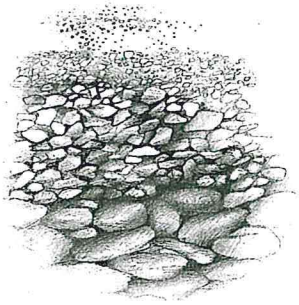

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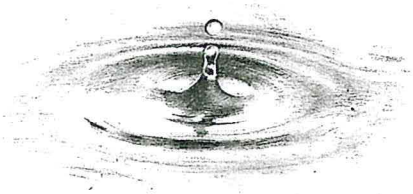

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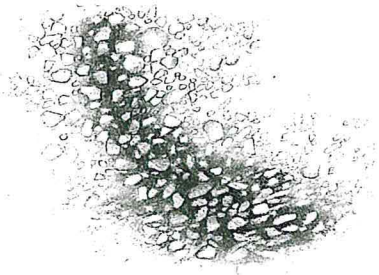

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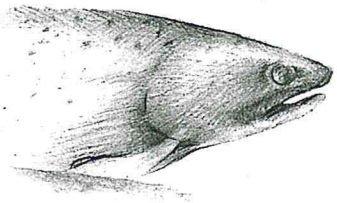

Ecological/Biological Sciences

Geologic Assessments

Associated Earth Sciences, Inc.

Subsurface Exploration, Geologic Hazard, and Geotechnical Engineering Report

TUKWILA STATION

Tukwila, Washington

Prepared for

Pacific Commercial Properties, Inc.

Project No. KE05127A
August 3, 2005

PW06-069
D06-309

Associated Earth Sciences, Inc.

August 3, 2005
Project No. KE05127A

Pacific Commercial Properties, Inc.
P.O. Box 53405
Bellevue, Washington 98015

Attention: Mr. Ken Kester

Subject: Subsurface Exploration, Geologic Hazard, and Geotechnical Engineering Report
Tukwila Station
Tukwila, Washington

Dear Mr. Kester:

We are pleased to present the enclosed copies of the above-referenced report. This report summarizes the results of our subsurface exploration, geologic hazard, and geotechnical engineering studies and offers recommendations for the design and development of the proposed project.

We have enjoyed working with you on this study and are confident that the recommendations presented in this report will aid in the successful completion of your project. If you should have any questions or if we can be of additional help to you, please do not hesitate to call.

Sincerely,
ASSOCIATED EARTH SCIENCES, INC.
Kirkland, Washington

G. Aaron McMichael

G. Aaron McMichael P.E., P.E.G.
Associate Engineer

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SUBSURFACE EXPLORATION, GEOLOGIC HAZARD, AND GEOTECHNICAL ENGINEERING REPORT

TUKWILA STATION

Tukwila, Washington

Prepared for:
Pacific Commercial Properties, Inc.
P.O. Box 53405
Bellevue, Washington 98015

Prepared by:
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August 3, 2005
Project No. KE05127A

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I. PROJECT AND SITE CONDITIONS

1.0 INTRODUCTION

This report presents the results of our subsurface exploration, geologic hazard, and geotechnical engineering study for the proposed new Tukwila Station retail/multi-family development to be located in Tukwila, Washington. The site location is presented on Figure 1, Vicinity Map. The proposed building location and approximate locations of the explorations accomplished for this study are presented on the Site and Exploration Plan, Figure 2. In the event that any changes in the nature, design, or location of the structure are planned, the conclusions and recommendations contained in this report should be reviewed and modified, or verified, as necessary.

1.1 Purpose and Scope

The purpose of this study was to provide subsurface data to be utilized in the design and development of the referenced project. The study included drilling four exploration borings and installing one ground water monitoring well, advancing four cone penetrometer tests (CPTs), and performing geologic studies to assess the type, thickness, distribution, and physical properties of the subsurface sediments and ground water conditions. We also reviewed the following geotechnical reports for project sites in the immediate project vicinity:

- Associated Earth Sciences Inc. (AESI), "Subsurface Exploration, Geologic Hazard, and Geotechnical Engineering Report, Tukwila Family Fun Center Proposed New Hotel and Office Building," November 15, 2000;

- AESI, "Subsurface Exploration, Geologic Hazard, and Preliminary Geotechnical Engineering Report, Tukwila Family Fun Center, Proposed New Office Building," July 22, 2003; and

- GeoEngineers, Inc., "Report Geotechnical Engineering Services and Phase I Environmental Site Assessment, Proposed Exhibition Center, Tukwila, Washington," August 1990.

Geologic hazard evaluations and geotechnical engineering studies were also conducted to determine suitable geologic hazard mitigation techniques, the type of suitable pile foundation, pile design recommendations, anticipated settlements, floor support recommendations, detention vault retaining wall lateral earth pressures and uplift pressures, pavement design criteria, and site preparation, structural fill, and drainage considerations. This report

summarizes our current fieldwork and offers geologic hazard mitigation and development recommendations based on our present understanding of the project.

1.2 Authorization

Written authorization to proceed with this study was granted by Pacific Commercial Properties, Inc. Our study was accomplished in general accordance with our scope of work letter dated March 3, 2005. This report has been prepared for the exclusive use of Pacific Commercial Properties, Inc. and their agents for specific application to this project. Within the limitations of scope, schedule, and budget, our services have been performed in accordance with generally accepted geotechnical engineering and engineering geology practices in effect in this area at the time our report was prepared. Our observations, findings, and opinions are a means to identify and reduce the inherent risks to the owner. No other warranty, express or implied, is made.

2.0 PROJECT AND SITE DESCRIPTION

This report was completed with an understanding of the project based on a topographic survey, Topography Survey by Eastside Consultants, Inc. dated January 2005, and civil engineering details contained in the Preliminary Grading and Utilities Plan dated April 12, 2005 provided by Pacific Engineering Design, LLC. We understand that the project will consist of the development of a five-story, retail/multi-family residential building with a ground-floor parking area. The building footprint will cover an approximate area of 120,000 square feet. The building will be rectangular in shape with dimensions of approximately 900 feet north to south by about 130 feet east to west. The project structural engineer estimates that building column loads will be in the range of 500 kips (250 tons) per column. Storm water detention vaults will be located at the north end of the building and near the southeast building corner and will be approximately 7 to 8 feet deep. The detention facilities will be constructed with bottom of footing elevations 7 feet below existing grade within the north vault and 3 feet below existing grade within the south vault. Approximately 1 to 4 feet of fill soil will be added to the site to reach the proposed site grades.

The building site is located just west of the intersection of South Longacres Way and the Boeing Access Road, and northwest of the future site of the Sounder and Amtrack Cascades Station. The site is bounded by a Burlington Northern Santa Fe (BNSF) railroad track embankment to the east, a Union Pacific railroad track embankment to the west, a City of Tukwila construction yard and Interstate 405 to the north, and South Longacres Way to the south. The proposed building area consists of a flat, open field approximately 2 feet above the street elevation of adjacent South Longacres Way. Site grades within the flat portion of the

site range from elevation 14 feet to elevation 18 feet along the east and west perimeters, respectively. The railroad embankments slope steeply upward from the site to the track levels, which are approximately 10 feet above the surrounding ground surface. A large drainage ditch is located along the east perimeter of the site.

3.0 SUBSURFACE EXPLORATION

Our field study included drilling four exploration borings to 90 to 100 feet below existing grades, installing one ground water monitoring well, and collecting soil samples with a trailer-mounted drill rig to gain subsurface information about the site. In addition, four CPT explorations were advanced to depths of 75 to 90 feet to help characterize subsurface conditions. Our explorations were approximately located in the field by measuring from known site features shown on Figure 2. The various types of sediments, as well as the depths where characteristics of the sediments changed, are indicated on the exploration logs presented in the Appendix to this report. Results of the CPTs are also included in the Appendix and generally agree with soil types and strength data indicated by the soil borings. The depths indicated on the boring logs where conditions changed may represent gradational variations between sediment types in the field as demonstrated by the CPT results. If changes occurred between sample intervals in our borings, they were interpreted.

The conclusions and recommendations presented in this report are based on the eight explorations completed for this study. The number, type, locations, and depths of the explorations were completed within site and budgetary constraints. Because of the nature of exploratory work below ground, extrapolation of subsurface conditions between field explorations is necessary. It should be noted that differing subsurface conditions are sometimes present due to the random nature of deposition and the alteration of topography by past grading and/or filling. The nature and extent of any variations between the field explorations may not become fully evident until construction. If variations are observed at that time, it may be necessary to re-evaluate specific recommendations in this report and make appropriate changes.

3.1 Exploration Borings

The exploration borings were completed by advancing a $3^3/_8$-inch, inside-diameter, hollow-stem auger with a trailer-mounted drill. Below the water table, borings were completed with mud-stabilization drilling techniques. During the drilling process, samples were obtained at generally 2.5- or 5-foot-depth intervals. The borings were continuously observed and logged by a geotechnical engineer from our firm. The exploration logs presented in the Appendix are based on the field logs, drilling action, and inspection of the samples obtained.

Disturbed but representative samples were obtained by using the Standard Penetration Test (SPT) procedure in accordance with American Society for Testing and Materials (ASTM):D 1586. This test and sampling method consists of driving a standard 2-inch, outside-diameter, split-barrel sampler a distance of 18 inches into the soil with a 140-pound hammer free-falling a distance of 30 inches. The number of blows for each 6-inch interval is recorded and the number of blows required to drive the sampler the final 12 inches is known as the Standard Penetration Resistance ("N") or blow count. If a total of 50 is recorded within one 6-inch interval, the blow count is recorded as the number of blows for the corresponding number of inches of penetration. The resistance, or N-value, provides a measure of the relative density of granular soils or the relative consistency of cohesive soils; these values are plotted on the attached boring log.

The samples obtained from the split-barrel sampler were classified in the field and representative portions placed in watertight containers. The samples were then transported to our laboratory for further visual classification and laboratory testing, as necessary.

3.2 Cone Penetrometer Tests

The CPTs were completed by advancing a 36-millimeter-diameter, 60-degree point angle cone through the soil to depth. The cone is attached onto the end of a friction sleeve. As the cone penetrates the soil, the ratio of sleeve resistance to cone resistance is measured. Changes in this ratio are used to estimate soil strength (Qc) and type. Correlations can then be made to standard penetration test N-values described above.

3.3 Laboratory Tests

We performed the following tests on selected samples collected from our borings to aid in our pile calculations, settlement estimates, and liquefaction analysis. The test results are included in the Appendix.

- Percent Passing the No. 200 Sieve (ASTM:D 1140)
- Moisture Content (ASTM:D 2216)
- One Dimensional Consolidation Test (ASTM:D 2435-92)
- Specific Gravity (ASTM:D 854)
- Atterberg Limits (ASTM:D 4318)

The following table lists results of the percent soil fines passing the No. 200 sieve and moisture content test.

Table 1
Selected Laboratory Test Results

Exploration Location	Depth (feet)	Moisture Content (percent)	Percent Fines
EB-4	3.5	42.3	88.5
EB-4	13.5	47.2	98.7
EB-4	23.5	26.2	2.7
EB-4	33.5	27.0	4.0
EB-4	43.5	21.2	6.5
EB-4	53.5	26.9	5.4
EB-4	63.5	35.1	20.3

4.0 SUBSURFACE CONDITIONS

The encountered soils were consistent with the geology mapped in the site area as shown on the *Geologic Map of King County, Washington* by Booth et al., 2002. This map shows the site area is mantled by alluvial soil.

4.1 Stratigraphy

Fill

Man-placed fill consisting of silty sand with gravel was encountered in all explorations to depths of roughly 4 feet. The fill is currently in a medium dense to dense condition. In general, the soil moisture content of the surface fill soils were wet of optimum at the time of our site exploration. However, during summer season construction, the fill soils may be reused for structural fill where soil moisture contents are near the optimum moisture content necessary to achieve adequate compaction.

Alluvium

Sediments encountered beneath fill generally consisted of about 20 feet of soft to medium stiff, gray, compressible silt overlying black, fine to medium sand with occasional lenses of silty sand and gravel. In general, the sand was in a medium dense condition to a depth of roughly 75 to 80 feet with localized areas of dense soil below 50 to 60 feet. The deeper sand deposits also contained shell fragments and a few organics. We interpret these sediments to be representative of recent alluvium deposited by the Green River within the last 10,000 years.

It should be noted that the alluvial silt soils are above their optimum moisture content for compaction and are moisture-sensitive and easily disturbed. Their reuse as structural fill during all but the driest times of the year will be difficult and require significant aeration and scarification to facilitate reduction of moisture levels to achieve compaction.

4.2 Hydrology

Ground water was generally encountered at a depth of about 11 feet below the existing ground surface within the borings and several of the cone penetrometers during exploration. We also measured the static water level in monitoring well MW-1 at 5.4 feet on April 13, 2005. Please refer to Table 2 showing ground water levels correlated with site elevation.

Table 2
Ground Water Depths and Elevations

Exploration Boring and Monitoring Location	Ground Water Depth Below Existing Ground Surface ADT[1] (feet)	Ground Surface Elevation (feet)	Ground Water Elevation ADT[1] (feet)
EB-1	11	17	6
EB-2	11	16	5
EB-3	11	15	4
EB-4	6	15	9
MW-1	11 5.4[2]	17 17	6 12[2]

[1] ATD = At time of drilling
[2] Stabilized reading 5 days after drilling

It should be noted that fluctuations in the level of the ground water may occur due to the time of the year and variations in rainfall and adjacent river levels. For design and potential dewatering plans, we recommend setting the ground water elevation at a depth 3 feet below existing site grades since ground water levels have been suppressed due to below-normal 2004/2005 winter precipitation.

II. GEOLOGIC HAZARDS AND MITIGATIONS

The following discussion of potential geologic hazards is based on the geologic, slope, and ground water conditions as observed and discussed herein. The discussion will be limited to seismic, landslide, and erosion hazards, including sediment transport.

5.0 SLOPE STABILITY HAZARDS AND RECOMMENDED MITIGATION

Reconnaissance of this site was limited to the area shown on Figure 2. The site topography is relatively flat to gently sloping except for the approximately 10-foot-high fill embankments that provide support for the railroad tracks. Although no tests were performed on these fill embankments, they have existed for many years without obvious signs of slope instability, erosion, or seismically induced lateral spreading into the drainage ditch adjacent to the east embankment. Therefore, in our opinion, the risk of landsliding is low and no mitigation measures are warranted.

6.0 SEISMIC HAZARDS AND RECOMMENDED MITIGATION

Earthquakes occur in the Puget Sound Lowland with great regularity. The vast majority of these events are small and are usually not felt by people. However, large earthquakes do occur as evidenced by the most recent 6.8-magnitude event on February 28, 2001 near Olympia Washington; the 1965, 6.5-magnitude event; and the 1949, 7.2-magnitude event. The 1949 earthquake appears to have been the largest in this area during recorded history. Evaluation of return rates indicates that an earthquake of the magnitude between 5.5 and 6.0 is likely within a given 20- to 40-year period.

