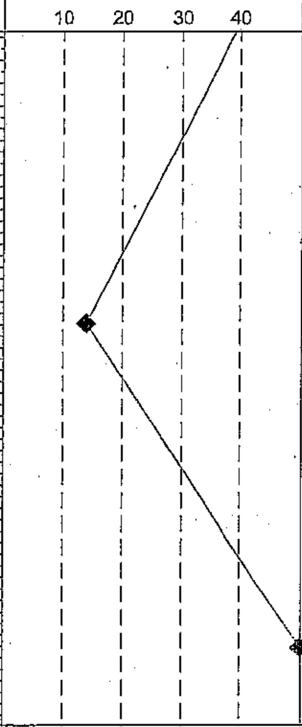
Job No. OL-3518 SR I-90 Elevation 76.2 ft (23.2 m)

Project I-90 Two Way Transit and HOV Operations

Driller Kerry Cooper Lic# 2552

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
	29	20 22 (42)			Length Recovered 1.5 ft, Length Retained 1.0 ft
	30				
100		3 5 9 (14)	D-25	GS MC AL	CL, MC=29%,PI=17 Lean CLAY with horizontal fine grained sand lenses, stiff, dark gray, moist, laminated, blocky, (Took moisture can MC-25a from same depth. Retained 0.2'). Length Recovered 1.5 ft, Length Retained 1.0 ft
	31				
105	32	19 35 50/3" (85/9")	D-26		Sandy SILT, very dense, dark gray, moist, homogeneous, (Took moisture can MC-26a from same depth. Retained 0.2'). Length Recovered 1.2 ft, Length Retained 1.2 ft
	33				End of test hole boring at 105.7 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data. Hole plug seal to 25.0'. Water table in casing before bailing hole is at surface, bailed hole to 24.0', water table recharged to 9.3' after 15 minutes delay. Installed 1" ID Piezo Well at 25.0'. Water table in Well after bailing and 30 minutes delay for recharged is 9.3'. See Piezo diagram. 8/10/05. Note test hole was moved 10.0' North and 3.5' West of original stake in field
110	34				
115	35				
	36				
120					

Standard Penetration Blows/ft



Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-66048

HOLE No. BH-2-05

Sheet 1 of 5

Job No. OL-3518 SR I-90 Elevation 76.6 ft (23.3 m)

Project I-90 Two Way Transit and HOV Operations

Driller Thomas Harvey Lic# 2599

Site Address SR-90 Vicinity of 80th Ave. SE

Inspector James Fetterly

Start August 9, 2005 Completion August 10, 2005 Well ID# AKL-168

Equipment Burly 4500 w/ cathead

Station 261+83.1 Offset 44.64' Rt. Casing 4"x100'

Method Wet Rotary

Northing 217474 Easting 1295501.35 Latitude

Longitude

County King Subsection NE/NE Section 12 Range 4 EWM Township 24 N

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
5	1									
	2			5 4 3 (7)		D-1		Poorly graded SAND with gravel, loose, Lt. brown, moist, homogeneous, HCl reaction not tested. Length Recovered 0.6 ft, Length Retained 0.6 ft		
10	3		>>	10 23 28 38 (51)		D-2		SILT, very dense, grey, moist, homogeneous, HCl reaction not tested. Silt contact at 10.0'. Length Recovered 1.0 ft, Length Retained 1.0 ft		
	4		>>	13 23 28 40 (51)		D-3	GS MC	ML, M.C.=19% SILT, very dense, grey, moist, homogeneous, HCl reaction not tested. Length Recovered 1.0 ft, Length Retained 1.0 ft		
15	5		>>	11 27 28 (55)		D-4		SILT, very dense, grey, moist, homogeneous, HCl reaction not tested. Length Recovered 1.0 ft, Length Retained 0.8 ft		
20	6							8/10/05	∇	

Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-66048

Job No. OL-3518 SR I-90 Elevation 76.6 ft (23.3 m)

HOLE No. BH-2-05

Sheet 2 of 5

Project I-90 Two Way Transit and HOV Operations

Driller Thomas Harvey Lic# 2599

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater
						A.T.D.
		18 35 41 (76)	D-5		SILT, very dense, grey, moist, homogeneous, HCl reaction not tested. Small Sand layer at 20.0'. Length Recovered 0.4 ft, Length Retained 0.4 ft	
	7					
25	8	35 50/4" (50)	D-6		SILT, and seashell fragments, very dense, grey, moist, homogeneous, weak HCl reaction, HCL reaction was on shell fragments. Length Recovered 0.9 ft, Length Retained 0.9 ft	▼ 8/24/05
30	9	33 50 (50)	D-7		SILT, very dense, grey, moist, homogeneous, HCl reaction not tested. Length Recovered 0.9 ft, Length Retained 0.9 ft	
	10					
35	11	30 43 50/3" (50)	D-8		SILT with sand, very dense, grey, moist, homogeneous, HCl reaction not tested. Length Recovered 0.3 ft, Length Retained 0.3 ft	
	12					
40		17 19 39 (58)	D-9		SILT with sand, very dense, grey, moist, homogeneous, HCl reaction not tested. Small gravel layer at 39.0' as indicated by Drilling. Length Recovered 0.3 ft, Length Retained 0.3 ft	
	13					
45						

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card R-66048

HOLE No. BH-2-05

Job No. OL-3518 SR I-90 Elevation 76.6 ft (23.3 m)

Project I-90 Two Way Transit and HOV Operations

Driller Thomas Harvey Lic# 2599

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
	14	6 5 4 (9)	D-10	GS MC	ML, M.C.=20% SILT with sand, loose, grey, moist, homogeneous, HCl reaction not tested. Most of Sample Knocked out by reverse hammer extraction, Sandy layers encountered at 44.0' Length Recovered 0.2 ft, Length Retained 0.2 ft
50	15	25 39 43 (82)	D-11		Sandy SILT, very dense, grey, moist, homogeneous, HCl reaction not tested. Length Recovered 0.6 ft, Length Retained 0.6 ft
55	16–17	32 42 50 (92)	D-12		Sandy SILT, very dense, grey, wet, homogeneous, HCl reaction not tested. Length Recovered 1.0 ft, Length Retained 1.0 ft
60	18	41 50/4" (50)	D-13	GS MC	ML, M.C.=19% Sandy SILT, very dense, grey, moist, stratified, HCl reaction not tested, stratified with silt lenses. Length Recovered 0.9 ft, Length Retained 0.9 ft
65	20	4 18 50 (68)	D-14	GS MC	SP-SM, M.C.=16% Poorly graded SAND with silt, very dense, grey, moist, stratified, HCl reaction not tested, stratified with gavel layers, heavier gravel contact at 63.0'. Length Recovered 1.0 ft, Length Retained 1.0 ft
70	21				

Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-66048

HOLE No. BH-2-05

Job No. OL-3518 SR I-90 Elevation 76.6 ft (23.3 m)

Sheet 4 of 5

Project I-90 Two Way Transit and HOV Operations

Driller Thomas Harvey Lic# 2599

SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
50/4" (50)	D-15		Sandy SILT with gravel, dense, grey, moist, stratified, HCl reaction not tested. Length Recovered 0.2 ft, Length Retained 0.2 ft
50/6" (50)	D-16		Sandy SILT with gravel, very dense, grey, moist, stratified, HCl reaction not tested. Most of upper sample appears to be slough. Length Recovered 0.1 ft, Length Retained 0.1 ft
67/6" (67)	D-17		Sandy SILT, very dense, grey, moist, stratified, HCl reaction not tested. Stratified with silt. Length Recovered 0.4 ft, Length Retained 0.4 ft
55/6" (55)	D-18	GS MC	ML, M.C.=17% Sandy SILT, very dense, grey, moist, stratified, HCl reaction not tested. Stratified with silt. Length Recovered 0.4 ft, Length Retained 0.4 ft
70/5" (70)	D-19		Sandy SILT, very dense, grey, moist, stratified, HCl reaction not tested. Drilling indicates gravels at 87.0' Length Recovered 0.2 ft, Length Retained 0.2 ft

Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-66048

HOLE No. BH-2-05

Sheet 5 of 5

Job No. OL-3518 SR I-90 Elevation 76.6 ft (23.3 m)

Project I-90 Two Way Transit and HOV Operations

Driller Thomas Harvey Lic# 2599

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	29		◆	25 50 (50)		D-20		Sandy SILT, very dense, grey, moist, stratified, HCl reaction not tested. Stratified with silt. Length Recovered 1.0 ft, Length Retained 1.0 ft		
	30							End of test hole boring at 97 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data.		
100										
	31							Bailed hole to 55.0' after 10 minutes recharged to 51.0'.		
105	32									
	33									
110										
	34									
115	35									
	36									
120										

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card R-66049
HOLE No. BH-3-05
Sheet 1 of 5

Job No. OL-3518 SR I-90 Elevation 76.4 ft (23.3 m)

Project I-90 Two Way Transit and HOV Operations

Driller Robert Haller Lic# 2779T

Site Address SR-90 Vicinity of 80th Ave. SE

Inspector Joe Judd

Start August 9, 2005 Completion August 10, 2005 Well ID# AKL-171

Equipment CME 45 w/ autohammer

Station 262+58.12 Offset 47.14' Rt. Casing 4.0

Method Wet Rotary

Northing 217432.7 Easting 1295562.48 Latitude

Longitude

County King Subsection NE 1/4 NE 1/4 Section 12 Range 4 EWM Township 24 N

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
5		7 8 10 (18)	D-1		Silty SAND with gravel, medium dense, olive brown, moist, homogeneous, no HCl reaction. Gravels through drill run. Length Recovered 0.2 ft, Length Retained 0.2 ft
	2				
10	3	27 16 19 (36)	D-2		Sandy SILT with gravel, dense, gray, moist, from 10.0 - 10.4, gray SILT from 10.4' to 11.0' Length Recovered 1.0 ft, Length Retained 1.0 ft
	4	13 18 23 (41)	D-3		SILT, dense, gray, moist, homogeneous. Length Recovered 1.1 ft, Length Retained 1.1 ft
15	5	8 13 18 (31)	D-4	GS MC	ML, M.C.=23% SILT, dense, gray, moist, homogeneous, no HCl reaction. Length Recovered 1.2 ft, Length Retained 1.2 ft
		12 14 13 (27)	D-5		SILT, dense, gray, moist, homogeneous. Length Recovered 1.2 ft, Length Retained 1.2 ft
20	6				

Standard Penetration Blows/ft: 10 20 30 40

Washington State
Department of Transportation

LOG OF TEST BORING

Start Card R-66049

HOLE No. BH-3-05

Sheet 2 of 5

Job No. OL-3518 SR I-90 Elevation 76.4 ft (23.3 m)

Project I-90 Two Way Transit and HOV Operations

Driller Robert Haller Lic# 2779T

Depth (ft)	Meters (m)	Profile	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater
			14 18 18 (36)		D-6		SILT, dense, gray, moist, homogeneous, no HCl reaction. Length Recovered 1.4 ft, Length Retained 1.4 ft	
	7							
25			15 29 26 (46)		D-7		SILT, dense, gray, moist, homogeneous, no HCl reaction. Length Recovered 1.5 ft, Length Retained 1.5 ft	
	8							
	9						8/24/05	▽
30			6 11 13 (23)		D-8	GS MC	ML, M.C.=21% SILT with sand, medium dense, gray, wet, stratified, no HCl reaction. Length Recovered 1.4 ft, Length Retained 1.4 ft	
	10							
35			23 27 31 (58)		D-9		SILT with sand, very dense, gray, moist, homogeneous, no HCl reaction. Length Recovered 1.3 ft, Length Retained 1.3 ft	
	11							
							8/10/05 A.T.D.	▼
	12							
40			12 25 30 (55)		D-10		SILT with sand, very dense, gray, moist, homogeneous, no HCl reaction. Length Recovered 1.2 ft, Length Retained 1.2 ft	
	13							
45								

Standard Penetration Blows/ft: 10 20 30 40

Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-66049

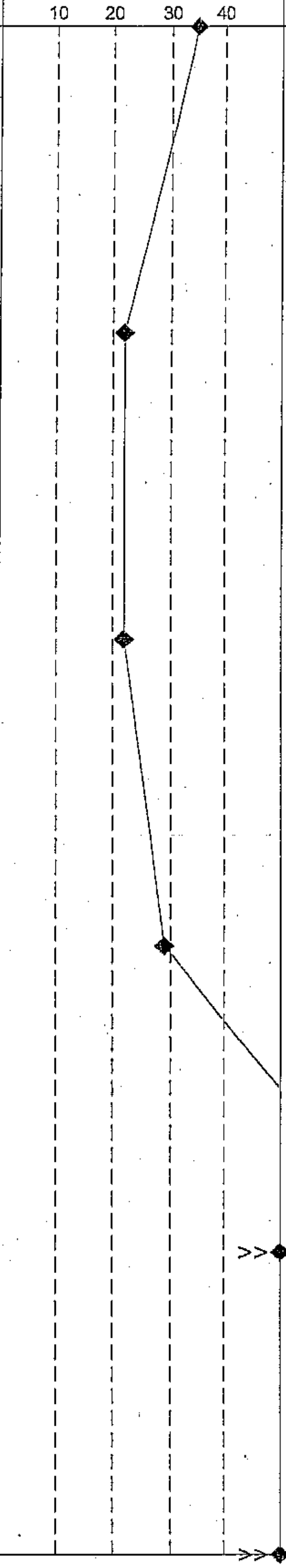
HOLE No. BH-3-05

Job No. OL-3518 SR I-90 Elevation 76.4 ft (23.3 m)

Sheet 3 of 5

Project I-90 Two Way Transit and HOV Operations

Driller Robert Haller Lic# 2779T



Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
	14	9 14 21 (35)	D-11		SILT with sand, dense, gray, moist, homogeneous, no HCl reaction. Length Recovered 1.3 ft, Length Retained 1.3 ft
	15				
50		11 12 10 (22)	D-12		SILT with sand, medium dense, gray, wet, stratified, no HCl reaction, sand lenses. Length Recovered 1.4 ft, Length Retained 1.4 ft
	16				
55	17	8 11 12 (22)	D-13		SILT with sand, medium dense, gray, wet, homogeneous, no HCl reaction. Length Recovered 1.4 ft, Length Retained 1.4 ft
	18				
60		10 12 17 (29)	D-14		SILT with sand, dense, gray, wet, homogeneous, no HCl reaction. Length Recovered 1.5 ft, Length Retained 1.5 ft
	19				
65	20	23 42 32 (74)	D-15		SILT with sand, very dense, gray, moist, stratified, no HCl reaction. 1 mm poorly graded sand lens wet. Length Recovered 1.3 ft, Length Retained 1.3 ft
	21				
70					

LOG OF TEST BORING

Washington State Department of Transportation

Start Card R-66049

HOLE No. BH-3-05

Sheet 4 of 5

Job No. OL-3518 SR I-90 Elevation 76.4 ft (23.3 m)

