FINAL REPORT

FISHER SLOUGH RESTORATION PROJECT

SKAGIT COUNTY, WASHINGTON

REPORT OF GEOTECHNICAL INVESTIGATION
FISHER SLOUGH RESTORATION PROJECT
URS JOB NO. 33760911

Prepared for
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December 15, 2009

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December 15, 2009

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Fisher Slough Restoration Project
Skagit County, Washington
<u>URS Job No. 33760911</u>

Dear Mr. Cline,

URS is submitting herewith the final Report of Geotechnical Investigation at the site of the proposed Fisher Creek Restoration project near Conway, Washington in Skagit County. Work on this project was authorized by your Subconsultant Professional Services Agreement (Job T22391) signed on April 1, 2008, and was in general accordance with the scope of services identified in the April 2, 2008 Request For Proposal from Tetra Tech. This report presents the results of the initial phase of geotechnical investigation and testing, and later investigation phases, including modifications to certain conclusions and recommendations, are presented in subsequent design memoranda.

Please contact the undersigned if questions arise or additional information is required.

Sincerely,

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REPORT OF GEOTECHNICAL INVESTIGATION
FISHER SLOUGH RESTORATION PROJECT
SKAGIT COUNTY, WASHINGTON

1.0 INTRODUCTION

This report presents the results of a geotechnical investigation at the site of the proposed siphon replacement, levee setback, Big Ditch drainage channel realignment and wetland restoration project at Fisher Slough, one mile south of the Town of Conway in Skagit County, Washington. A site vicinity map is shown on Figure 1. The general purpose of the geotechnical investigation is to investigate soil and groundwater conditions throughout the site and provide recommendations suitable for design and construction of the project.

2.0 PROPOSED CONSTRUCTION

Available information indicates that the existing north-south trending drainage channel currently referred to as the “Big Ditch” is to be re-routed and the siphon now used to carry the ditch flow beneath Fisher Slough will be re-located. The existing siphon, located two thousand feet upstream of the Fisher Slough bridge on Pioneer Highway, will be replaced by a new siphon located immediately upstream of the bridge and parallel to Pioneer Highway. The existing Big Ditch will be rerouted along the north side of Fisher Slough to the new siphon location and then along Pioneer Highway until it joins the existing channel at the junction of the old railroad grade and Pioneer Highway. Current preliminary plans indicate that the new siphon will consist of two pipes, one 4 feet in diameter and the other approximately 3.5 feet in diameter, extending a distance of approximately 250 feet between the inflow and outflow structures. The invert of the siphon pipes will be at roughly Elevation -8 (NAVD) in order to provide for at least 4 feet of cover below the bottom of Fisher Slough (bottom at approximately Elevation 0). The siphon pipe alignments run beneath the existing levees on the north and south side of Fisher Slough. During the construction period the water in the slough is expected to be in the Elevation range from about +3 to +5 feet. It is also proposed that the existing levee on the south side of Fisher Slough will be removed and a new setback levee will be constructed as shown in Figure 2. Associated modifications to Fisher Sough and the adjacent fields will be needed to provide habitat restoration features.

3.0 SCOPE

The scope of services for this project is described in the December 2007 Request For Proposal provided by Tetra Tech, which included investigating subsurface conditions using drill holes and test pits, testing selected soil samples in the laboratory, evaluating shallow foundation support for a new siphon under static and seismic loading, assessing levee design criteria and analysis, assessing construction considerations, and providing a written report that presents the results of the investigation and geotechnical recommendations for the project.

The report is to provide information regarding the following issues:

- Suitability of foundation materials, anticipated settlement, seepage and piping potential, appropriate geometry and related considerations for the new setback levee.
- Suitability of foundation materials for the siphon replacement and siphon inlet and outlet structures, and discussion of alternative foundations as required.
- Channel side slope stability in the rerouted Big Ditch.
- Use of excavated materials from the Big Ditch reroute, old railroad alignment, and the existing levee along the south side of Fisher Slough for re-use in the new setback levee.
- Effects of excavation in the wetlands, sloughing, erosion potential, and boiling.
- Construction issues relating to shoring, dewatering, preloading earth fill for the levee and compaction requirements.
- Effects of seismic activity on the design and performance of the restoration features.
- Provide recommendations for seismic design of the setback levee and siphon per the requirements of the 2006 International Building Code.