Generally, there are four types of potential geologic hazards associated with large seismic events: 1) surficial ground rupture; 2) seismically induced landslides; 3) liquefaction; and 4) ground motion. The potential for each of these hazards to adversely impact the proposed project is discussed below.

6.1 Surficial Ground Rupture

Generally, the largest earthquakes which have occurred in the Puget Sound/Seattle area are sub-crustal events with epicenters ranging from 50 to 70 kilometers in depth. For this reason, no surficial faulting or earth rupture as a result of deep, seismic activity has been documented to date in the site vicinity. Therefore, it is our opinion, based on existing geologic data, that

the risk of surface rupture impacting the proposed project is low and no mitigations are recommended.

6.2 Seismically Induced Landslides

Reconnaissance of this site was limited to the area shown on Figure 2. The site topography is relatively flat to gently sloping except for the fill embankments that provide support for the railroad tracks. Although no tests were performed on these fill embankments, they have existed for many years without obvious signs of instability. Therefore, in our opinion, the risk of landsliding is low and no mitigation measures are warranted.

6.3 Liquefaction

We performed a liquefaction hazard analysis for this site in accordance with guidelines published in Seed & Idriss, 1982; Seed et al., 1985; and Kramer, 1996. Our liquefaction analysis was completed with the aid of LiquefyPro computer software Version 4.3 by CivilTech Corporation. Liquefaction occurs when vibration or ground shaking associated with moderate to large earthquakes (generally in excess of Richter magnitude 6.0) results in loss of internal strength in certain types of soil deposits. These deposits generally consist of loose to medium dense sand or silty sand that is saturated (e.g., below the water table). Loss of soil strength can result in consolidation and/or lateral spreading of the affected deposit with accompanying surface subsidence and/or heaving.

The liquefaction potential is dependent on several site-specific factors, such as soil grain size, density (modified to standardize field-obtained values), site geometry, static stresses, level of ground acceleration considered, and duration of the event. The recommended design-level earthquake parameters (a magnitude 7.5 earthquake occurring directly beneath the site with a peak horizontal ground acceleration of 0.30g) are set forth in the 2003 *International Building Code* (IBC) guidelines. However, a magnitude 6.5 to 7.0 earthquake with a peak ground acceleration of 0.20g, such as used for the current analysis, is typically used by most area municipalities for determination of seismic hazards, such as liquefaction.

Figure 3a considers a maximum ground water table of 5 feet during a magnitude 7.0 event for existing site conditions. Figures 3b and 3c consider the existing site soil conditions with the addition of between 1 and 4 feet of new structural fill in accordance with planned grade revisions. Our analysis indicates that under existing conditions, the site soils have a high risk of liquefaction above a depth of 70 feet. Settlements ranging from roughly 15 to 19 inches were calculated for the site soil profile. With the addition of 1 foot of structural fill, Figure 3b shows that only a slight reduction in settlement is predicted. With the addition of 4 feet of new structural fill, Figure 3c shows the predicted settlement is reduced by about 4.5 inches. Therefore, we

recommend that all building elements, including floor slabs and both vault structures, be supported on pile foundations if the building and vault structures cannot tolerate the estimated liquefaction-induced settlements. The vault structures could be supported on a structural mat foundation if designed to function with the estimated settlements. Pile foundations that extend to the minimum depths described in the *Design Recommendations* section of this report should reduce seismically induced structure settlement to tolerable levels.

6.4 Ground Motion

Design of the project should be consistent with 2003 IBC guidelines. In accordance with the 2003 IBC, the following values should be used for the site:

Site Class "F"
S_S = 142% (Figure 1516[1])
S_1 = 49% (Figure 1516[2])

7.0 EROSION HAZARDS AND RECOMMENDED MITIGATION

To mitigate and reduce the erosion hazard potential and off-site soil transport, we recommend the following:

1. All storm water from impermeable surfaces should be tightlined into an approved storm water drainage system or temporary storage facilities and kept away from the proposed work areas.

2. If possible, construction should proceed during the drier periods of the year and disturbed areas should be revegetated, paved, or otherwise protected as soon as possible.

3. Clearing beyond the construction areas should be kept to a minimum.

4. Temporary silt fences should be provided along the lower margins of cleared/disturbed areas and upslope from the existing ditch.

5. Temporary sediment catchment facilities should be cleaned out and maintained periodically, as necessary, to maintain their capacity and function.

6. Soils, which will be stockpiled at the site, should be stored in such a manner as to reduce erosion. Protective measures may include, but are not necessarily limited to, covering with plastic sheeting or the use of straw bales/silt fences.

7. Temporary construction entrances should be constructed with quarry spalls or equivalent according to King County and City of Tukwila standards.

III. DESIGN RECOMMENDATIONS

8.0 INTRODUCTION

The proposed project is feasible from a geotechnical engineering standpoint provided the recommendations contained herein are properly followed. Based on our subsurface exploration, the site contains significant risk of foundation settlement if conventional spread footings are utilized to carry the proposed heavy column and wall loads. The weight of the proposed structural fill and concrete slab-on-grade floors would also induce site settlements. Foundation and slab settlement would occur due to the presence of approximately 20 feet of soft compressible silt underlain by approximately 50 feet of saturated, loose and medium dense granular soils susceptible to liquefaction during a design-level earthquake. To mitigate the risk of foundation and slab settlement, we recommend the use of pile foundations for support of these structures. It is our understanding that the project owner has elected to utilize a pile-supported foundation and post-tensioned slab-on-grade floor within the ground floor parking area. Therefore, we have provided recommendations for pile foundation design criteria within the *Foundations* section of this report. To mitigate development of differential settlement between the pile-supported slab-on-grade floor and the adjacent parking areas susceptible to post-construction settlement, concrete aprons will be extended from the entrances to the ground floor slab-on-grade and allowed to hinge in proportion to the settlements.

Shallow ground water may complicate design and construction of storm water detention vault facilities and site utilities where they extend beyond approximately 5 feet below the existing site ground surface. Where the proposed excavations are anticipated to encounter ground water, the project design should consider dewatering, mitigation of soft soil bearing support, and control of potential buoyant uplift forces on these structures. These issues will likely need to be addressed for construction of the northern vault, which we anticipate will require excavating approximately 2 to 3 feet below the seasonal high ground water surface. Deep site utility trenches may also require dewatering and use of trench box shoring during construction.

Pavement support on structural fill overlying the existing fill is possible with near-surface remedial grading and compaction improvements. Both the existing surface fill soils and the underlying alluvial soils that will be excavated for construction of the storm water detention vaults, utilities, and pavement areas are moisture- and disturbance-sensitive, and will require careful control of their moisture content if they are to be used as structural fill. Use of site soils for structural fill will only be feasible during the driest periods of the year, and even then the use of the alluvial silts underlying the surface fill soils will be very difficult.

We understand the driveway and parking areas around the building will be constructed approximately 1 to 4 feet above existing grades. The addition of fill to the site will induce immediate primary settlement within the underlying soils, and continuing long-term secondary settlement. One option to mitigate these settlements would include surcharging the site with temporary fill soil in addition to the structural fill necessary to achieve planned grades. However, we understand that the owner of the project does not intend to complete a surcharge program. As an alternative option, some mitigation of the estimated primary settlement can be gained by placing the proposed fill soil on-site early in the construction sequence to "preload" the pavement areas, allowing most of the primary settlements to occur before final construction. However, the post-preload secondary settlement should be expected and will require future maintenance and repair of asphalt pavements and possibly utilities. To mitigate damage to utility pipes from the estimated settlement, restrained and flexible connections should be used, particularly at the connection with pile-supported structures. Further, increasing the slope gradient of gravity flow lines is recommended to make them less sensitive to settlement damage.

Excavations for the storm water vaults and utility excavations below a depth of 5 to 11 feet are expected to encounter ground water. This ground water may be under hydrostatic pressure, and sheet piling or dewatering wells may be necessary to dewater the excavation if volumes cannot be adequately controlled with small excavation pumps. Typically, excavation dewatering using pumped wells is a contractor design. An initial assumption of well size spacing and pump capacity is made and the wells installed. If desired drawdown is achieved, the excavation proceeds. If desired drawdown is not achieved, additional wells are installed until the desired effect is achieved. We are available to help estimate the depth, number, and capacity of dewatering wells, if desired, for cost-estimating purposes. Full-scale dewatering design is beyond our current scope of work. However, we have included preliminary sheet pile design criteria in the *Wall Design Parameters* section of this report. In addition, the vaults will require appropriate design and sizing to accommodate full hydrostatic and buoyant forces considering empty tank conditions and a static ground water surface located 3 to 5 feet below existing grade (approximate elevations of 14 to 12 feet). Ground water monitoring well MW-1 is currently in place. We recommend periodic monitoring of the ground water levels within this well to refine current ground water level design assumptions.

The conclusions and recommendations in this report are based upon the assumption that installation of the foundations for all structures, backfilling of the retaining walls for the detention vaults, and grading construction for site utilities and pavement are observed by a representative from our firm to ensure that our geotechnical recommendations have been adequately incorporated into the project design and construction. The following sections of the report discuss the above-mentioned design considerations in more detail and offer site preparation and construction recommendations.

9.0 SITE PREPARATION

Site preparation of planned building and road/parking areas that will not be supported by pile foundations should include mowing and removal of all grass and brush growth, construction debris, and any other surficial deleterious materials that are not part of the planned project. The existing thin layer of grass sod/topsoil may be left in place blow the planned fill soils to provide a more stable working surface. Areas where loose surficial soils exist due to construction traffic disturbance or grubbing operations should be considered as fill to the depth of disturbance and treated as subsequently recommended for structural fill placement. The monitoring well (MW-1) installed for the current study should be properly abandoned in accordance with Washington State Department of Ecology (Ecology) regulations subsequent to vault construction.

The fill encountered in our explorations was in a medium dense to dense condition. However, the density, thickness, and rubble content of the fill across the site may be highly variable. We anticipate that any upper loose surficial fill soils, once recompacted or replaced with new structural fill required to achieve site grades, will be suitable for support of pavement and other surfacing, such as sidewalks. However, there will be a risk of long-term damage to these surfaces including, but not limited to, rutting, yielding, cracking, etc. if any uncontrolled loose fill is not adequately recompacted to a firm and unyielding condition, or replaced with compacted structural fill. Utilities founded above loose uncontrolled fill or fill that contains abundant rubble are also at risk of settlement and associated damage. Use of restrained pipe connections and flexible connections at the building interface should be considered to limit damage to utility connections from settlement. For grade-sensitive storm sewer and sanitary sewer pipes, increasing pipe slopes is also recommended.

The extent of stripping necessary in areas of the site to receive structural fill for placement of external surfacing, such as sidewalks and pavement, can best be determined in the field by the geotechnical engineer or his representative. We recommend proof-rolling the road and parking areas with a loaded dump truck and systematic hand probing to identify any soft spots. These soft areas should be overexcavated and backfilled with structural fill.

The on-site fill soils contain a high percentage of fine-grained material which makes them moisture-sensitive and subject to disturbance when wet. The contractor must use care during site preparation and excavation operations so that the underlying soils are not softened. If disturbance occurs, the softened soils should be removed and the area brought to grade with structural fill. Consideration should be given to protecting access and staging areas with an appropriate section of crushed rock or asphalt treated base (ATB).

If crushed rock is considered for the access and staging areas, it should be underlain by engineering stabilization fabric to reduce the potential of fine-grained materials pumping up through the rock and turning the area to mud. The fabric will also aid in supporting construction equipment, thus reducing the amount of crushed rock required. We recommend that at least 10 inches of rock be placed over the fabric; however, due to the variable nature of the near-surface soils and differences in wheel loads, this thickness may have to be adjusted by the contractor in the field.

10.0 STRUCTURAL FILL

All references to structural fill in this report refer to subgrade preparation, fill type and placement, and compaction of materials as discussed in this section. If a percentage of compaction is specified under another section of this report, the value given in that section should be used.

After any stripping, planned excavation, and any required overexcavation have been performed to the satisfaction of the geotechnical engineer or his representative, the upper 12 inches of exposed ground in areas to receive fill should be recompacted to 90 percent of the modified Proctor maximum density using ASTM:D 1557 as the standard. If the subgrade contains silty soils and too much moisture, adequate recompaction may be difficult or impossible to obtain and should probably not be attempted. In lieu of recompaction, the area to receive fill should be blanketed with clean crushed rock or quarry spalls to act as a capillary break between the new fill and the wet subgrade. Where the exposed ground remains soft and further overexcavation is impractical, placement of an engineering stabilization fabric may be necessary to prevent contamination of the free-draining layer by silt migration from below.

After recompaction of the exposed ground is tested and approved, or a free-draining rock course is laid, structural fill may be placed to attain desired grades. Structural fill is defined as non-organic soil, acceptable to the geotechnical engineer, placed in maximum 8-inch loose lifts with each lift being compacted to 95 percent of the modified Proctor maximum density using ASTM:D 1557 as the standard. In the case of roadway and utility trench filling, the backfill should be placed and compacted in accordance with current City of Tukwila codes and standards. Adjacent to slopes (drainage ditch or raised grade edges) the top of the compacted fill should extend horizontally outward a minimum distance of 3 feet beyond the location of the roadway and parking area edges before sloping down at an angle of 2H:1V (Horizontal: Vertical).

The contractor should note that any proposed fill soils must be evaluated by AESI prior to their use in fills. This would require that we have a sample of the material 72 hours in advance to

perform a Proctor test and determine its field compaction standard. Soils in which the amount of fine-grained material (smaller than the No. 200 sieve) is greater than approximately 5 percent (measured on the minus No. 4 sieve size) should be considered moisture-sensitive. Use of moisture-sensitive soil in structural fills should be limited to favorable dry weather conditions. The on-site soils generally contained significant amounts of silt and are considered moisture-sensitive. In addition, construction equipment traversing the site when the soils are wet can cause considerable disturbance. If fill is placed during wet weather or if proper compaction cannot be obtained, a select import material consisting of a clean, free-draining gravel and/or sand should be used. Free-draining fill consists of non-organic soil with the amount of fine-grained material limited to 5 percent by weight when measured on the minus No. 4 sieve fraction with at least 25 percent retained on the No. 4 sieve.

A representative from our firm should inspect the stripped subgrade and be present during placement of structural fill to observe the work and perform a representative number of in-place density tests. In this way, the adequacy of the earthwork may be evaluated as filling progresses and any problem areas may be corrected at that time. It is important to understand that taking random compaction tests on a part-time basis will not assure uniformity or acceptable performance of a fill. As such, we are available to aid the owner in developing a suitable monitoring and testing program.

11.0 SURCHARGING AND PRELOADING

As mentioned previously, it is our understanding that the owner has elected not to surcharge the parking areas outside the pile-supported building and ground floor parking slab, and is willing to accept future maintenance/repairs associated with post-construction settlement. However, we have provided a discussion of a surcharge program in the event that design plans change.