Project I-90 Two Way Transit and HOV Operations

Driller Robert Haller Lic# 2779T

Depth (ft)	Meters (m)	SPT Blows/6" (N)	Sample No. (Tube No.)	Lab Tests	Description of Material
		55 (55/6")	D-16		SILT with sand, very dense, gray, moist, homogeneous, no HCl reaction, gravels as indicated by drilling. Length Recovered 0.5 ft, Length Retained 0.5 ft
	22				
75	23	52 (52/6")	D-17		SILT with sand, very dense, gray, moist, homogeneous, no HCl reaction. Length Recovered 0.3 ft, Length Retained 0.3 ft
	24				
80		56 (56/6")	D-18		SILT with sand, very dense, gray, moist, stratified, no HCl reaction, SAND Lenses Length Recovered 0.4 ft, Length Retained 0.4 ft
	25				
85	26	14 19 36 (55)	D-19		Silty SAND, very dense, gray, moist, stratified, no HCl reaction, ss w/silt lense. Length Recovered 1.3 ft, Length Retained 1.3 ft
	27				
90		24 54 (54/6")	D-20		SILT with sand, very dense, gray, moist, homogeneous, no HCl reaction, 88.2 - 90.0 gravel layers encountered. Length Recovered 0.5 ft, Length Retained 0.5 ft
	28				
95					

Washington State Department of Transportation

LOG OF TEST BORING

Start Card R-66049

HOLE No. BH-3-05

Sheet 5 of 5

Job No. OL-3518 SR I-90 Elevation 76.4 ft (23.3 m)

Project I-90 Two Way Transit and HOV Operations

Driller Robert Haller Lic# 2779T

Depth (ft)	Meters (m)	Profile	Standard Penetration Blows/ft (10 20 30 40)	SPT Blows/6" (N)	Sample Type	Sample No. (Tube No.)	Lab Tests	Description of Material	Groundwater	Instrument
	29			18 36 54 (90)		D-21		SILT with sand, very dense, gray, moist, homogeneous, no HCl reaction. Length Recovered 1.2 ft, Length Retained 1.2 ft		
	30									
100				11 15 34 (49)		D-22		SILT with sand, dense, gray, moist, stratified, no HCl reaction, w/sand Lenses Length Recovered 1.1 ft, Length Retained 1.1 ft		
	31							End of test hole boring at 101.5 ft below ground elevation. This is a summary Log of Test Boring. Soil/Rock descriptions are derived from visual field identifications and laboratory test data. Bailed to 64.9 . 1 hour later 38.1		
105	32									
	33									
110										
	34									
115	35									
	36									
120										

Appendix C

Laboratory Testing

Job No. **OL-3518** Date **August 22, 2005**
Hole No. **BH-1-05** Sheet **1** of **2**
Project **I-90 Two Way Transit and HOV Operations**

Laboratory Summary

Washington State Department of Transportation

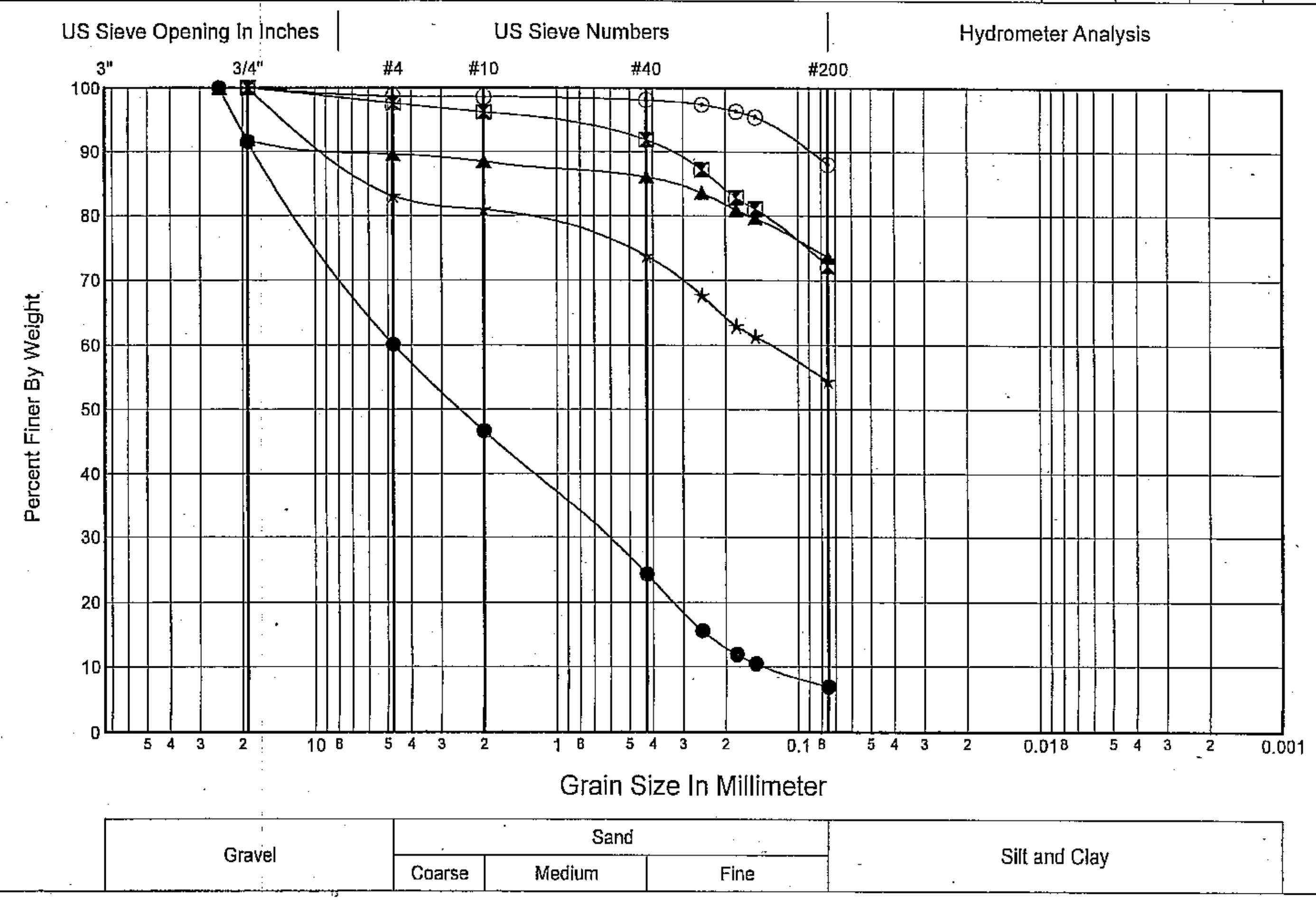
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	11.5	3.51	D-6	SP-SM	See Boring Log	POORLY GRADED SAND with SILT and GRAVEL	9			
⊠	39.5	12.04	D-13	ML	See Boring Log	SILT with SAND	16			
▲	44.4	13.53	D-14	ML	See Boring Log	SILT with SAND	21			
★	54.5	16.61	D-16	ML	See Boring Log	SANDY SILT with GRAVEL (sample too small for 'legal' PI)	18	21	NP	NA
⊙	59.5	18.14	D-17	ML	See Boring Log	SILT	22			

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cc	Cu
●	39.9	53.2	6.9	0.6	34.3
⊠	2.3	25.4	72.2		
▲	10.5	16.0	73.6		
★	17.0	28.6	54.4		
⊙	1.3	10.7	88.0		