4.0 SITE CONDITIONS

4.1 SURFACE DESCRIPTION

The existing Fisher Slough channel runs from the confluence of three small streams downstream through a set of parallel levees, under the bridge at Pioneer Highway and connects to the lower end of the South Fork of the Skagit River. Fisher Slough water levels are impacted by stream flow, Skagit River flows and tidal fluctuations in Puget Sound. A tide gate structure is located on the downstream side of the bridge to control higher tides and flood flows from the Skagit River from the flooding Fisher Slough and overtopping the existing levees. These levees protect homesteads and farm fields in the area. The fields are relatively flat and are currently farmed by local landowners. Big Ditch carries year round flows under Fisher Slough through an existing concrete siphon structure, runs east-west along an abandoned railroad embankment fill, turns south and runs beside Pioneer Highway.

4.2 GEOLOGIC SETTING

The 2002 USGS Geologic Map of Washington Northwest Quadrangle (Dragovich et. al., 2002) indicates that the Fisher Slough Restoration Project site lies within an area of Quaternary alluvium (Qa) consisting of sorted combinations of silt, sand and gravel deposited in streambeds, alluvial fans and locally including peat and lacustrine deposits. Near the eastern border of the site, the alluvium transitions to undifferentiated glacial outwash (Qgo), characterized as recessional and proglacial stratified sand, gravel, and cobbles with minor silt and clay interbeds deposited in delta, ice-contact, beach, and melting water stream environments.

4.3 SUBSURFACE CONDITIONS

4.3.1 SOIL

Information on subsurface conditions were obtained from a previous report prepared by WSDOT for the Pioneer Highway bridge (WSDOT, 1984), and from borings drilled by URS during this phase of the work. The URS investigation included drilling eight bore holes (B-1 to B-4, AB-1 to AB-4), excavating nine test pits (TP-1 to TP-6, ATP-1 to ATP-3), and drilling and installing three groundwater monitoring wells (GW-1 to GW-3) at locations shown on Figure 2. Test Pits TP-1, TP-2 and ATP2 were excavated into the existing South Levee, and Test Pits TP-3 and TP-4 were excavated into the existing railroad embankment. The soil borings were drilled using a Mobile B-61 truck mounted drill rig. The test pits were excavated with a backhoe. The soil boring logs and test pit logs are presented in Appendix A. In general, the borings and test pits revealed soft marine and alluvial sediments with low to medium shear strength and moderate to high compressibility. The following is a summary of the soil layers encountered at locations off the existing levees/embankments, starting from the ground surface and proceeding downward:

<u>Stratum 1: FILL- Soft to medium stiff SILT [ML/MH]</u>

This layer was encountered in all of the borings drilled for this project, and is typically 4 to 9 feet thick. The soil is generally brown in color and soft to medium stiff in consistency. N-values range from 1 to 7 blows per foot. Approximate soil strength measured in the field from pocket penetrometer testing indicated that the undrained shear strength ranges between 250 and 750 pounds per square foot (psf) except at occasional locations where it increases to more than 750 psf , such as at Boring AB-2/GW-1. Laboratory sieve analysis tests on four samples indicate fines contents ranging from 73 to 98 percent. Modified Proctor compaction tests on samples from TP-1 and TP-6 indicate that the optimum moisture content is roughly 18 to 25 percent, which is considerably higher than the existing moisture content.

<u>Stratum 2A – Very soft to soft clayey SILT [ML]</u>

This unit was encountered below Stratum 1, and extended in some borings to the maximum depth drilled. It was dark gray to gray in color, and very soft to soft in consistency. The SPT sampler N-values that were recorded during drilling range from 0 to 10 blows per foot. Approximate soil strength measured in the field from pocket penetrometer testing indicated that the undrained shear strength ranges between 50 and 500 pounds per square foot (psf). Sea shell fragments were encountered in this layer. This layer was encountered in all of the borings drilled for the project. Laboratory tests on five samples indicate fines contents ranging from 54 to 98 percent, but with an average above 93 percent. Other tests showed this soil to be low to medium plasticity (plasticity Index values ranging from 5 to 24), moderately high compressibility, and low permeability.

<u>Stratum 2B – Very loose to loose SILT/sandy SILT/silty SAND [ML/SM]</u>

This unit was interpreted to be a sandier version of the Stratum 2A deposit described above. It was dark gray to gray in color, and very loose to loose in character. The SPT sampler N-values that were recorded during drilling range from 0 to 6 blows per foot. Approximate soil strength measured in the field in fine-grained zones using pocket penetrometer testing indicated that the undrained shear strength range between 110 and 250 pounds per square foot (psf). Sea shell fragments were encountered in this layer. This layer was encountered at shallow depths less than 5 feet in borings B-1 and AB-4, and at depths greater than 9 to 12 feet in Borings AB-1, GW-2 and GW-3 and in Test Pits ATP-1, ATP-3 and TP-5. Laboratory tests on four samples indicate that the fines content of the Stratum 2B is typically in the range from 28 to 89 percent. One sample from Boring AB-1 showed a low permeability value similar to that of Stratum 2A, probably because there appeared to be a greater amount of fines (85 percent) in the test sample than is typical for this stratum.