Temporary surcharge fills have been widely used as an economical means to reduce post-construction settlements to acceptable levels. The site soils consist of soft to medium stiff compressible silt underlain by saturated, loose to medium dense liquefiable sand. We understand the driveway and parking areas around the building will be constructed approximately 1 to 4 feet above existing grades. Our settlement estimates indicate that primary site settlements in the range of 1 to 4.5 inches would likely be induced within the first 30 to 60 days after placement of the proposed new fill loads if surcharging is not performed. Secondary settlement over the next 20 years is estimated to be in the range of an additional 2 to 4 inches. Therefore, it would be advantageous to surcharge the proposed deeper fill areas in order to reduce future maintenance associated with settlement of the soft alluvium.

A typical surcharge program consists of surcharging the proposed pavement areas with an excess amount of fill soils for a relatively short period of time in order to cause pre-construction primary settlements to occur in the soft soils within a shorter time period, and to decrease the amount of long-term secondary settlement. Once the rate of settlement indicates that secondary settlement has been reached and is proceeding at an acceptable rate, the excess fill is stripped off of the surcharged area and could be placed as structural fill or removed from the site.

Generally, except in the case of lightly loaded structures with heavy surcharge fills, surcharging does not eliminate all long-term settlement, but places it within acceptable ranges. With any surcharging program, the amount of post-construction settlement to be expected depends on several factors including: 1) height of surcharge; 2) time of surcharging; 3) subsurface soil characteristics; and 4) anticipated site loads. Within limits, the greater the surcharge intensity, the less time is required.

We anticipate that the time required for the majority of the primary settlement to occur would be on the order of 30 to 60 days. To monitor the progress of the surcharge program and minimize the time the surcharge would remain in place, settlement markers would be placed prior to filling and monitored on a weekly basis up to and including the first month after completion of the surcharge fill. Thereafter, bi-weekly readings would provide adequate data. Considering the subsurface conditions and the time schedule proposed above, we recommend that at least 3 feet of fill be placed on the proposed pavement areas. Thus, the total fill height above existing grade would be the thickness of the permanent fill plus 3 feet of temporary surcharge fill resulting in total fill depths of 4 to 7 feet.

Without the use of a surcharge program, some mitigation of the primary settlements can be achieved by placing the fill necessary to raise grades early in the construction sequence to allow some of the primary settlements to occur prior to construction of site utilities and pavements.

12.0 FOUNDATIONS

To mitigate post-construction building and ground floor slab settlement and the effects of seismically induced liquefaction, a pile foundation system is recommended. For this project, we recommend the use of 18- or 24-inch-diameter augercast piles. The following sections provide augercast pile recommendations based on the assumed column loads described previously.

12.1 Augercast Piles

We recommend that the construction of piles be accomplished by a contractor experienced in their installation. Although significant amounts of debris was not encountered within the fill soils covering the site, fill soils can have concrete, brick, wood, and other demolition waste in them, and soils of alluvial origin may have gravel lenses or logs present in them. It may be necessary to have a backhoe present during pile installation to dig out obstacles and backfill the excavation prior to drilling piling. If obstacles are encountered at depths where removal with a backhoe is not feasible, it might be necessary for the project structural engineer to modify the pile layout to replace piles that cannot be completed according to the original design. Observation of pile installation by AESI is important to verify that the subsurface conditions observed at pile locations are consistent with the observations in our subsurface explorations, and consistent with assumptions made during preparation of the recommendations in this report. The City of Tukwila will likely require such inspections of foundation piles.

The augercast piles will gain support primarily from end bearing with a smaller component resulting from skin friction. The pile lengths recommended in this report are based on anticipated depths where suitable soils for end-bearing capacity were encountered in our explorations. Augercast piles are formed by drilling to the required depth with a continuous flight, hollow-stem auger. Fluid grout is then pumped down the hollow stem under pressure as the auger is withdrawn. Reinforcing steel cages are then lowered into the unset grout. A single reinforcing bar is installed for the full length of the pile for transfer of uplift loads. Since the grout is placed under pressure, actual grout volumes used are typically 15 to 50 percent greater than the theoretical volume of the pile. Actual grout volumes for piles constructed through some types of fill and peat can be much more. The pile contractor should be required to provide a pressure gauge and a calibrated pump stroke counter so that the actual grout volume for each pile can be determined. Typically, a nine sack, minimum 4,000 pounds per square inch (psi) grout mix is used for augercast piles.

Once complete, the piles would then connect to a pile cap and grade beam system comprising the building foundation. Allowable capacities for the augercast piles are given in Table 3. Development of the design capacities presented in Table 3 requires a minimum overall pile length of at least 15 pile diameters.

To satisfy required length-to-diameter ratios, 18-inch piles are limited to 75 feet in length. Allowable design axial compressive loads may be increased by one-third for short-term wind or seismic loading. Anticipated settlement of the pile-supported foundations will generally be on the order of ½ inch.

Table 3
Augercast Pile Recommendations

Pile Diameter (inches)	Minimum Length (feet)	Allowable Vertical Compressive Load (tons)	Allowable Lateral Load (tons)[1]	Depth of fixity (feet)[2]	Allowable Uplift Load (tons)[3]
18	50	35	10	21	20
18	75	60	10	21	45
24	50	50	20	26	35
24	75	85	20	26	60

(1) Allowable lateral loads are for fixed-headed conditions (incorporation into pile caps and grade beam system), and ½ inch of deflection at the ground surface. Greater lateral capacities are possible for greater allowable deflections.
(2) The depth of fixity includes the code-required 20 percent increase for reinforcing cage design.
(3) Allowable uplift loads are based on minimum pile length of 50 feet.

Piles with lateral spacing less than 6 pile diameters from another pile along the direction of force should be considered to be in the zone of influence, and the lateral capacity and the reduction factors presented below should be used. If the lateral contribution of the piles is critical to the design of the structure, we can provide a comprehensive lateral pile analysis. Such an analysis would present lateral pile capacities taking into account the interaction between piles.

Based on the loose conditions of the soils through which the augercast piles are to be installed, care should be taken in construction planning to allow grout time to set prior to drilling adjacent piles. Typically, 24 hours of set time is recommended for piles closer than 3 diameters or 10 feet, whichever is greater. The 24 hours can be reduced for adjacent piles drilled on different workdays.

12.2 Group Effects

Where piles are installed in groups and subject to lateral loading, reductions in lateral capacity to account for group effects should be included in design. The effects of group performance should be considered where piles are spaced closer than 6 pile diameters center-to-center and are aligned in the direction of loading. Piles should not be spaced closer than 3 diameters center-to-center to achieve full vertical and uplift capacity. If piles are staggered in the x and y directions a minimum of 3 pile diameters, there is no reduction in lateral loading.

For the determination of individual capacities for load application parallel to the line of spacing, the following spacing and reduction factors presented in Table 4 should apply. The last pile in a row can be assumed to develop the full lateral capacity.

Table 4
Lateral Reduction Factors

Pile Spacing	Reduction Factor
6 diameters	1.0
5 diameters	0.8
4 diameters	0.6
3 diameters	0.4

12.3 Shallow Storm Water Vault Foundations

Storm water detention vaults will be constructed at the north end of the building and near the southeast building corner, and will be approximately 7 to 8 feet deep. The detention facilities will be constructed with bottom of footing elevations 7 feet below existing grade within the north vault and 3 feet below existing grade within the south vault. Approximately 1 to 4 feet of fill soil will be added to the site to reach the proposed site grades within the north and south vault areas, respectively. It appears that the north vault excavation will extend approximately 2 to 3 feet below the surface of the existing water table, while the south vault excavation will extend to within 2 feet of the existing ground water surface. We recommend that the vault foundations be designed to accommodate ground water elevations located at a depth of 3 feet below existing site grades since ground water levels have been suppressed due to below-normal 2004/2005 winter precipitation.

Although the vault excavations will remove soil weight roughly equal to the imposed stored water and vault structure weight, potential vault settlement may still occur due to placement of structural fill around the vault and potential earthquake-induced liquefaction. To mitigate the effects of the fill and earthquake-induced liquefaction settlement, we recommend supporting the vault structures on pile foundations. However, if the design team is willing to accept the risk of these settlements, which are estimated to be similar to those discussed previously, we recommend that the vaults be constructed on mat foundations bearing on 2-foot-thick structural fill pads placed and compacted as previously discussed. Construction of the structural fill pads beneath mat foundations is intended to provide a prism of uniform bearing material, which will reduce the effects of differential settlement. An allowable bearing pressure of 500 pounds per square foot (psf), including both dead and live loads, and a coefficient of subgrade reaction of

20 pounds pcf may be utilized for design purposes for mat foundations placed on the recommended structural fill pads. An increase of one-third may be used for short-term wind or seismic loading. The mat foundations should not be founded directly on existing native soils.

12.4 Passive Resistance and Friction Factors

Lateral loads on the foundations caused by seismic or transient loading conditions may be resisted by a combination of passive soil pressure against the side of the foundation and frictional resistance along the base. An allowable base friction value of 0.25 and an allowable passive earth pressure of 185 pounds per cubic foot (pcf) is recommended for vertical foundation elements cast "neat" against undisturbed earth or structural fill placed around vault mat foundations or building foundation grade beams. Below the ground water surface, a passive earth pressure of 75 pcf should be used. These values are allowable and include a safety factor of at least 1.5. All fill placed against building grade beams and vault footings must be compacted to at least 90 to 92 percent of ASTM:D 1557.

12.5 Buoyant Conditions

Where the vaults extend below the ground water surface, the foundations should be designed for submerged buoyant conditions. Buoyant uplift force may be calculated by multiplying the volume of ground water displaced by the vault by the unit weight of water. The uplift force can be resisted by the dead weight (vault empty) of the vault structure, and by the weight of the soils located above the vault. Native soils placed as structural fill compacted to at least 90 to 92 percent of the ASTM:D 1557 can be assumed to have a moist unit weight of 110 pcf. Imported fill soils can be assumed to have a moist unit weight of 120 pcf. Testing during the backfill procedure is recommended to confirm that this unit weight is achieved. It should be noted that the unit weight of the foundation material and backfill soils below the water table will be reduced to buoyant unit weights.

Buoyant forces can also be resisted by the frictional shear resistance of the soils located along the perimeter of the foundation element. These shear forces would be mobilized when the foundation experiences uplift conditions. To calculate the soil uplift shear resistance on the vault sidewalls above and below the ground water surface, the following equations may be used:

Uplift Resistance = F_sL $\qquad$ $F_s = 10H_2^2 + 4H_1^2 + 20H_2H_1$

Where:

F_s = shearing resistance of soil to foundation sidewalls (lb/ft of foundation wall)
H_2 = depth of foundation above ground water surface (ft)
H_1 = depth of foundation below ground water surface (ft)
L = perimeter of foundation sidewalls (ft)

Additional uplift resistance can be achieved by extending the base of the vault mat foundation beyond the sidewalls. In this case, the following equation may be used.

Uplift Resistance = F_sL $\qquad$ $F_s = 15H_2^2 + 6H_1^2 + 29H_2H_1$

The structural engineer should apply an adequate factor of safety to these equations.

All vault foundation areas should be inspected by AESI prior to placing concrete to verify that the design bearing capacity of the soils has been attained and that construction conforms to the recommendations contained in this report. Such inspections may be required by the City of Tukwila.

13.0 FLOOR SUPPORT

As discussed earlier in this report, existing site soils are considered to be settlement-prone and we therefore recommend that floor slabs be designed as structural slabs and supported on pile foundations. Floor slabs should be cast atop a minimum of 4 inches of clean, washed, crushed rock or pea gravel to act as a capillary break. The slab should also be protected from dampness by an impervious moisture barrier at least 10 mils thick. The impervious barrier should be placed between the capillary break material and the concrete slab. We recommend that samples of the capillary break material be submitted to AESI for approval prior to placement.

14.0 WALL DESIGN PARAMETERS

14.1 Temporary Sheet Pile Walls

Temporary sheet pile walls may be necessary for vault construction if ground water flow cannot be controlled and well point dewatering is not feasible. Sheet pile embedment depths

should satisfy moment equilibrium conditions plus a factor of safety of at least 1.5. They should be designed by a qualified structural engineer using the following recommended earth pressures. Sheet pile walls that are free to yield laterally at least 0.1 percent of their height may be designed using an equivalent fluid equal to 40 pcf. Fully restrained, rigid walls, which cannot yield, should be designed for an equivalent fluid of 60 pcf. Below the water table, an equivalent fluid of 82 and 100 pcf should be used for yielding and restrained conditions, respectively. These values include hydrostatic fluid pressures. To account for construction traffic adjacent to walls, a surcharge equivalent to 2 feet of soil should be added to the wall height in determining lateral design forces. Surcharges due to equipment loads or material stockpiles should also be added to the wall loads, as applicable. An allowable passive equivalent fluid pressure of 185 pcf should be used to calculate lateral resistance above the water table, and 75 pcf below the water table. These values are allowable values and include a safety factor of at least 1.5.

14.2 Permanent Vault Retaining Walls

All backfill behind concrete cast-in-place vault retaining walls should be placed as per our recommendations for structural fill and as described in this section of the report. Design loads given above for temporary sheet pile walls may be used for design of the vault retaining walls. In addition to these loads, a coefficient of friction of 0.25 can be used to determine base sliding resistance.

As required by the 2003 IBC, permanent retaining wall design should include a seismic surcharge pressure in addition to the equivalent fluid pressures presented above. Considering the site soils and the recommended wall backfill materials, we recommend a seismic surcharge pressure of 4H and 8H psf where H is the wall height in feet for the "active" and "at-rest" loading conditions, respectively. The seismic surcharge should be modeled as a rectangular distribution with the resultant applied at the mid-point of the wall.

The lateral pressures presented above are based on the conditions of a uniform backfill consisting of imported free-draining structural fill compacted to 90 percent of ASTM:D 1557. A higher degree of compaction is not recommended as this will increase the pressure acting on the walls. A lower compaction may result in settlement of the slab-on-grade or other structures supported above the walls. Thus, the compaction level is critical and must be tested by our firm during placement. Cast-in-place retaining wall backfill is recommended to consist of free-draining granular material. All free-draining backfill should contain less than 5 percent fines (passing U.S. No. 200 sieve) based upon the fraction passing the U.S. No. 4 sieve with at least 50 percent retained on the U.S. No. 4 sieve and a maximum aggregate size of 2½ inches. (On-site soils are not suitable for this use.) The primary purpose of the free-draining material is reduction of hydrostatic pressure above the water table and to facilitate compaction.

Surcharges from adjacent footings or heavy construction equipment, or sloping backfill must be added to the above values.

Perimeter footing drains should be provided for all retaining walls as discussed under the section on *Drainage Considerations* unless the walls are designed to resist hydrostatic pressures. It is imperative that proper drainage be provided so that hydrostatic pressures do not develop against the walls unless the walls are designed to resist hydrostatic pressures. This would involve installation of a minimum, 1-foot-wide blanket drain to within 1 foot of finish grade for the full wall height using imported washed gravel against the walls.