GRADATION VALUES

	D60	D50	D30	D20	D10
●	4.734	2.49	0.63	0.33	0.138
⊠					
▲					
★	0.131				
⊙					



Job No. OL-3518 | Date **August 22, 2005**
Hole No. BH-1-05 | Sheet 2 of 2
Project **I-90 Two Way Transit and HOV Operations**

Laboratory Summary

Washington State Department of Transportation

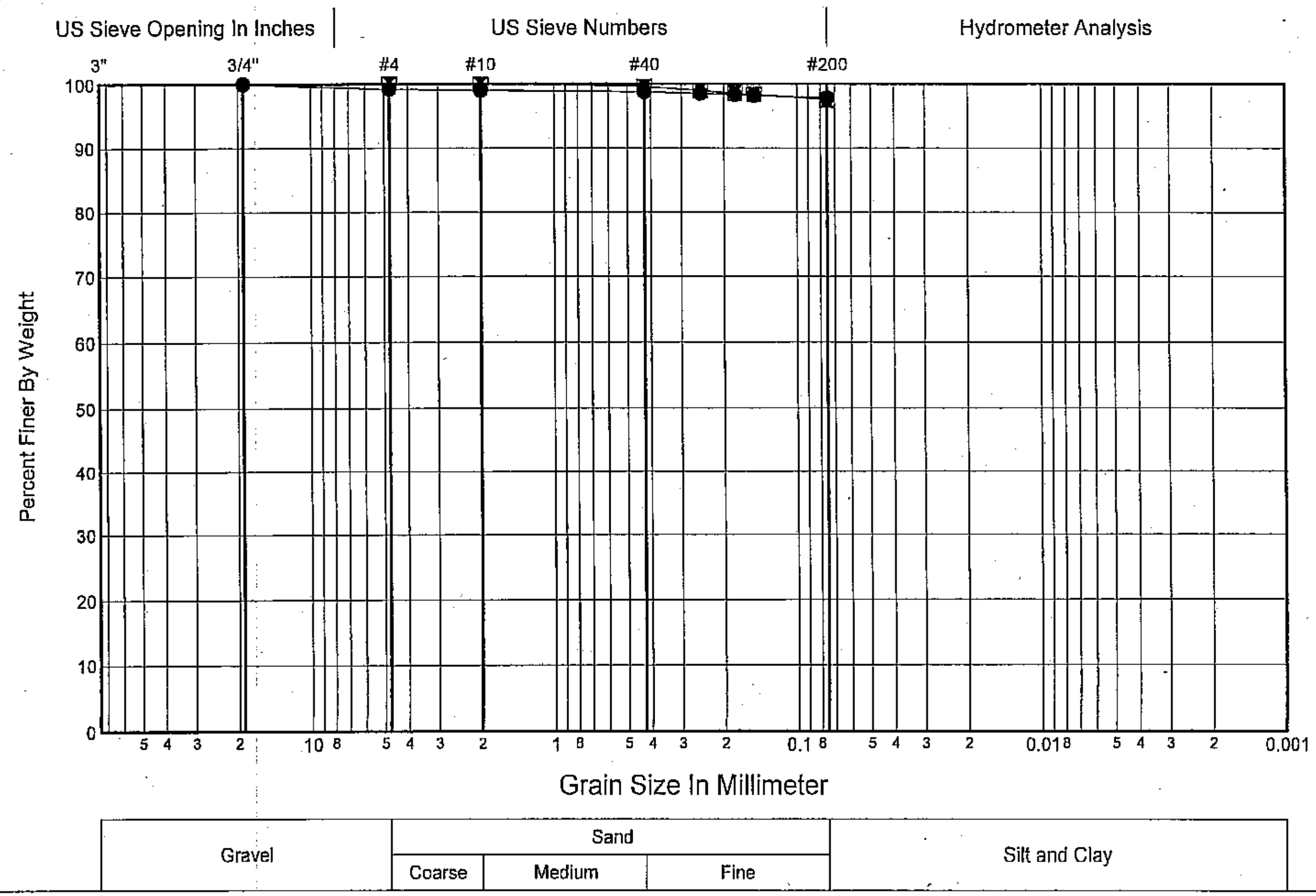
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	89.5	27.28	D-23	CH	See Boring Log	FAT CLAY	29	76	32	44
☒	99.5	30.33	D-25	CL	See Boring Log	LEAN CLAY	29	43	26	17

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cc	Cu
●	0.8	1.4	97.8		
☒	0.0	2.5	97.5		

GRADATION VALUES

	D60	D50	D30	D20	D10
●					
☒					



Job No. OL-3518 Date August 18, 2005

Hole No. BH-2-05 Sheet 1 of 1

Project I-90 Two Way Transit and HOV Operations

Laboratory Summary

Washington State Department of Transportation

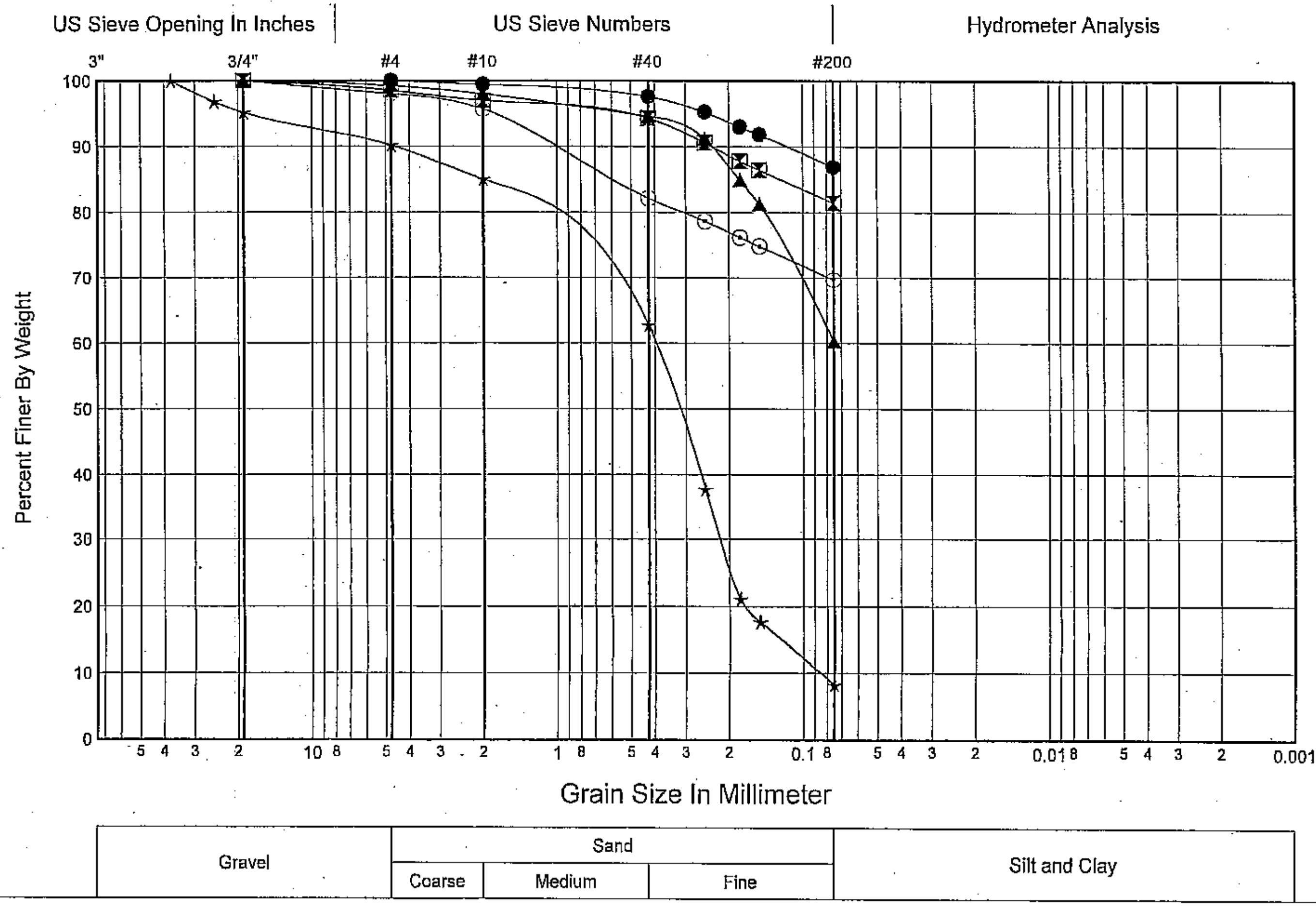
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	13.0	3.96	D-3	ML	See Boring Log	SILT	19			
⊠	46.0	14.02	D-10	ML	See Boring Log	SILT with SAND	20			
▲	61.0	18.59	D-13	ML	See Boring Log	SANDY SILT , fragments of rusted steel in sample	19			
★	66.0	20.12	D-14	SP-SM	See Boring Log	POORLY GRADED SAND with SILT	16			
⊙	86.0	26.21	D-18	ML	See Boring Log	SANDY SILT	17			

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cc	Cu
●	0.0	13.1	86.9		
⊠	1.5	17.1	81.5		
▲	0.7	39.0	60.3		
★	9.8	81.9	8.3	1.3	4.7
⊙	2.0	28.3	69.7		

GRADATION VALUES

	D60	D50	D30	D20	D10
●					
⊠					
▲					
★	0.401	0.32	0.21	0.17	0.085
⊙					



Job No. OL-3518
Hole No. BH-3-05
Project I-90 Two Way Transit and HOV Operations

Date August 25, 2005
Sheet 1 of 1

Laboratory Summary

Washington State Department of Transportation

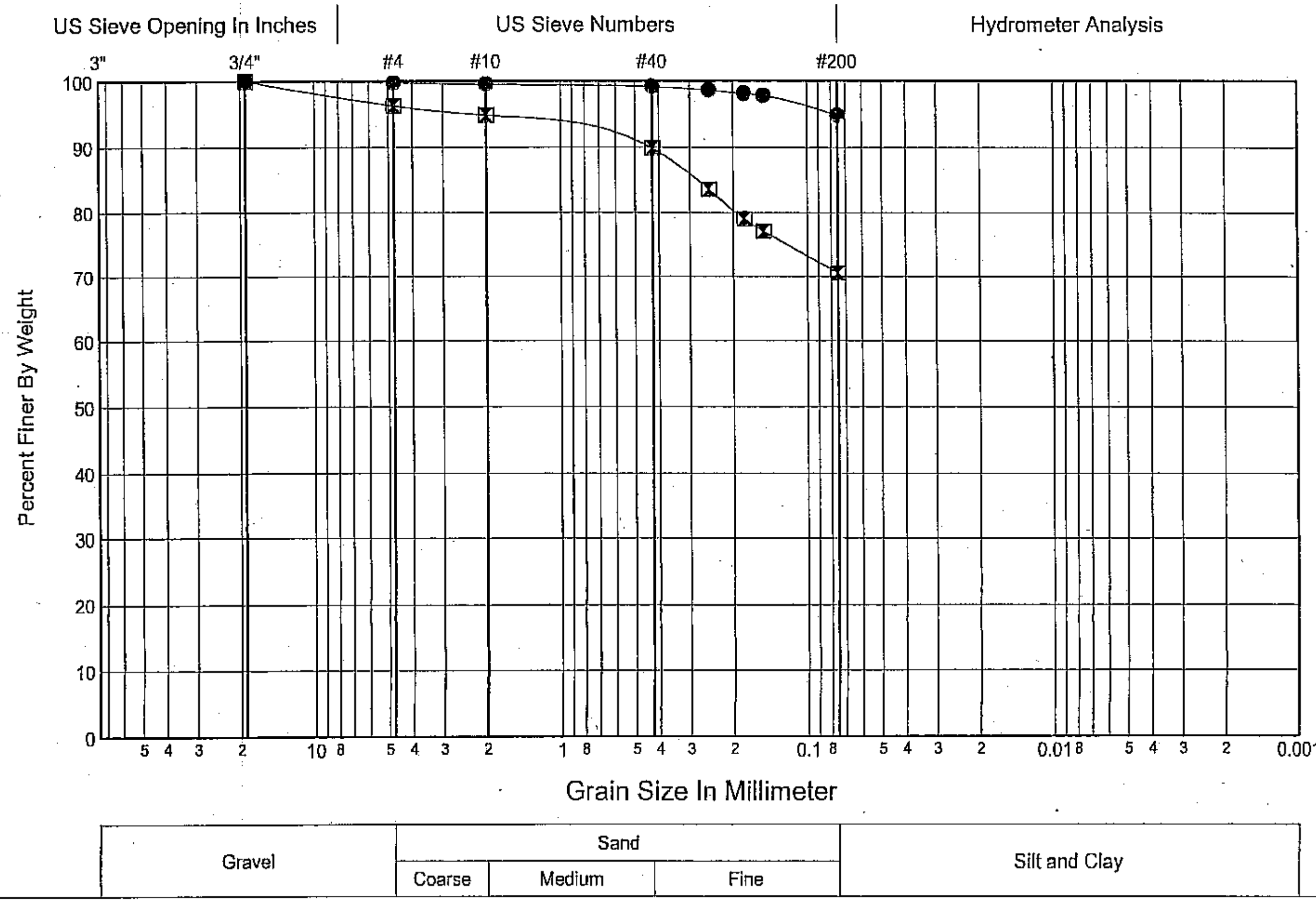
	Depth (ft)	Depth (m)	Sample No.	USCS	Color	Description	MC%	LL	PL	PI
●	15.0	4.57	D-4	ML	See Boring Log	SILT	23			
⊠	30.0	9.14	D-8	ML	See Boring Log	SILT with SAND	21			