15.0 DRAINAGE CONSIDERATIONS

All exterior building grade beam foundations and vault mat foundations (if they will be drained) should be provided with a drain at least 12 inches below the base of the adjacent interior slab elevation. Drains should consist of rigid, perforated, polyvinyl chloride (PVC) pipe surrounded by washed pea gravel. The drains should be constructed with sufficient gradient to allow gravity discharge away from the structure. Roof and surface runoff should not discharge into the footing drain system, but should be handled by a separate, rigid, tightline drain. In planning, exterior grades adjacent to walls should be sloped downward away from the structure to achieve surface drainage.

16.0 PAVEMENT RECOMMENDATIONS

The majority of the parking and access areas are planned for those portions of the site underlain by fill materials overlying loose soils. Where planned fill and liquefaction-induced settlement can be tolerated, site soils can be used to support sidewalks, pavement, or other similar structures contingent upon adequate remedial preparation and understanding of uncertainties in settlement performance. Hardscape or pavement should be supported on at least 2 feet of structural fill consisting of existing fill soil or imported material compacted to 95 percent of ASTM:D 1557.

To reduce the depth of overexcavation required to achieve a suitable subgrade for support of the pavement, we recommend that an engineering stabilization fabric be placed over the subgrade prior to filling if silty, soft, loose, or wet soils are encountered.

The addition of an engineering stabilization fabric permits heavier traffic over soft subgrade and increases the service life of the system. The fabric acts as a separator between relatively fine-grained surficial materials on the site and the load-distributing aggregate (sand or crushed

rock). The high tensile strength and low modulus of elongation of the fabric also act to reduce localized stress by redistributing traffic loads over a wider area of subgrade. In addition, the recommended method of installation (proof-rolling) identifies weak areas, which can be improved prior to paving.

An engineering stabilization fabric, such as AMOCO 2002 or equivalent, should be placed over any encountered soft/loose subgrade that cannot be recompacted to a firm, non-yielding condition with the edges overlapped in accordance with the manufacturer's recommendations. Following subgrade preparation, clean, free-draining structural fill should be placed over the fabric and compacted to 95 percent of ASTM:D 1557. Where fabric is exposed, spreading should be performed such that the dozer remains on the fill material and is not allowed to operate on uncovered fabric. When 12 inches of fill has been placed, the fabric should be proof-rolled with a loaded dump truck to pretension the fabric and identify soft spots in the fill. Upon completing the proof-rolling operation, additional structural fill should be placed and compacted to attain desired grades.

Upon completion of the structural fill, a general pavement section consisting of 2½ inches of asphalt concrete pavement (ACP) underlain by 2 inches of $^{5}/_{8}$-inch crushed surfacing top course and 4 inches of 1¼-inch crushed surfacing base course is the recommended minimum. Within driveway areas and areas serviced by delivery and garbage trucks, a pavement section consisting of 3 inches of ACP underlain by 2 inches of $^{5}/_{8}$-inch crushed surfacing top course and 6 inches of 1¼-inch crushed surfacing base course is the recommended minimum. The crushed rock courses must be compacted to 95 percent of maximum density. Given the potentially variable in-place density of the existing fill subgrade, some settlement of paved areas should be anticipated unless the existing fill is entirely removed and replaced with structural fill.

17.0 PROJECT DESIGN AND CONSTRUCTION MONITORING

At the time of this report, site grading, structural plans, and construction methods have not been completely finalized. We are available to provide additional geotechnical consultation as the project design develops and possibly changes from that upon which this report is based. We recommend that AESI perform a geotechnical review of the plans prior to final design completion. In this way, our earthwork and foundation recommendations may be properly interpreted and implemented in the design.

We are also available to provide geotechnical engineering and monitoring services during construction. The integrity of the pile foundation system and vault construction depends on proper site preparation and construction procedures. In addition, engineering decisions may

have to be made in the field in the event that variations in subsurface conditions become apparent. Construction monitoring services are not part of this current scope of work. If these services are desired, please let us know and we will prepare a cost proposal.

We have enjoyed working with you on this study and are confident that these recommendations will aid in the successful completion of your project. If you should have any questions or require further assistance, please do not hesitate to call.

Sincerely,
ASSOCIATED EARTH SCIENCES, INC.
Kirkland, Washington

G. AARON McMICHAEL
STATE OF WASHINGTON
33222
REGISTERED
PROFESSIONAL ENGINEER

8/3/05

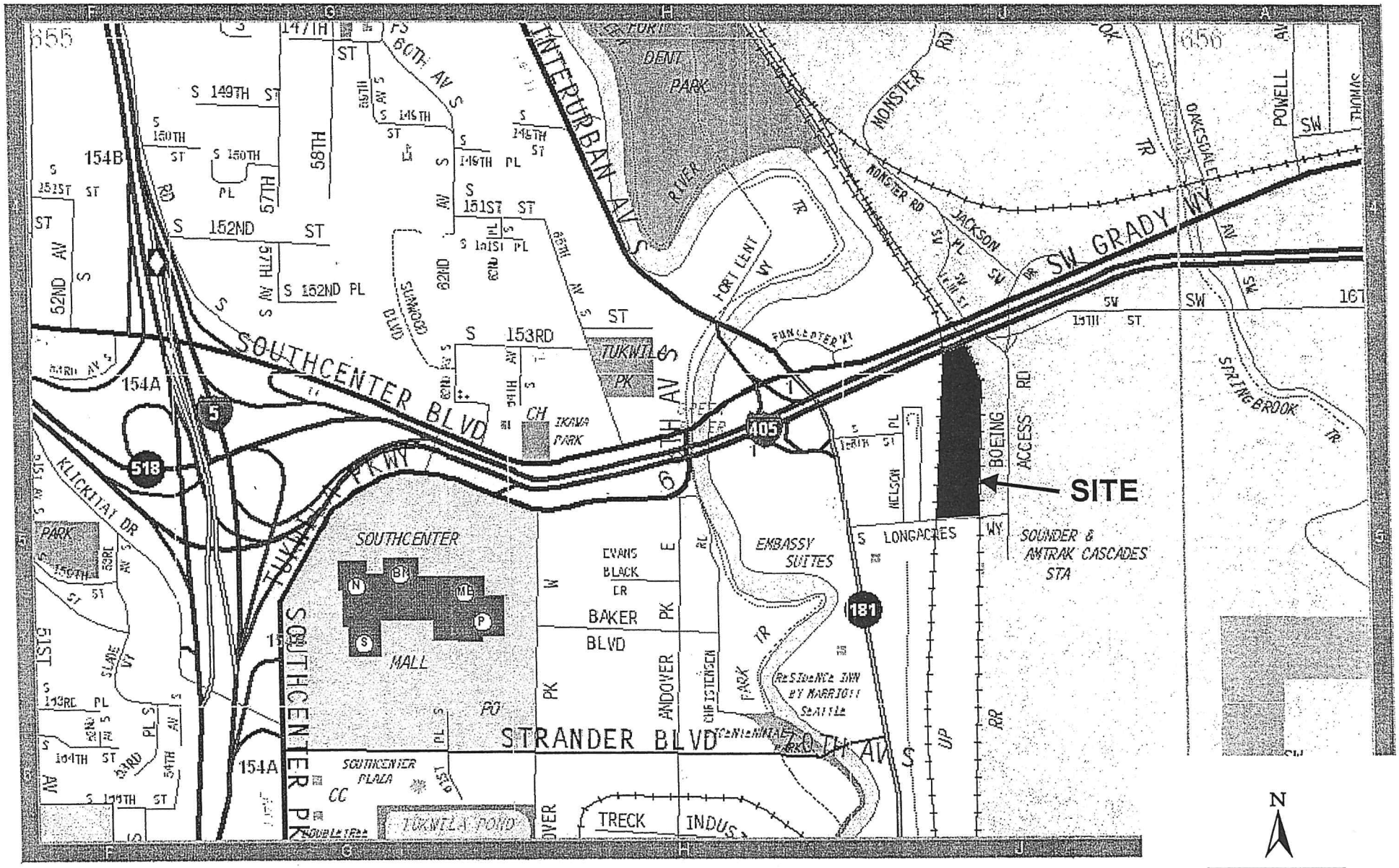
EXPIRES 2/27/2007

Susan G. Beckham, P.E., P.G., P.Hg.
Project Engineer

G. Aaron McMichael, P.E., P.E.G.
Associate Engineer

cc: Pacific Engineering Design, LLC
4180 Lind Avenue SW
Renton, Washington 98055
Attn: Mr. Greg Diener

Rutledge Maul Architects
19336 47th Avenue NE
Seattle, Washington 98155
Attn: Mr. Bill Rutledge



NO SCALE

Associated Earth Sciences, Inc.

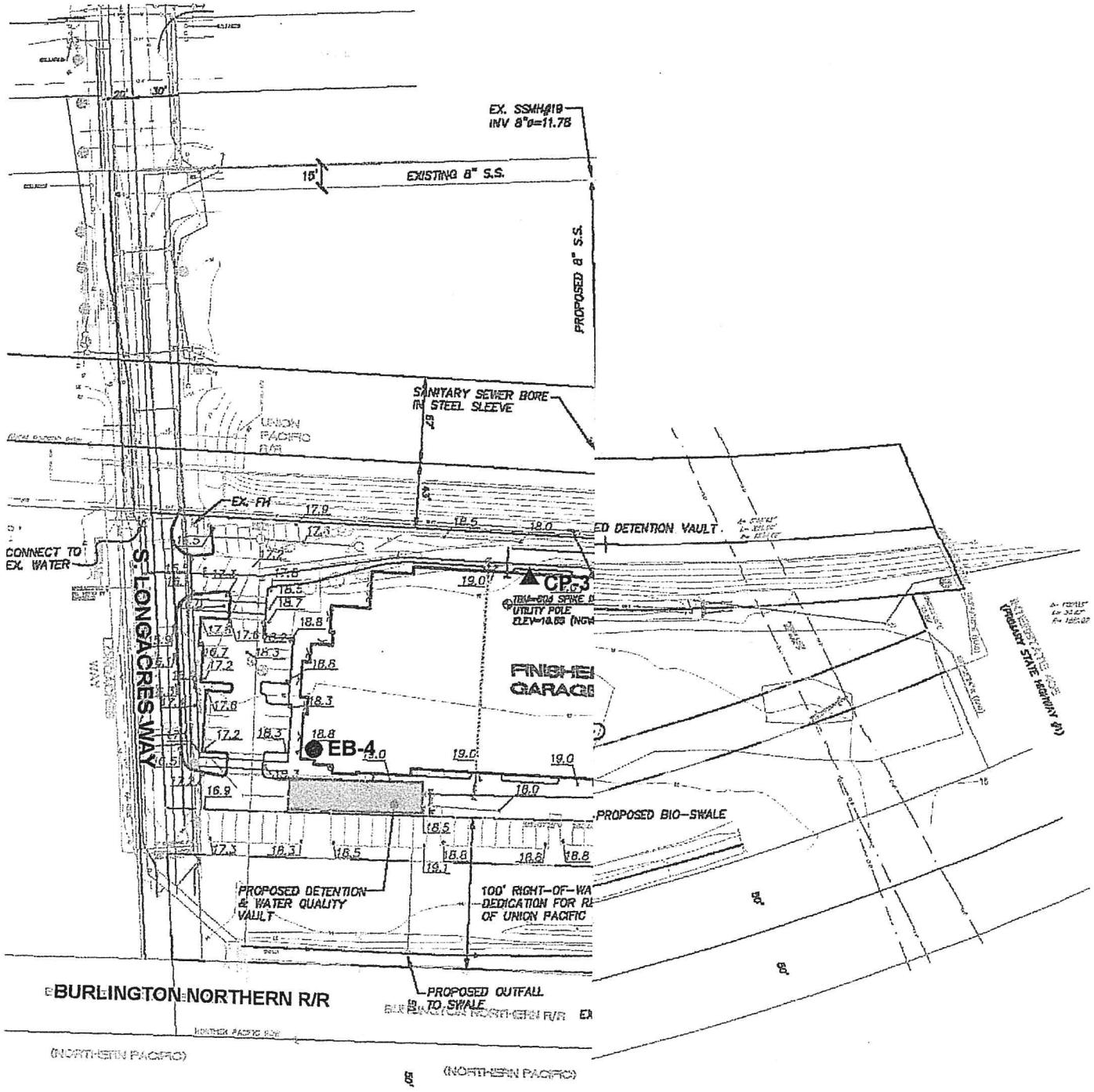
VICINITY MAP
TUKWILLA STATION
TUKWILLA, WASHINGTON

FIGURE 1

DATE 04/05

PROJ. NO. KE05127A

05127 TukStation \ 05127 Vicinity.cdr



LEGEND

EB-1 ● Approximate location of exploratic

CP-1 ▲ Approximate location of cone pen

MW-1 ⊙ Approximate location of monitorin

N

0 100

SCALE IN FEET

Reference: Pacific Engineering Design, LLC

Associated Earth Sciences, Inc.

FIGURE 2

DATE 04/05

PROJ. NO. KE05127A

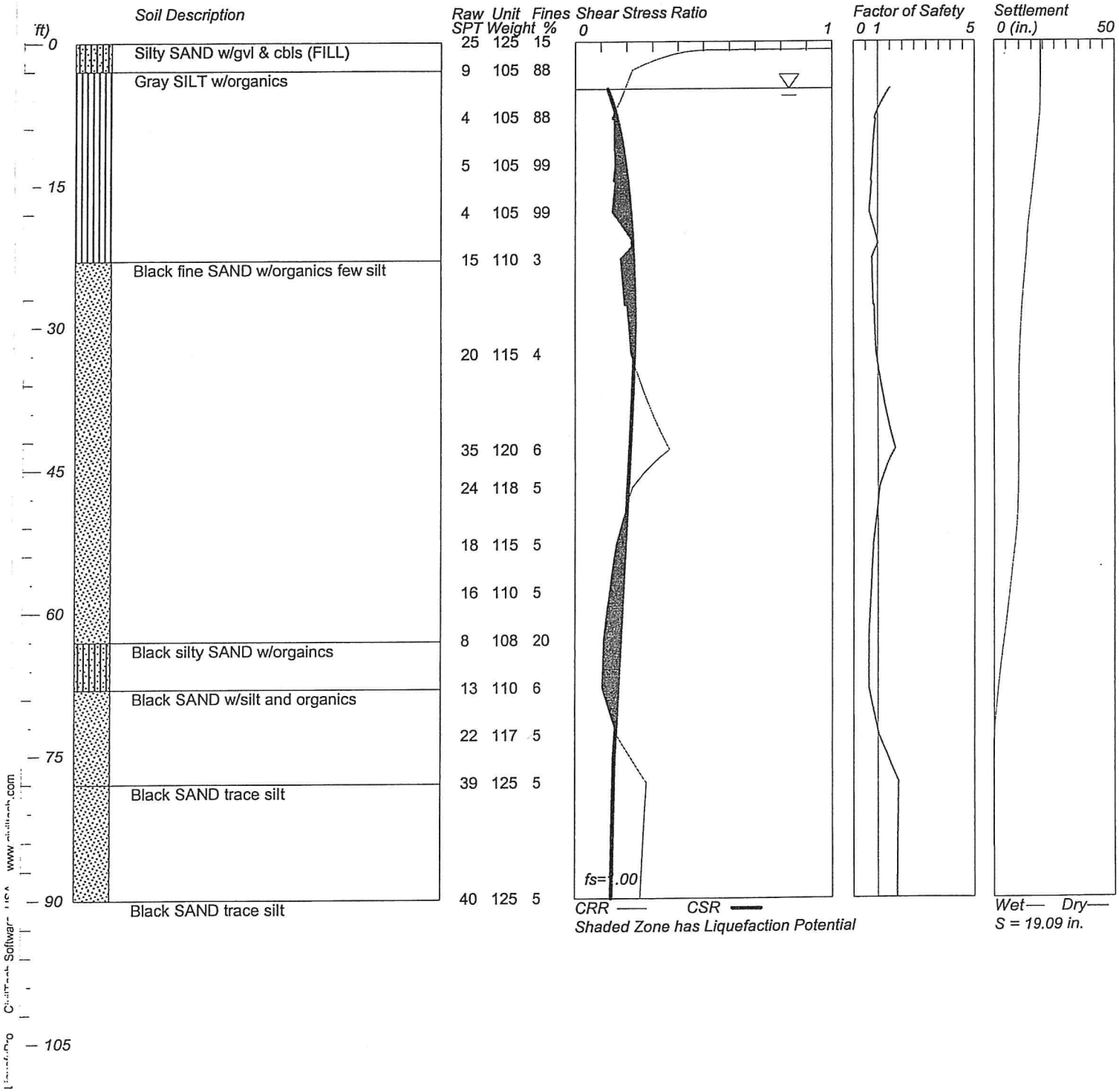
05127 TukStation \ 05127 Site and Expl.cdr Task A