GRADATION FRACTIONS

	%Gravel	%Sand	%Fines	Cc	Cu
●	0.3	4.9	94.8		
⊠	3.7	25.8	70.5		

GRADATION VALUES

	D60	D50	D30	D20	D10
●					
⊠					



Appendix D

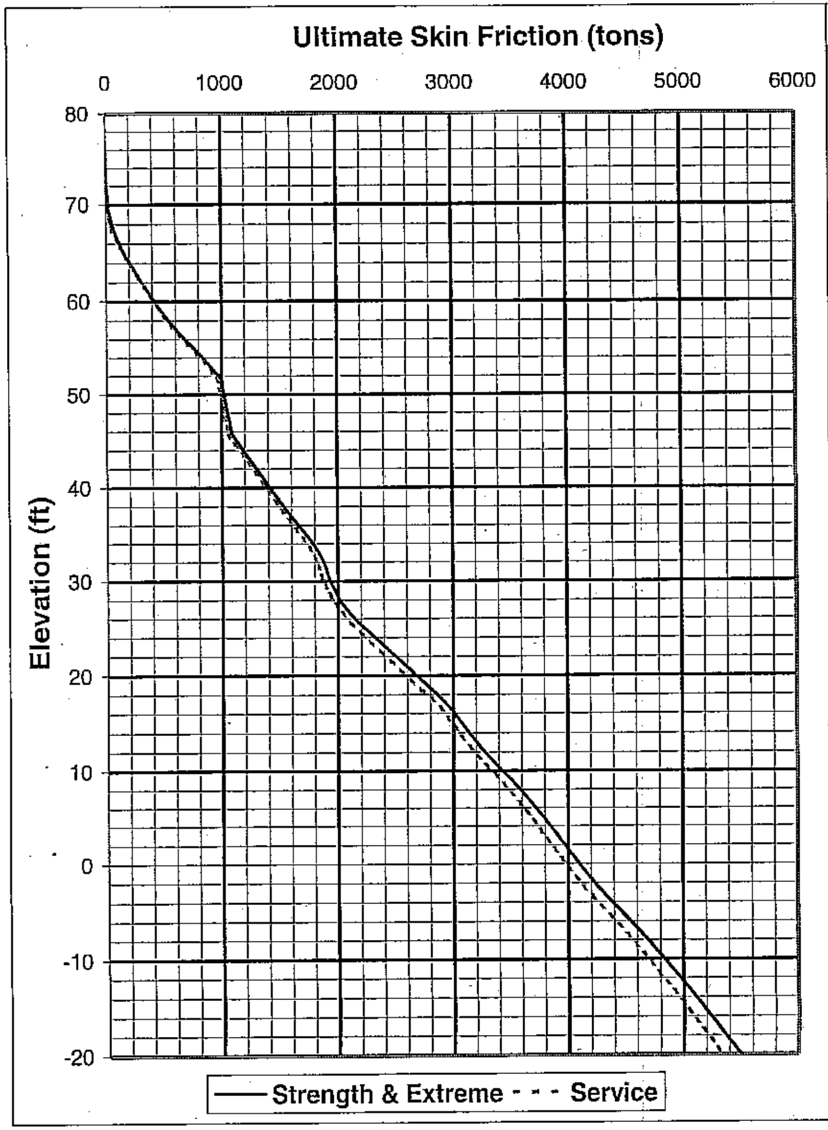
Shaft Capacity Charts and Lateral Analysis Parameters

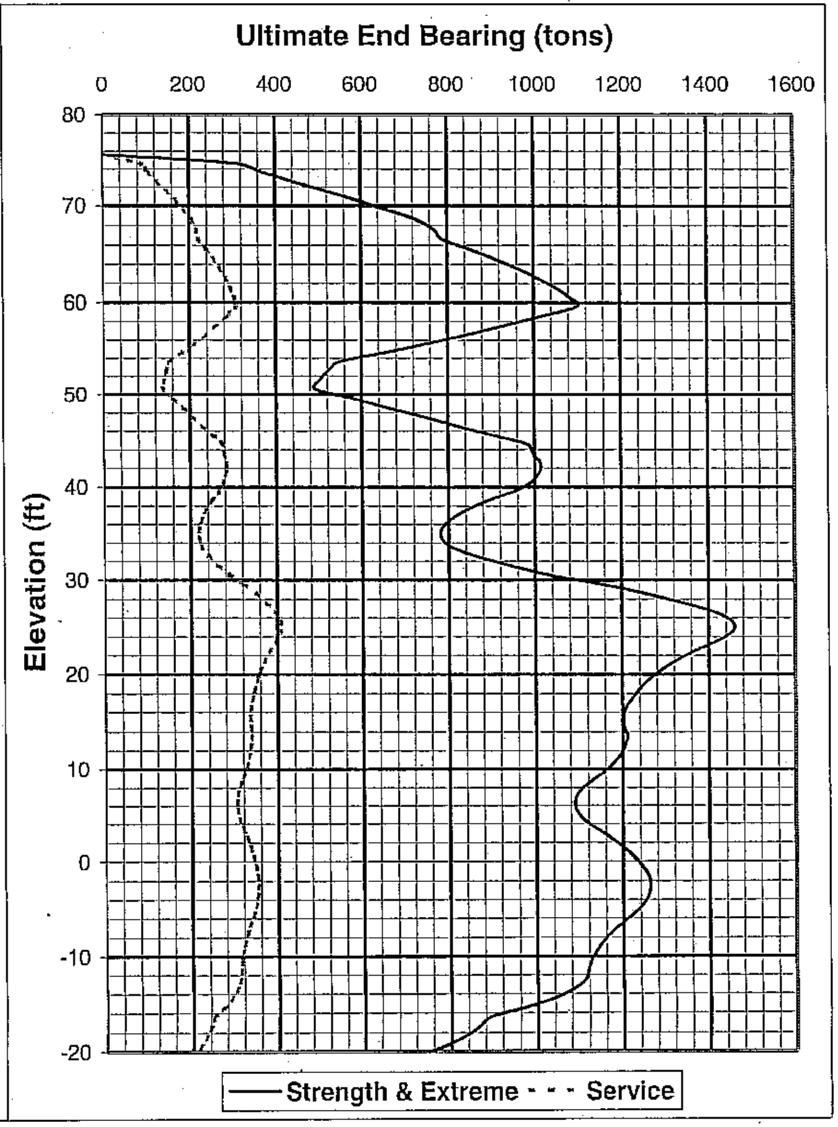
SR 90

Two Way Transit and HOV Operations

Pier: 1

Shaft Diameter: 8 ft.