LIQUEFACTION ANALYSIS

Tukwila Station

Hole No.=EB-4 Water Depth=5 ft Surface Elev.=15

Magnitude=7
Acceleration=.20g



LIQUEFACTION ANALYSIS

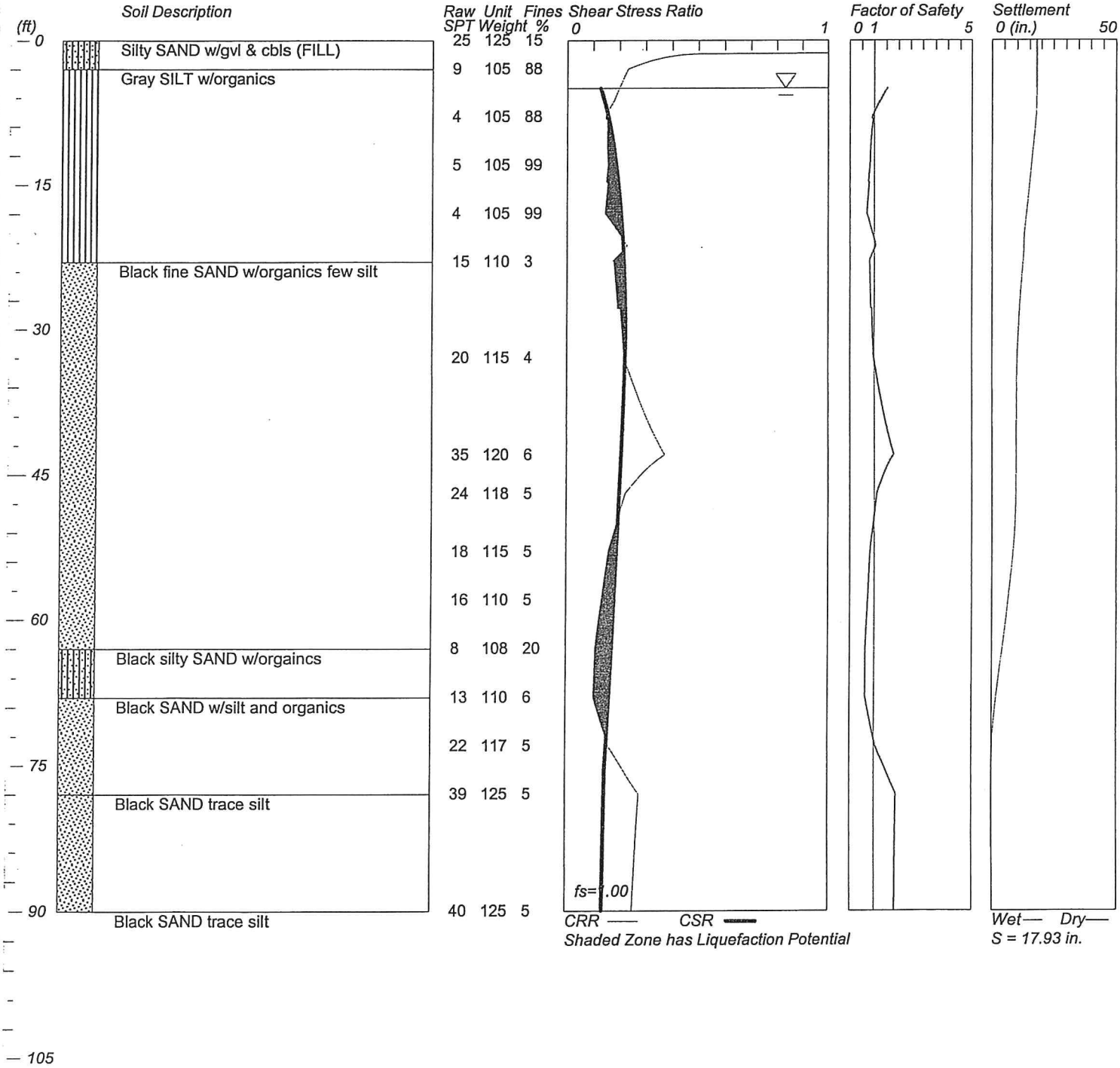
Tukwila Station

Hole No.=EB-4 Water Depth=5 ft Surface Elev.=15

Ground Improvement of Fill=1 ft

Magnitude=7

Acceleration=.20g



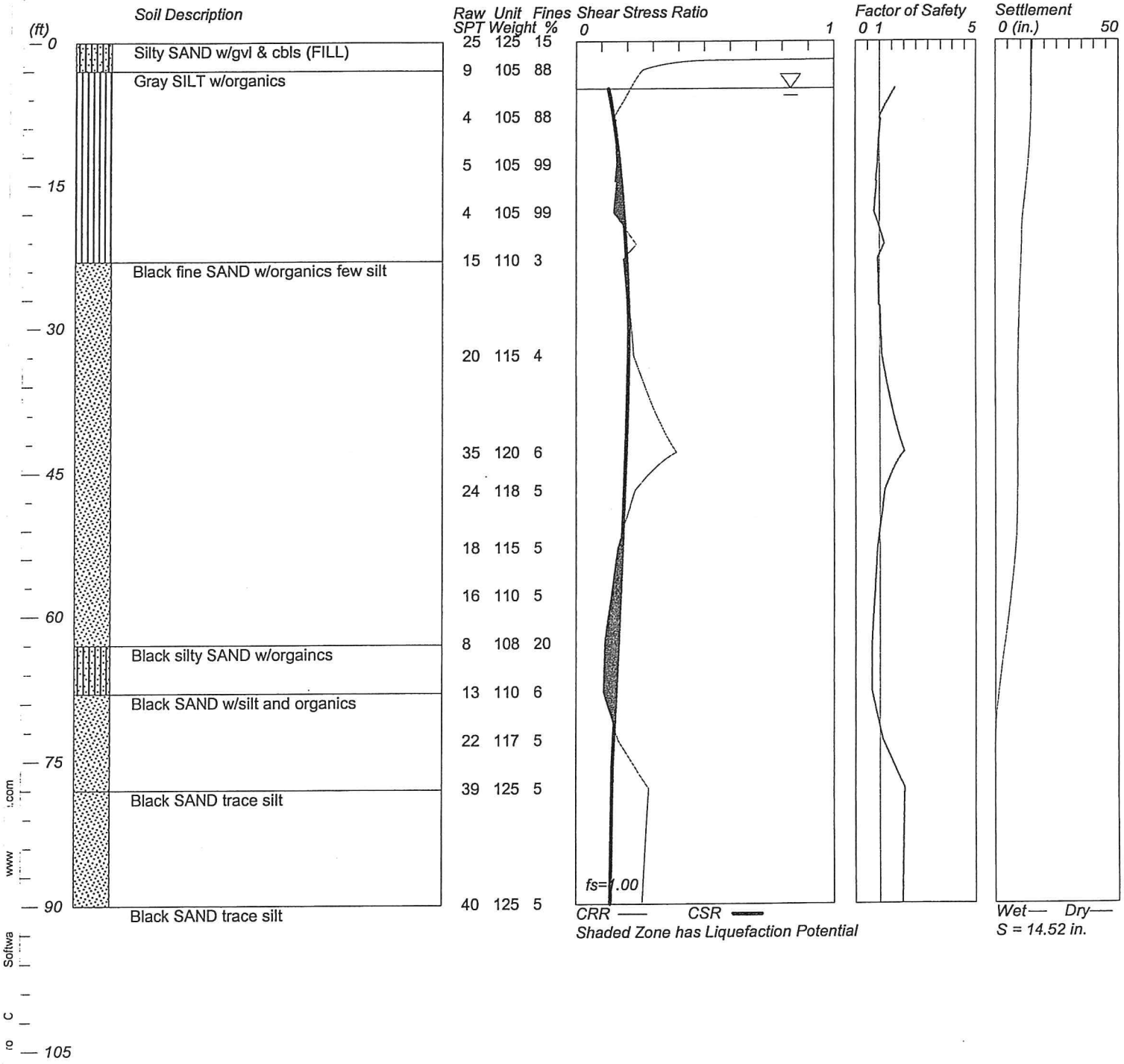
LIQUEFACTION ANALYSIS

Tukwila Station

Hole No.=EB-4 Water Depth=5 ft Surface Elev.=15

Ground Improvement of Fill=4 ft

Magnitude=7
Acceleration=.20g



APPENDIX

Coarse-Grained Soils - More than 50%[1] Retained on No. 200 Sieve	Gravels - More than 50%[1] of Coarse Fraction Retained on No. 4 Sieve	≤5% Fines[5]	GW	Well-graded gravel and gravel with sand, little to no fines
			GP	Poorly-graded gravel and gravel with sand, little to no fines
		≥15% Fines[5]	GM	Silty gravel and silty gravel with sand
			GC	Clayey gravel and clayey gravel with sand
	Sands - 50%[1] or More of Coarse Fraction Passes No. 4 Sieve	≤5% Fines[5]	SW	Well-graded sand and sand with gravel, little to no fines
			SP	Poorly-graded sand and sand with gravel, little to no fines
		≥15% Fines[5]	SM	Silty sand and silty sand with gravel
			SC	Clayey sand and clayey sand with gravel
Fine-Grained Soils - 50%[1] or More Passes No. 200 Sieve	Silts and Clays Liquid Limit Less than 50		ML	Silt, sandy silt, gravelly silt, silt with sand or gravel
			CL	Clay of low to medium plasticity; silty, sandy, or gravelly clay, lean clay
			OL	Organic clay or silt of low plasticity
	Silts and Clays Liquid Limit 50 or More		MH	Elastic silt, clayey silt, silt with micaceous or diatomaceous fine sand or silt
			CH	Clay of high plasticity, sandy or gravelly clay, fat clay with sand or gravel
			OH	Organic clay or silt of medium to high plasticity
Highly Organic Soils			PT	Peat, muck and other highly organic soils

Terms Describing Relative Density and Consistency

	Density	SPT[2] blows/foot
Coarse-Grained Soils	Very Loose	0 to 4
	Loose	4 to 10
	Medium Dense	10 to 30
	Dense	30 to 50
	Very Dense	>50

	Consistency	SPT[2] blows/foot
Fine-Grained Soils	Very Soft	0 to 2
	Soft	2 to 4
	Medium Stiff	4 to 8
	Stiff	8 to 15
	Very Stiff	15 to 30
	Hard	>30

Test Symbols

G = Grain Size
M = Moisture Content
A = Atterberg Limits
C = Chemical
DD = Dry Density
K = Permeability

Component Definitions

Descriptive Term	Size Range and Sieve Number
Boulders	Larger than 12"
Cobbles	3" to 12"
Gravel	3" to No. 4 (4.75 mm)
Coarse Gravel	3" to 3/4"
Fine Gravel	3/4" to No. 4 (4.75 mm)
Sand	No. 4 (4.75 mm) to No. 200 (0.075 mm)
Coarse Sand	No. 4 (4.75 mm) to No. 10 (2.00 mm)
Medium Sand	No. 10 (2.00 mm) to No. 40 (0.425 mm)
Fine Sand	No. 40 (0.425 mm) to No. 200 (0.075 mm)
Silt and Clay	Smaller than No. 200 (0.075 mm)

[3] Estimated Percentage

Component	Percentage by Weight
Trace	<5
Few	5 to 10
Little	15 to 25
With	- Non-primary coarse constituents: ≥ 15% - Fines content between 5% and 15%

Moisture Content

Dry - Absence of moisture, dusty, dry to the touch

Slightly Moist - Perceptible moisture

Moist - Damp but no visible water

Very Moist - Water visible but not free draining

Wet - Visible free water, usually from below water table

Symbols

Sampler Type

2.0" OD Split-Spoon Sampler (SPT)

Bulk sample

Grab Sample

Blows/6" or portion of 6"

10
15
20

Sampler Type Description
3.0" OD Split-Spoon Sampler
3.25" OD Split-Spoon Ring Sampler
3.0" OD Thin-Wall Tube Sampler (including Shelby tube)
Portion not recovered

Cement grout surface seal

Bentonite seal

(4)

Filter pack with blank casing section

(4)

Screened casing or Hydrotip with filter pack

End cap

(1) Percentage by dry weight
(2) (SPT) Standard Penetration Test (ASTM D-1586)
(3) In General Accordance with Standard Practice for Description and Identification of Soils (ASTM D-2488)
(4) Depth of ground water
ATD = At time of drilling
Static water level (date)
(5) Combined USCS symbols used for fines between 5% and 15%

Classifications of soils in this report are based on visual field and/or laboratory observations, which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field or laboratory testing unless presented herein. Visual-manual and/or laboratory classification methods of ASTM D-2487 and D-2488 were used as an identification guide for the Unified Soil Classification System.

blacksllog_key.dwg 11/02/01

Associated Earth Sciences, Inc.