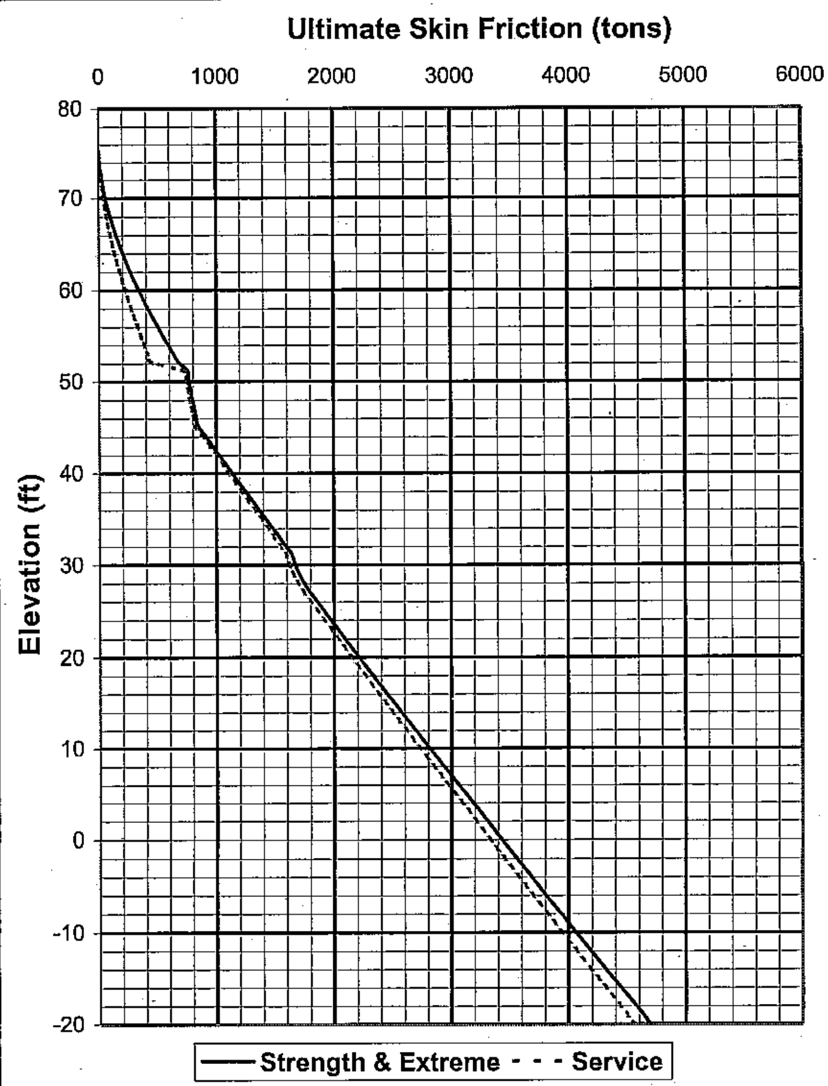


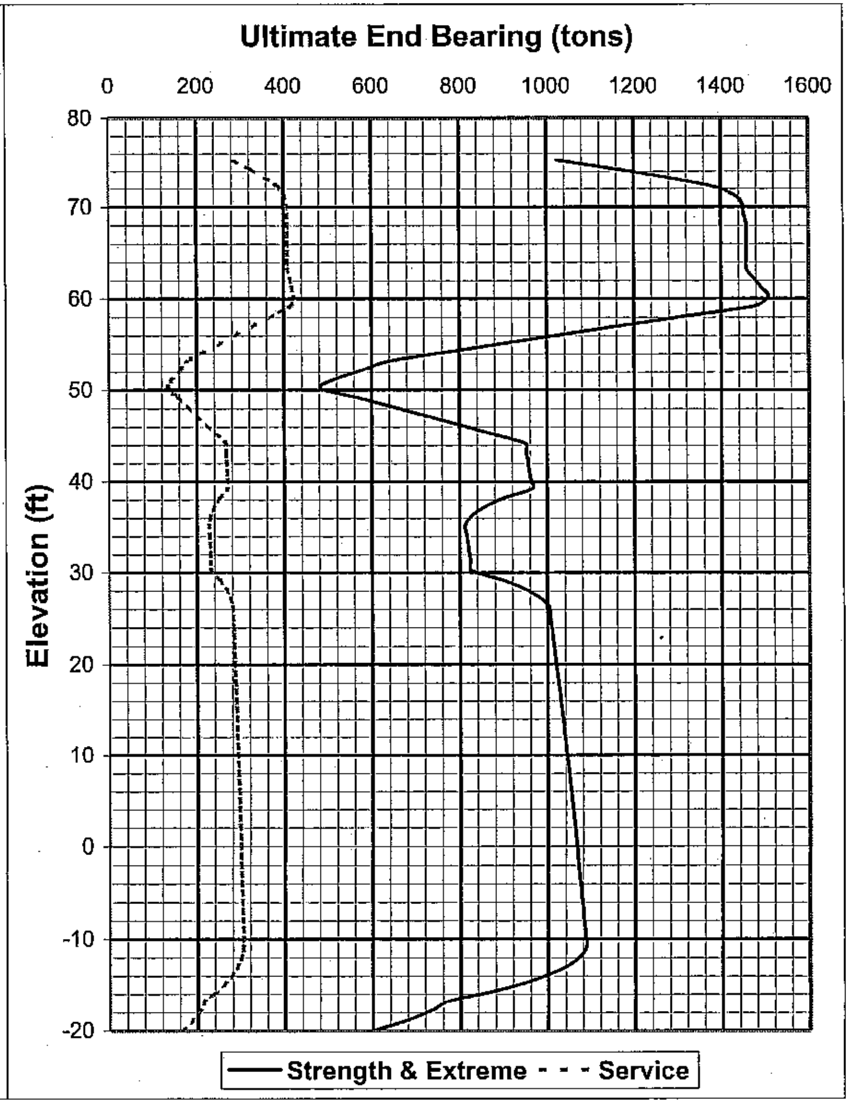
SR 90

Two Way Transit and HOV Operations

Pier: 2

Shaft Diameter: 8 ft.