Exploration Log Key

FIGURE A-1

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE05127A	EB-1 (vault)	1 of 3

Project Name: Tukwila Station
Location: Tukwila, WA
Driller/Equipment: Bortech HSA
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 17'
Datum: WM
Date Start/Finish: 4/7/05,4/7/05
Hole Diameter (in): 6"

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
				Grass and Thin Topsoil					
				Fill					
				Loose, moist, brown-gray, silty fine to medium SAND with gravel and cobbles (SM).					
		S-1		Moist, gray, silty fine to medium SAND with gravel and cobbles and some organic matter (SM).			8 9 9	▲18	
5		S-2		**Alluvium** Very moist, gray, very fine sandy elastic SILT (MH).			3 3 4	▲7	
10		S-3		Very moist, gray, very fine sandy elastic SILT, becomes mottled at 10 1/2' (MH).		▼	1 2 3	▲5	
		S-4					3 3 3	▲6	
				Saturated, gray, fine to medium SAND with silt (SP).					
15		S-5		Saturated, interlayered fine SAND, peat, and fine sandy organic SILT (SP/PT/OL).			4 4 1	▲5	
		S-6					3 6 4	▲10	
20				Saturated, black, fine SAND (SP).					
		S-7		Saturated, black, fine to medium SAND with occasional coarse sand and orange feldspars (SP).			6 11 11	▲22	
25				Becomes mostly fine SAND.					
		S-8					17 15 19	▲34	
30				Saturated, gray, SILT with peat interlayers (ML/PT).					
		S-9		Saturated, black, fine to medium SAND with coarse sand with occasional thin peat layers (SP).			6 14 18	▲32	
35				Saturated, black, fine SAND (SP).					
				Saturated, black, fine to coarse SAND with fine gravel (SW).					
		S-10					4 7	▲16	

Sampler Type (ST):
- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture
▽ Water Level ()
▼ Water Level at time of drilling (ATD)

Logged by: SGB
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE05127A	EB-1 (vault)	2 of 3

Project Name: Tukwila Station
Location: Tukwila, WA
Driller/Equipment: Bortech HSA
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 17'
Datum: WM
Date Start/Finish: 4/7/05,4/7/05
Hole Diameter (in): 6"

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
				Saturated, black, fine to medium SAND (SP).			9		
				Saturated, black, fine to medium SAND with few fine gravel (SP).					
45		S-11					2 7 11	▲18	
				Saturated, fine to medium SAND with coarse SAND and fine gravel (SP).					
50		S-12					5 7 11	▲18	
				Saturated, fine to medium SAND with occasional shell fragments and coarse SAND (SP).					
55		S-13					8 15 18	▲33	
				Shell fragments increase.					
60		S-14					6 4 7	▲11	
				Saturated, fine to medium SAND with occasional shell fragments and coarse SAND (SP).					
65		S-15					9 13 15	▲28	
70		S-16		Saturated, fine to medium SAND with occasional shell fragments and coarse SAND (SP).			9 13 15	▲28	
				Saturated, fine SAND with medium sand and few shell fragments (SP).					
75		S-17					9 13 14	▲27	
		S-18		Saturated, fine SAND with medium sand and few shell fragments (SP).			9 17	▲36	

Sampler Type (ST):
- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture
Water Level ()
Water Level at time of drilling (ATD)

Logged by: SGB
Approved by:

AESIBOR 05127A.GPJ August 1, 2005

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE05127A	EB-1 (vault)	3 of 3

Project Name: Tukwila Station
Location: Tukwila, WA
Driller/Equipment: Bortech HSA
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 17'
Datum: WM
Date Start/Finish: 4/7/05,4/7/05
Hole Diameter (in): 6"

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
							19		
				Saturated, gray, fine to medium SAND with coarse SAND and few shell fragments (SP).					
85		S-19					13 26 27	▲53	
				Saturated, gray, fine to medium SAND with coarse SAND and few shell fragments, increasing shell fragments (SP).			15 29 22	▲51	
90		S-20							
				Saturated, black-gray, sandy fine gravel (GP).					
95		S-21					17 25 28	▲53	
		S-22		Saturated, black, gravelly fine to medium SAND with coarse sand (SP).			9 15 16	▲31	
100				Bottom of exploration boring at 100 feet					
105									
110									
115									

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: SGB
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE05127A	EB-2 (north)	1 of 3

Project Name: Tukwila Station
Location: Tukwila, WA
Driller/Equipment: Bortech HSA
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 16'
Datum: WM
Date Start/Finish: 4/7/05,4/7/05
Hole Diameter (in): 6"

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
				Grass and Very Thin Topsoil					
				Fill Loose, moist, brown-gray, silty fine to medium SAND with gravel and cobbles and various organics (SM).					
		S-1					3 5 4	▲9	
				Alluvium Wet, gray, slightly sandy elastic SILT with organics (MH).					
5		S-2					1 1 1	▲2	
				Occasional thin sand stringers and less organics at 7'.					
		S-3							
10		S-4				▼	1 1 7	▲8	
				Saturated, gray, fine SAND with silt (SP).					
		S-5		Becomes mostly gray, fine SAND (SP).			3 7 8	▲15	
15		S-6					6 8 6	▲14	
				Saturated, brown-gray, slightly sandy SILT with organics (ML).					
		S-7					2 2 2	▲4	
20				Saturated, black, fine SAND (SP).					
		S-8					3 10 12	▲22	
25									
		S-9		Saturated, gray, fine SAND.			11 13 17	▲30	
30									
				Occasional medium to coarse SAND in sample.					
		S-10					2 8 15	▲23	
35									
				Increasing fine sand content and less medium to coarse sand.					
		S-11					5 12	▲25	

Sampler Type (ST):
- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: SGB
Approved by:

AESIBOR 05127A.GPJ June 10, 2005

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE05127A	EB-2 (north)	2 of 3

Project Name: Tukwila Station
Location: Tukwila, WA
Driller/Equipment: Bortech HSA
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 16'
Datum: WM
Date Start/Finish: 4/7/05,4/7/05
Hole Diameter (in): 6"

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
							13		
45		S-12					6 10 12	▲22	
50		S-13					7 9 12	▲21	
		S-14		Saturated, gray, fine to medium with occasional coarse SAND, few fine gravel and trace organics (SP).			7 9 16	▲25	
55									
60		S-15		Less medium SAND and fewer organics.			7 12 16	▲28	
65		S-16		Becomes coarser with occasional small shell fragments.			4 10 17	▲28	
70		S-17		Increasing shell fragments.			12 15 17	▲32	
75		S-18		Few fine gravel.			16 15 19	▲34	
		S-19					10 20	▲48	

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: SGB
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE05127A	EB-2 (north)	3 of 3

Project Name: Tukwila Station
Location: Tukwila, WA
Driller/Equipment: Bortech HSA
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 16'
Datum: WM
Date Start/Finish: 4/7/05,4/7/05
Hole Diameter (in): 6"

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
							28		
				Saturated, gray-black, sandy fine GRAVEL (GP).					
85		S-20		Saturated, gray, silty sandy fine GRAVEL and silty gravelly fine to coarse SAND with shell fragments (GM/SM).			13 15 18	▲33	
				Saturated, gray, gravelly fine to coarse SAND with shell fragments (SW).					
90		S-21					15 18 18	▲36	
95		S-22					15 26 16	▲42	
100		S-23		3" thick layer of very compact peat or wood at 99'.			10 25 28	▲43	
				Bottom of exploration boring at 100 feet					
105									
110									
115									

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: SGB
Approved by:

AESIBOR 05127A.GPJ June 10, 2005

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE05127A	EB-3 (middle)	1 of 3

Project Name: Tukwila Station
Location: Tukwila, WA
Driller/Equipment: Bortech HSA
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 15'
Datum: WM
Date Start/Finish: 4/7/05,4/7/05
Hole Diameter (in): 6"

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
				Fill					
				Loose to medium dense, moist, brown, silty SAND with gravel and cobbles. (SM)					
				No sample, pounding on rocks.					
		S-1		Moist, brown, silty SAND with gravel and cobbles, little recovery. (SM)			9 5 7	12	
				Alluvium					
5		S-2		Soft to medium stiff, black, elastic SILT with sand and organics. (MH)			3 4 4	8	
		S-3		Wet, black, elastic SILT with fine sand, peat stringers and sand lenses to 6" thick. (MH/PT)			2 3 5	8	
10				Saturated, black, elastic SILT with organics. (MH/OL)					
				Poor recovery - sand in tube - sample disgarded		▼			
		S-4		Saturated, black, SAND with silt. (SP)					
		S-4		Saturated, gray, elastic SILT with fine sand and trace organics and volcanic ash. (MH/CL)			3 2 5	7	
15				Sandy elastic SILT. (MH)					
				Sandy elastic SILT. (MH)					
				Saturated, gray, elastic SILT with fine sand, trace organics. (MH)					
		S-5					3 5 9	14	
20				Saturated, black, fine to medium SAND, trace silt. (SP)					
		S-6		Saturated, black, fine to medium SAND, trace silt. (SP)			10 15 15	30	
25									
				Saturated, black, fine to medium SAND, trace silt. (SP)					
		S-7					7 11 14	25	
30									
		S-8		Saturated, black, fine to medium SAND with coarse sand and gravel, trace silt. (SP)			9 10 10	20	
35									
		S-9		Saturated, black, medium SAND, few coarse sand, trace silt. (SP)			7 11	19	

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: SGB
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE05127A	EB-3 (middle)	2 of 3

Project Name: Tukwila Station
Location: Tukwila, WA
Driller/Equipment: Bortech HSA
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 15'
Datum: WM
Date Start/Finish: 4/7/05,4/7/05
Hole Diameter (in): 6"

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
							8		
45		S-10		Saturated, medium SAND, few coarse sand, trace shell fragments. (SP)			15 17 17	▲34	
50		S-11					9 17 15	▲32	
55		S-12		Saturated, medium SAND, few coarse sand and gravel and wood fragments. (SP)			7 8 14	▲22	
60		S-13		Trace wood and few shell fragments.			8 12 11	▲23	
65		S-14		Saturated, black, medium SAND with coarse sand and gravel, few silt, shells and wood. (SP)			8 13 15	▲28	
70		S-15		No wood.			11 12 15	▲27	
75		S-16					8 19 21	▲40	
				Gravel reported by driller.					
		S-17		Saturated, gray, gravelly medium to coarse SAND with silt. (SP)			9 15	▲41	

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: SGB
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE05127A	EB-3 (middle)	3 of 3

Project Name	Tukwila Station	Ground Surface Elevation (ft)	15'
Location	Tukwila, WA	Datum	WM
Driller/Equipment	Bortech HSA	Date Start/Finish	4/7/05,4/7/05
Hammer Weight/Drop	140# / 30"	Hole Diameter (in)	6"

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
							26		
85		S-18		Saturated, gray, fine to medium GRAVEL with sand, few silt. (GP)			15 15 15	▲30	
90		S-19		Saturated, gray, medium to coarse SAND with gravel and silt and few shell fragments. (SP)			18 20 16	▲36	
95		S-20		Saturated, gray, fine to medium SAND with coarse sand and gravel. (SP)			20 14 9	▲23	
				Peat with gray SILT. (ML/PT)					
100		S-21		Gray SILT with fine sand. (ML)			6 6	▲13	
		S-22		Gray, silty fine SAND with organic (peat) seams. (PT/SM)			7 5 14 40	▲54	
				Bottom of exploration boring at 101.5 feet					
105									
110									
115									

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: SGB

Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE05127A	EB-4 (south)	1 of 3

Project Name: Tukwila Station
Location: Tukwila, WA
Driller/Equipment: Bortech HSA
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 15'
Datum: WM
Date Start/Finish: 3/23/05,3/23/05
Hole Diameter (in): 6"

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
				Grass and Topsoil					
				Fill					
				Brown, medium dense, moist, silty SAND with gravel and cobbles, trace boulders. (SM)					
				Alluvium					
				Moist, gray, elastic SILT with fine to medium SAND. (MH)					
5		S-1				▼	6 5 4	▲9	
				Becomes wet.					
10		S-2		Wet, gray, elastic SILT with fine sand. (MH)			1 2 2	▲4	
15		S-3		Saturated, gray, elastic SILT with fine SAND and peat stringers. (MH/PT)			1 2 3	▲5	
20		S-4		Saturated, gray, elastic SILT with fine sand. (MH)			1 2 2	▲4	
25		S-5		Saturated, black, fine to medium SAND trace coarse sand and silt. (SP)			3 7 8	▲15	
30		S-6					4 7 12	▲19	
35		S-7					6 9 11	▲20	
		S-8					7 8	▲19	

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: SGB
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE05127A	EB-4 (south)	2 of 3

Project Name: Tukwila Station
Location: Tukwila, WA
Driller/Equipment: Bortech HSA
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 15'
Datum: WM
Date Start/Finish: 3/23/05,3/23/05
Hole Diameter (in): 6"

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
							11		
45		S-9		Saturated, black, fine to medium SAND with silt, few coarse sand. (SP-SM)			9 17 18	▲35	
50		S-10					4 10 14	▲24	
55		S-11					5 7 11	▲18	
60		S-12		Saturated, black, medium SAND with few shell fragments. (SP)			4 7 9	▲16	
65		S-13		Saturated, black, silty fine to medium SAND with wood, trace organics and shells. (SM)			4 5 3	▲8	
70		S-14		Saturated, black, fine SAND with silt, trace shells, trace gravel and coarse sand. (SP-SM)			6 6 7	▲13	
75		S-15		Saturated, black, fine to medium SAND, few silt, gravel and coarse sand. (SP)			8 10 12	▲22	
		S-16					9 16	▲39	

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample
- M - Moisture
- Water Level ()
- Water Level at time of drilling (ATD)

Logged by: SGB
Approved by:

Associated Earth Sciences, Inc.

Exploration Log

Project Number	Exploration Number	Sheet
KE05127A	EB-4 (south)	3 of 3

Project Name: Tukwila Station
Location: Tukwila, WA
Driller/Equipment: Bortech HSA
Hammer Weight/Drop: 140# / 30"

Ground Surface Elevation (ft): 15'
Datum: WM
Date Start/Finish: 3/23/05,3/23/05
Hole Diameter (in): 6"

Depth (ft)	ST	Samples	Graphic Symbol	DESCRIPTION	Well Completion	Water Level	Blows/6"	Blows/Foot (10 20 30 40)	Other Tests
							23		
85		S-17		Saturated, black, fine to medium SAND, trace silt and shell fragments. (SP)			11 18 22	▲40	
90		S-18					11 16 21	▲37	
				Bottom of exploration boring at 90 feet					
95									
100									
105									
110									
115									

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture
Water Level ()
Water Level at time of drilling (ATD)

Logged by: SGB
Approved by:

Associated Earth Sciences, Inc.

Geologic & Monitoring Well Construction Log

Project Number	Well Number	Sheet
KE05127A	MW-1	1 of 1

Project Name: Tukwila Station
Elevation (Top of Well Casing): 15'
Water Level Elevation:
Drilling/Equipment: Bortech HSA
Hammer Weight/Drop: 140# / 30"

Location: Tukwila, WA
Surface Elevation (ft):
Date Start/Finish: 4/8/05,4/8/05
Hole Diameter (in): 6"

Depth (ft)	Water Level	WELL CONSTRUCTION	ST	Blows/ 6"	Graphic Symbol	DESCRIPTION
		Flush monument				**Grass and Thin Topsoil**
		Bentonite Chips				**Fill** Loose, moist, brown-gray, silty fine to medium SAND with gravel and cobbles (SM). Moist, gray, silty fine to medium SAND with gravel and cobbles and some organic matter (SM).
5	▽					**Alluvium** Very moist, gray, very fine sandy elastic SILT (MH).
10	▼	2" I.D. Schedule 40 PVC machine slotted well screen 0.010" slots				Very moist, gray, very fine sandy elastic SILT, becomes mottled at 10 1/2' (MH).
15						Saturated, gray, fine to medium SAND with silt (SP).
						Saturated, interlayered fine SAND, peat, and fine sandy organic SILT (SP/PT/OL).
20						Boring terminated at 20 feet on 4/8/05
25						
30						
35						

Sampler Type (ST):

- 2" OD Split Spoon Sampler (SPT)
- 3" OD Split Spoon Sampler (D & M)
- Grab Sample
- No Recovery
- Ring Sample
- Shelby Tube Sample

M - Moisture
▽ Water Level (April 13, 2005)
▼ Water Level at time of drilling (ATD)

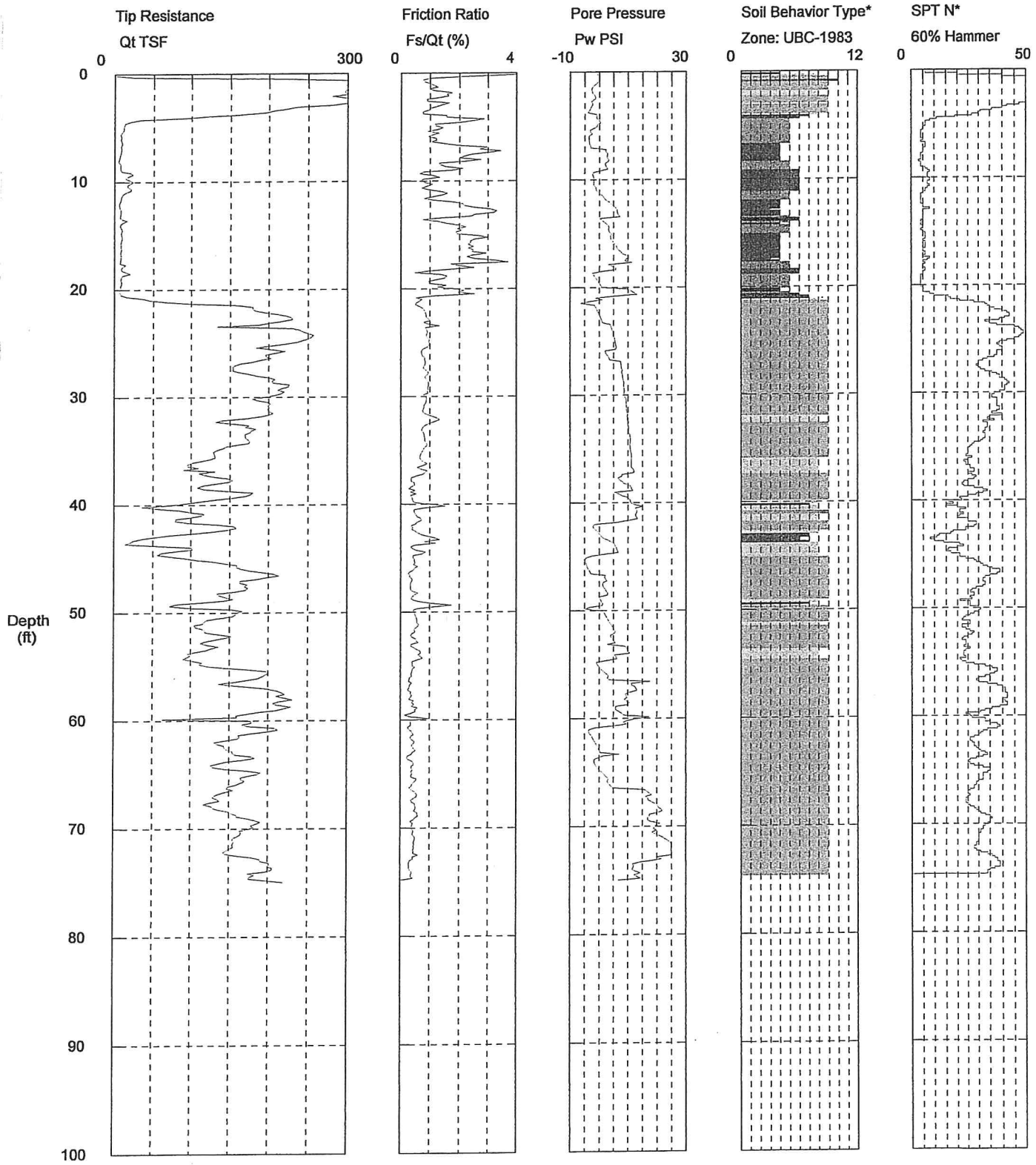
Logged by: SGB
Approved by:

NWWELL 05127A.GPJ BORING.GDT 8/1/05

AESI

Operator: Brown
Sounding: CPT-01
Cone Used: DSG0880

CPT Date/Time: 3/21/2005 9:19:40 AM
Location: Tukwila Station
Job Number: KE05127A



Maximum Depth = 74.97 feet

Depth Increment = 0.164 feet

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

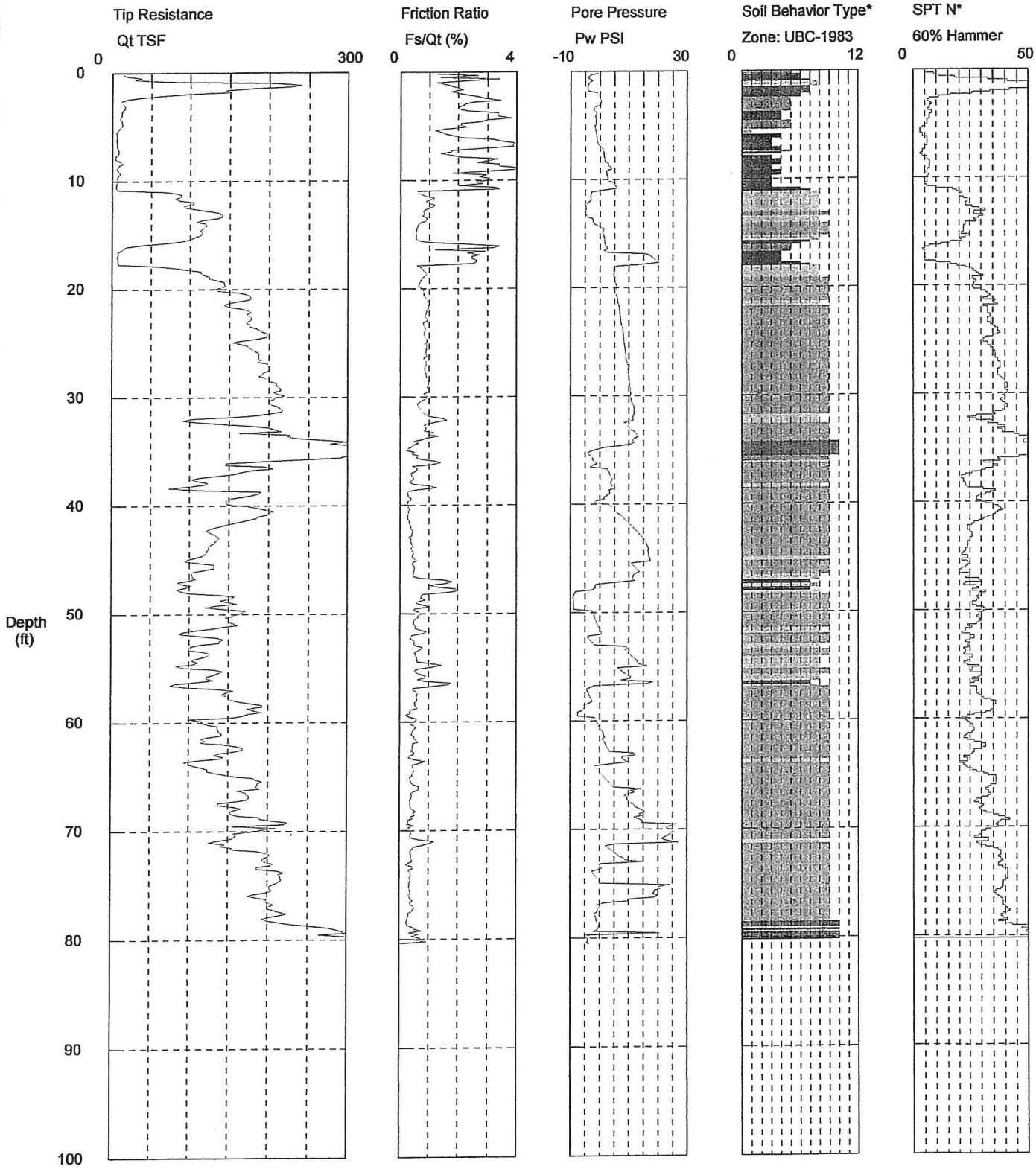
Northwest Cone Exploration

*Soil behavior type and SPT based on data from UBC-1983

AESI

Operator: Brown
Sounding: CPT-02
Cone Used: DSG0880

CPT Date/Time: 3/21/2005 10:20:38 AM
Location: Tukwila Station
Job Number: KE05127A



Maximum Depth = 80.54 feet

Depth Increment = 0.164 feet

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

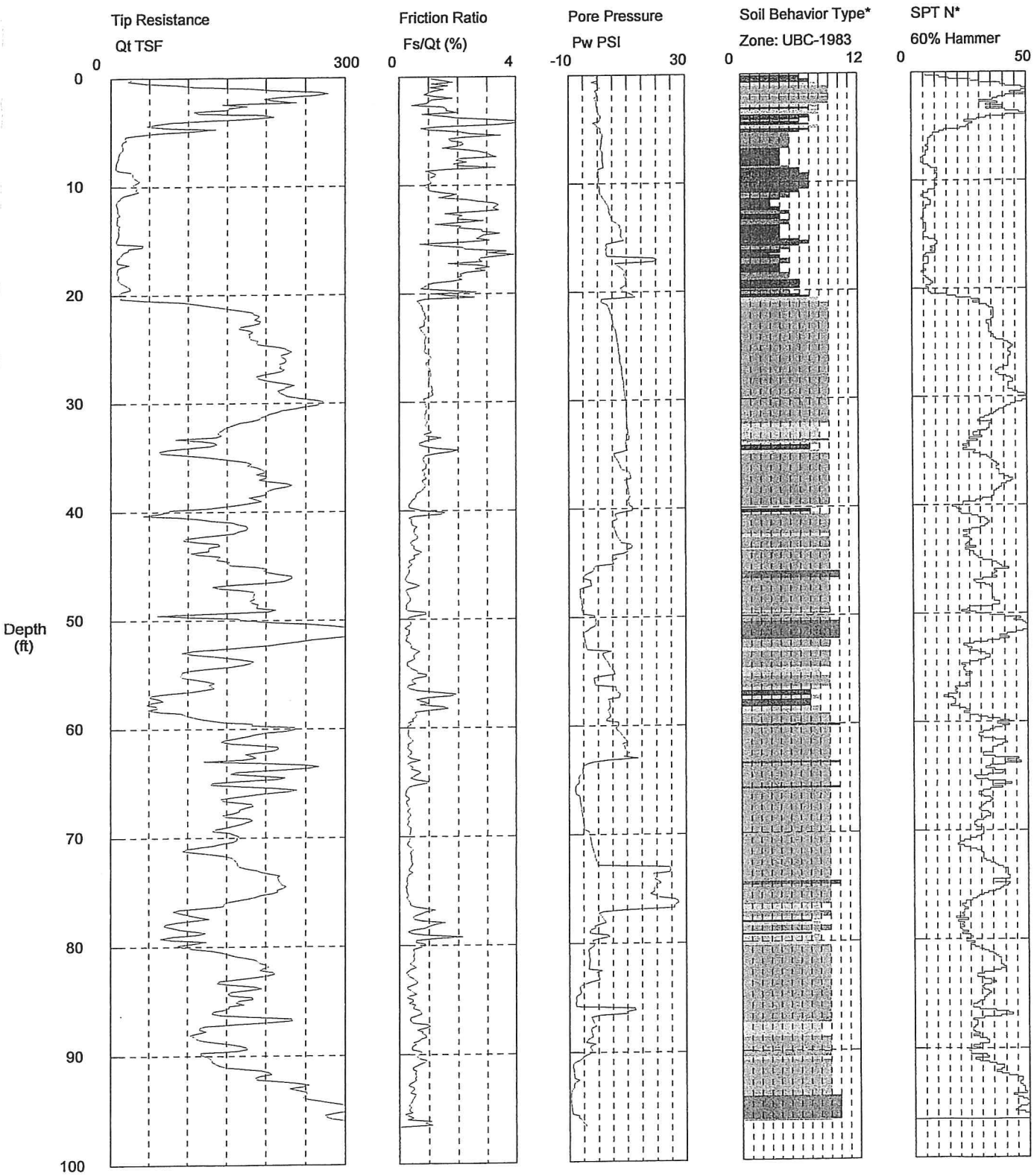
*Soil behavior type and SPT based on data from UBC-1983

Northwest Cone Exploration

AESI

Operator: Brown
Sounding: CPT-03
Cone Used: DSG0880

CPT Date/Time: 3/21/2005 1:37:21 PM
Location: Tukwila Station
Job Number: KE05127A