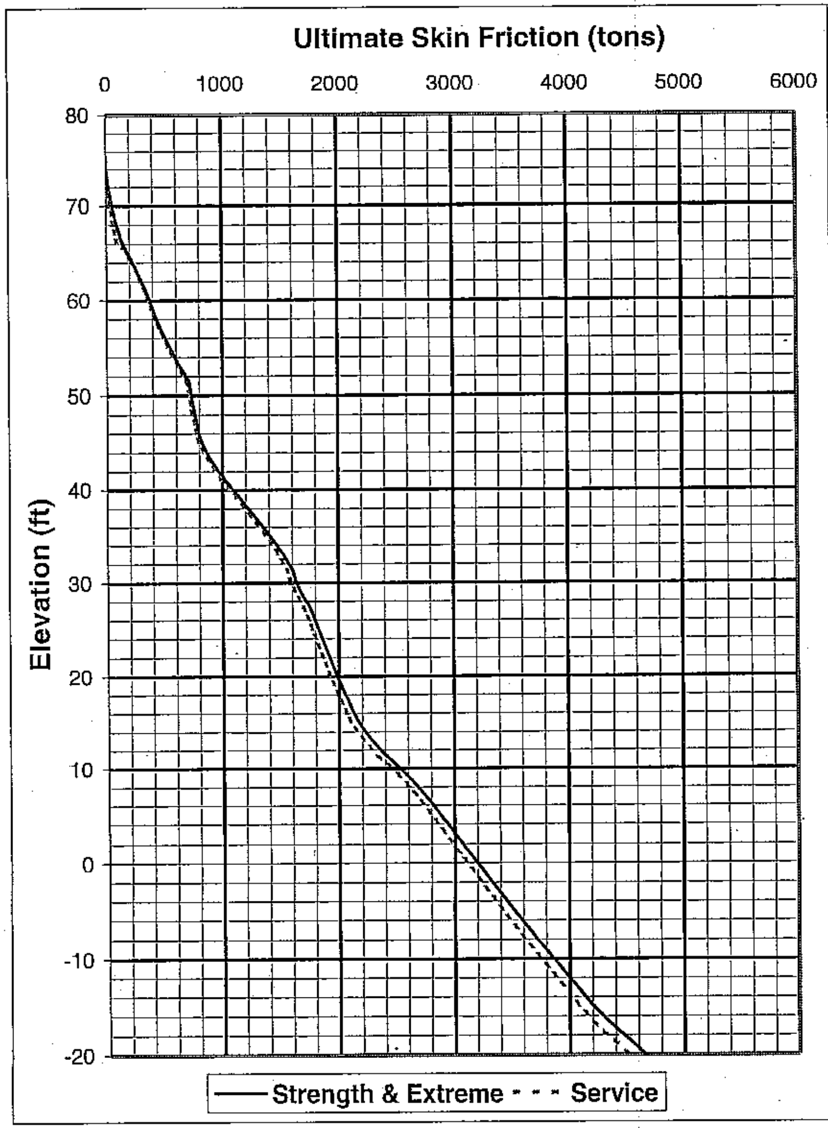


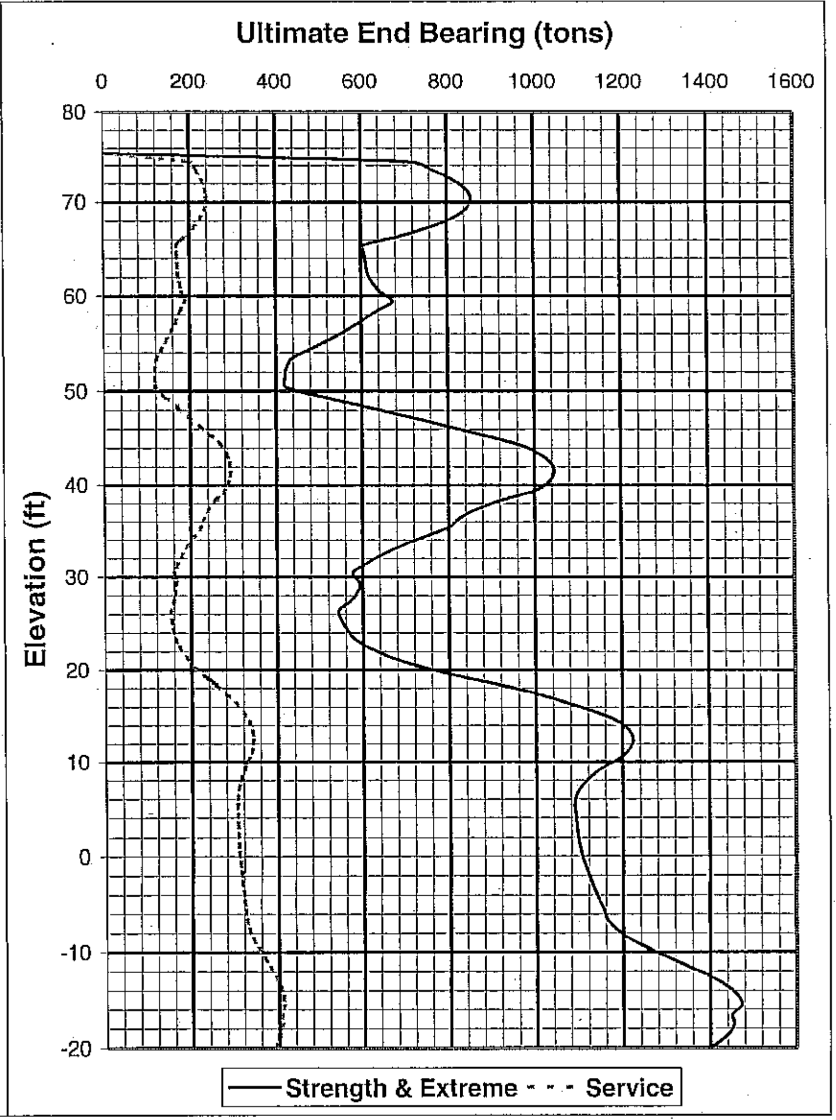
SR 90

Two Way Transit and HOV Operations

Pier: East Abutment

Shaft Diameter: 8 ft.





I 90 Two Way Transit & HOV Operations
P-Y Curve Parameters for LPILE Input - Static and Dynamic Analysis

Pier 2
Based on Boring BH-1-05

Soil Layer	Elevation	Soil Type	Soil Profile Type (KSOIL)	Effective Unit Weight of Soil	Saturated Undrained Shear Strength, S_u	Axial Strain ε_{50}	Friction Angle ϕ	Modulus of Subgrade Reaction
	(ft)			(pcf)	(psf)	(%)	(deg)	(pci)
1	71 - 76	SAND	4	120	-	-	32	75
2	51 - 71	SAND	4	125	-	-	40	140
3	-9 - 51	SAND	4	62.6	-	-	40	140
4	-29 - -9	CLAY	2	62.6	2000	0.005	-	-

Pier 1
Based on Boring BH-2-05

Soil Layer	Elevation	Soil Type	Soil Profile Type (KSOIL)	Effective Unit Weight of Soil	Saturated Undrained Shear Strength, S_u	Axial Strain ε_{50}	Friction Angle ϕ	Modulus of Subgrade Reaction
	(ft)			(pcf)	(psf)	(%)	(deg)	(pci)
1	66 - 76	SAND	4	120	-	-	32	75
2	50 - 66	SAND	4	125	-	-	40	250
3	-24 - 50	SAND	4	62.4	-	-	40	140

East Abutment
Based on Boring BH-3-05

Soil Layer	Elevation	Soil Type	Soil Profile Type (KSOIL)	Effective Unit Weight of Soil	Saturated Undrained Shear Strength, S_u	Axial Strain ε_{50}	Friction Angle ϕ	Modulus of Subgrade Reaction
	(ft)			(pcf)	(psf)	(%)	(deg)	(pci)
1	66 - 76	SAND	4	120	-	-	32	75
2	50 - 66	SAND	4	125	-	-	40	250
3	-24 - 50	SAND	4	62.4	-	-	40	140

I90: Two Way Transit & HOV Operations, Stage 1 - W80th Ramp Bridge

Input Parameters for Lateral Analysis - SIL-SHAFT

Pier 2: Based on Boring BH-1-05
Ground Elevation: 76.2 ft.

Soil Layer	Soil Type	Layer Thickness (ft)	Effective Unit Weight (pcf)	Friction Angle (deg)	ε_{50} (%)	Soil Cohesion (psf)	s_u at Top of Layer (psf)	s_u at Bottom of Layer (psf)	SPT Corrected Blowcounts	Fines Content (%)	Angularity
1	Sand	5	120	32	1.2	0			19	10	Sub-Rounded
2	Sand	20	125	40	1	0			50	7	Sub-Rounded
3	Sand	60	62.6	40	0.25	0			50	70	Sub-Rounded
4	Clay	20	62.6		0.5		2000	2000	35	100	

Pier 1: Based on Boring BH-2-05
Ground Elevation: 76.6 ft.

Soil Layer	Soil Type	Layer Thickness (ft)	Effective Unit Weight (pcf)	Friction Angle (deg)	ε_{50} (%)	Soil Cohesion (psf)	s_u at Top of Layer (psf)	s_u at Bottom of Layer (psf)	SPT Corrected Blowcounts	Fines Content (%)	Angularity
1	Sand	10	120	32	1.2				11	10	Sub-Rounded
2	Sand	16	125	40	0.25				50	70	Sub-Rounded
3	Sand	74	62.6	40	0.25				50	70	Sub-Rounded

East Abutment: Based on Boring BH-3-05
Ground Elevation: 76.4 ft.

Soil Layer	Soil Type	Layer Thickness (ft)	Effective Unit Weight (pcf)	Friction Angle (deg)	ε_{50} (%)	Soil Cohesion (psf)	s_u at Top of Layer (psf)	s_u at Bottom of Layer (psf)	SPT Corrected Blowcounts	Fines Content (%)	Angularity
1	Sand	10	120	32	1.2				23	10	Sub-Rounded
2	Sand	16	125	40	0.25				50	70	Sub-Rounded
3	Sand	74	62.6	40	0.25				50	70	Sub-Rounded

Appendix E

Spread Footing Design Information

I90 Two Way Transit & HOV Operations

East Abutment Bearing Capacity

East Abutment Maximum Footing Elevation : 65'

Footing Width (ft)	Ultimate Bearing Capacity (ksf)	Service Bearing Capacity (ksf) Based on 1" of Settlement
6	88.6	14.0
9	98.9	10.0
12	110.8	8.0
15	119.0	6.75
18	120.0	6.0
21	120.0	5.25

Lateral Earth Pressure Coefficients and Soil Parameters

Parameter	**Value**
Backfill Unit Weight (γ)	130 pcf
Backfill Soil Friction Angle (ϕ_f)	36°
Active Earth Pressure (K_a)	0.26
At Rest Earth Pressure (K_0)	0.41
Bearing Soil Friction Angle (ϕ_f)	40°
Passive Earth Pressure (K_p) - Unfactored	3.85
Coefficient of Sliding	0.84
Seismic Coefficient (K_{ae})	0.35

Shear Modulus versus Foundation Soil Strain

Pier 1

Shear Modulus, G	**Strain**	**Poisson's ratio, μ**
879 to 2638 ksf	0.2 to 0.02 %	0.35