Maximum Depth = 96.78 feet

Depth Increment = 0.164 feet

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

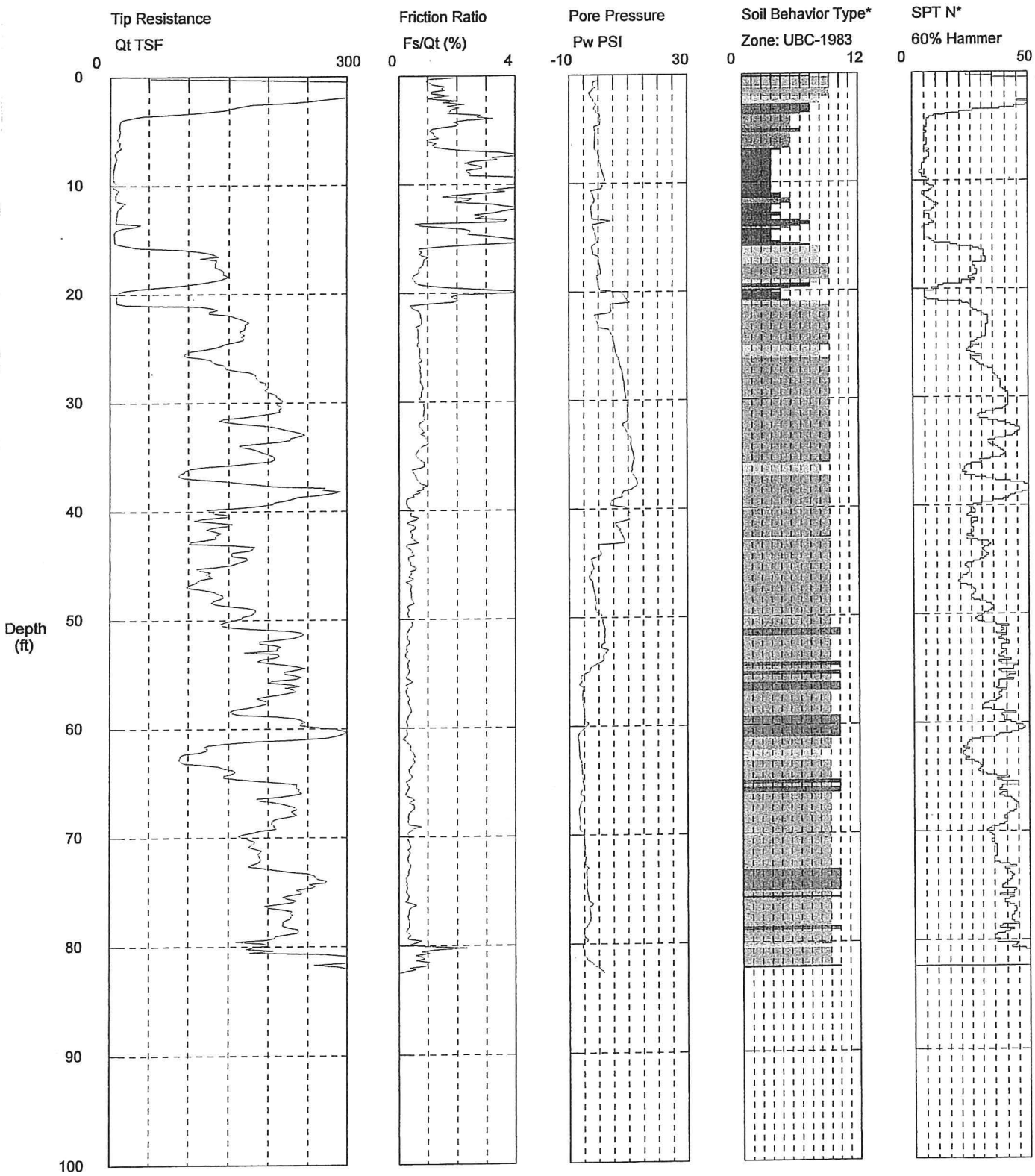
Northwest Cone Exploration

*Soil behavior type and SPT based on data from UBC-1983

AESI

Operator: Brown
Sounding: CPT-04
Cone Used: DSG0880

CPT Date/Time: 3/21/2005 2:54:09 PM
Location: Tukwila Station
Job Number: KE05127A



Maximum Depth = 82.68 feet

Depth Increment = 0.164 feet

1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

Northwest Cone Exploration

*Soil behavior type and SPT based on data from UBC-1983

Associated Earth Sciences, Inc.

Percent Passing #200
ASTM D 1140

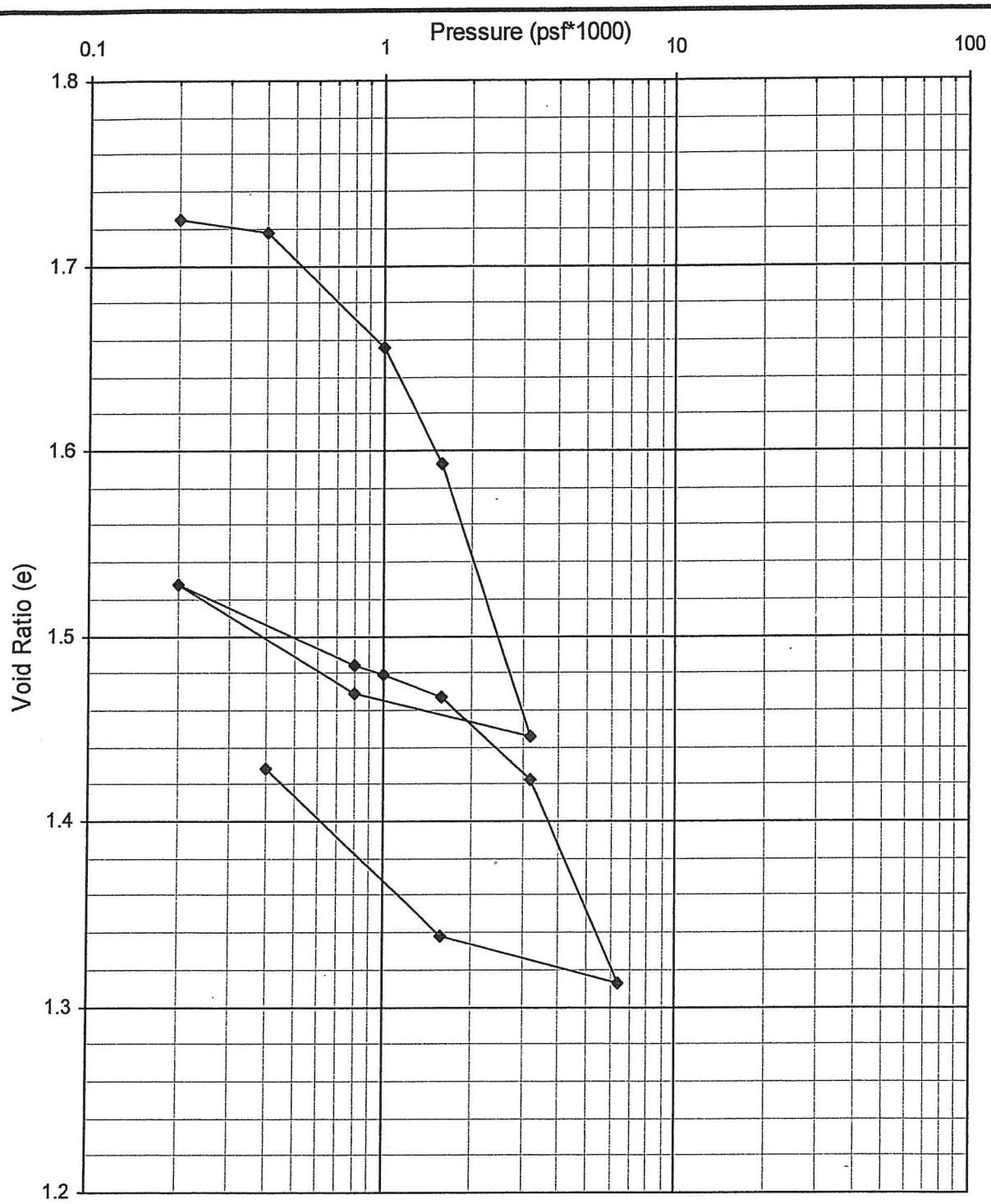
Date Sampled	Project	Project No.		Soil Description
4/13/2005	Tukwila Station	KE05127A		
Tested By	**Location**	**EB/EP No.**	**Depth**	
SGB				

Sample I.D.	EB-4 3.5'	EB-4 13.5'	EB-4 23.5'
Wet Weight	386.7	408.4	498.3
Dry Weight	338.2	350.7	439.7
Water Weight	48.5	57.7	58.6
Pan	223.7	228.4	216.2
Actual Dry Weight	114.5	122.3	223.5
Percent of Water Weight	42.4	47.2	26.2
After Wash Weight	13.1	1.5	217.5
Percent Passing #200	88.6	98.8	2.7

Sample I.D.	EB-4 33.5'	EB-4 43.5'	EB-4 53.5'	EB-4 63.5'
Wet Weight	526.4	473.6	476.3	504.9
Dry Weight	461.5	430.6	423.4	431.9
Water Weight	64.9	43.0	53.0	504.9
Pan	221.8	228.4	226.9	224.3
Actual Dry Weight	239.8	202.2	196.5	207.6
Percent of Water Weight	27.1	21.2	27.0	243.2
After Wash Weight	230.1	189.1	185.9	165.5
Percent Passing #200	4.0	6.5	5.4	20.3

ASSOCIATED EARTH SCIENCES, INC.

911 5th Ave., Suite 100 Kirkland, WA 98033 425-827-7701 FAX 425-827-5424



BORING NUMBER	SAMPLE DEPTH (FEET)	SOIL CLASSIFICATION	INITIAL MOISTURE CONTENT	INITIAL DRY DENSITY (LBS/FT³)
EB-2	7.5-9.5	Gray elastic silt (MH)	66.1	57.0

GEOENGINEERS

CONSOLIDATION TEST RESULTS

FIGURE

6840-042-00 JVJ : JVJ : jvj 5-3-05 (consol.ppt)

Consolidation Test Data Summary

Job Name: AESI Job #: 6840-042-00

Date: 4/20/2005 Tested By: Jake

Boring #: EB-2 Sample #: N/A Depth: 7.5-9.5'

Soil Description: Gray elastic silt (MH)

Load (psf)	Initial dial gauge reading (in)	Final dial gauge reading (in)	Average sample height (in)	t90 (min)	Cv (In.^{2} min)	Cv (ft.^{2} Day)
1600	0.0260	0.0486	0.9627	0.18	1.0916	10.92
3200	0.0491	0.1027	0.9241	0.16	1.1315	11.31

Soil Type	Moisture Content (%)	Dry Density (pcf)	Specific Gravity	$V_{initial}$
(MH)	66.1	57.0	2.49	27.56

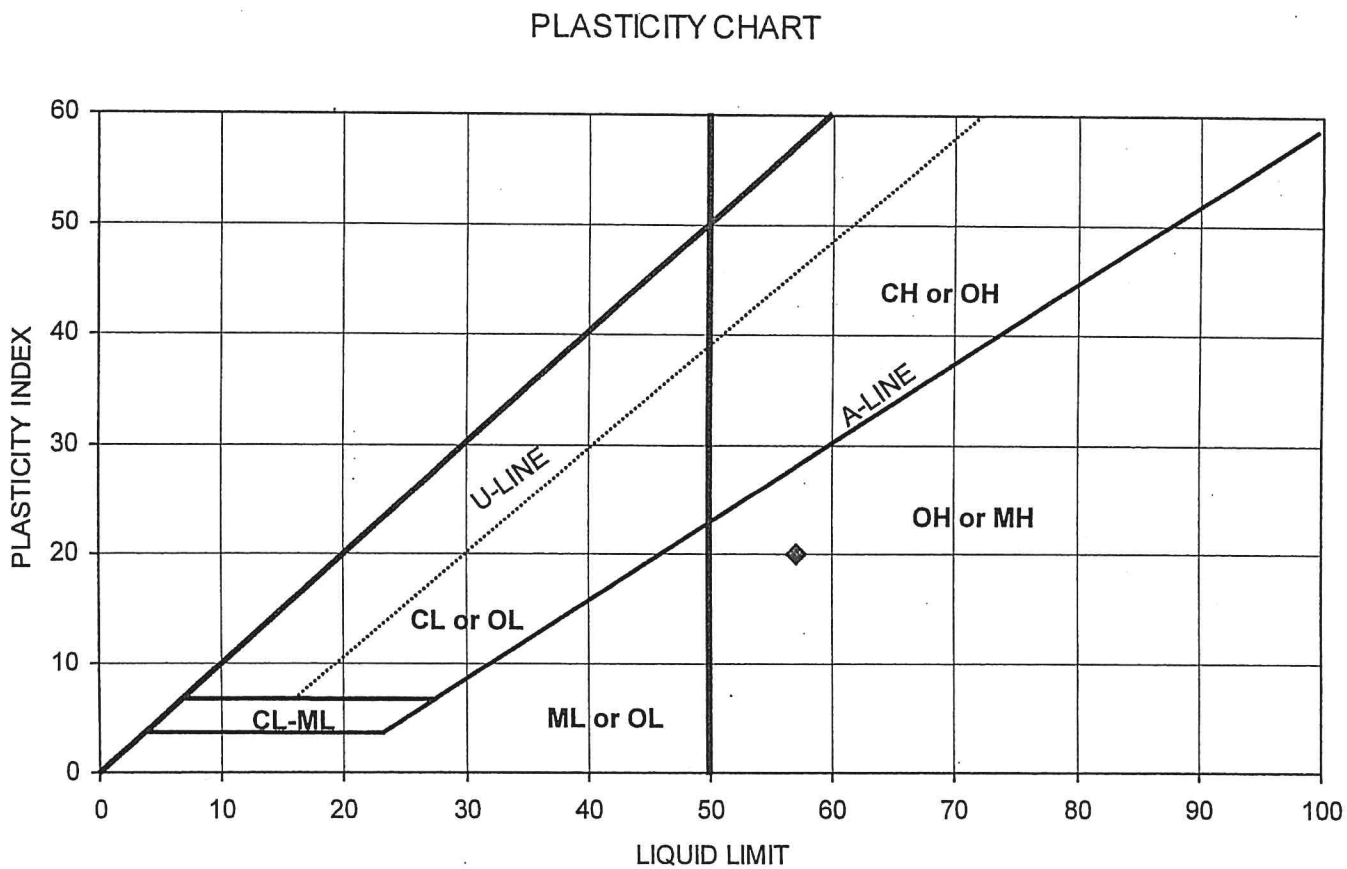
Pressure (ksf)	Consolidation (in)	Vl = Vt - Delta V	Vv = Vl-Vs	e = Vv/Vs
0.20	0.0005	75.09	47.53	1.7244
0.40	0.0028	74.92	47.35	1.7181
1.00	0.0255	73.21	45.65	1.6562
1.60	0.0486	71.47	43.91	1.5933
3.20	0.1027	67.41	39.85	1.4458
0.80	0.0941	68.06	40.49	1.4692
0.20	0.0726	69.67	42.11	1.5278
0.80	0.0886	68.47	40.91	1.4842
1.00	0.0903	68.34	40.78	1.4796
1.60	0.0951	67.98	40.42	1.4665
3.20	0.1114	66.76	39.19	1.4221
6.40	0.1517	63.73	36.17	1.3122
1.60	0.1421	64.45	36.89	1.3384
0.40	0.1090	66.94	39.38	1.4286

6840-042-00 JVJ : HMS : jvj 4-26-05 (Atterbergs.ppt)

GEOENGINEERS

FIGURE

ATTERBERG LIMITS TEST RESULTS



SYMBOL	EXPLORATION NUMBER	SAMPLE DEPTH	MOISTURE CONTENT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	SOIL DESCRIPTION
◆	EB-2	7.5-9.5'	60.4	57	20	Gray elastic silt (MH)

Specific Gravity Test
(ASTM D-854)

Job Name: AESI Date: 4-25-05

Job #: 6840-042-00 Tested By: Jake

Boring #:	EB-2		
Sample:			
Depth:	7.5-9.5'		
Flask No	B		
Temperature of Water and Soil (C)	23		
Pan No.	D-10		
Pan and Dry Soil	250.06		
Pan	226.37		
Dry Soil (Ws)	23.69		
Flask and Water at T (C)(Wbw)	341.43		
Ws + Wbw	365.12		
Flask and Water and Immersed Soil (Wbws)	355.62		
Displaced Water, Ws + Wbw - Wbws	9.50		
Correction Factor (k)	0.9993		
Specific Gravity (GS)=Ws*K/Ws+Wbw-Wbws	2.493		