<u>Stratum 3 – Loose to medium dense silty SAND [SM]</u>

This unit was encountered below Stratum 2A. It was dark gray to gray in color, and loose to medium dense in character. The SPT sampler N-values that were recorded during drilling range from 8 to 17 blows per foot. Sea shell fragments were encountered in this layer. This layer was encountered in three of the borings (B-3, B-4, and AB-2/GW-1) drilled for the project. Laboratory test indicates that this soil contains up to 28 percent fines.

<u>Stratum 4 – Medium dense to dense silty SAND/sandy SILT with gravel [SM/ML]</u>

This unit was encountered below either Stratum 2A or Stratum 3. It was dark gray to gray in color, and medium dense to very dense in character. The SPT sampler N-values that were recorded during drilling range from 24 to 63 blows per foot except at a particular location where the N-values increased to more than 100 at Boring AB-3. This high N-value might be attributed to presence of gravel. The gravel in this deposit ranges in shape from rounded to subangular. Four of the borings (B-3, B-4, AB-2/GW-1, and AB-3) drilled for this project were terminated in this material. A laboratory sieve analysis test on one sample showed 79 percent fines.

<u>Existing Embankment Fill – South Levee</u>

Most of the fill soil encountered in the test pits on the existing levee (TP-1, TP-2 and ATP-2) consists of a moist, low plasticity clayey silt (ML/CL) with sand content ranging from negligible to roughly 27 percent. This layer is typically 10 to 13 feet thick, and is generally brown in color and medium stiff to stiff in consistency. Approximate soil strength measured in the field from pocket penetrometer testing indicated that the undrained shear strength ranges between 500 and 1500 pounds per square foot (psf). At one location, only in ATP-2, the fill soil consisted of a silty gravelly sand to silty gravel (SM/GM) down to 10 feet depth.

<u>Embankment Fill – Old Railroad Grade</u>

Most of the fill soil encountered in the test pits on the existing rail embankment (TP-3 and TP-4) consists of a moist, low plasticity clayey silt (ML/CL) with sand content ranging from negligible to roughly 20 percent. This layer is typically 8 feet thick. This layer is generally brown in color and stiff to hard in consistency. Approximate soil strength measured in the field from pocket penetrometer testing indicated that the undrained shear strength ranges between 2000 and 4000 pounds per square foot (psf)

4.3.2 GROUNDWATER CONDITIONS

Groundwater was encountered both in the test pits and borings during the early October 2008 investigation period. Water was encountered in two of the test pits (TP-5 and TP-6), and was encountered at depths of about 10 feet (Elevation -6) and 5 feet (Elevation 0) below the ground surface respectively. The ground water levels did not stabilize before backfilling of the test pit occurred. Seepage inflow rates ranged from slight to rapid. Water levels measured in the wells GW-1, GW-2 and GW-3 in November 2008, at least 2 months after installation, indicated that the water table was at depths of approximately 0.5 feet (Elevation 6) to 3 feet (Elevation 3) below the ground surface. There was some indication that the well water levels may have been influenced by the presence of ponded water on the ground surface at the well locations. Local residents typically report that water levels are near the ground surface in winter. Stabilized long term groundwater level data have not yet been collected. Groundwater levels are expected to fluctuate in response to the seasons, the rainfall level and the tide levels.

5.0 FIELD AND LAB TESTING

The automatic hammer used for 2008 exploration program is now the standard of practice for geotechnical work because the N-values are less prone to operator and equipment influences than N-values from hammers previously used by the industry (e.g. safety hammers and donut hammers used with rope-and-cathead equipment). However, information published in the literature and collected by URS show that N-values from an automatic hammer are moderately to substantially lower than N values obtained from older type hammers. Automatic hammer N-values should be multiplied by a correction factor to obtain equivalent N-values for comparison with older data and with published correlations between N-value and soil engineering characteristics. There is no unanimous opinion in the geotechnical engineering community as to the magnitude of the correction factor, which could range from 1.2 to 2 or more.

Soil samples were obtained from the borings and test pits for visual classification and laboratory testing for physical properties. Tests were performed to measure moisture content, percent fines, particle size gradation (sieve test), plasticity (Atterberg Limits test), permeability by rigid wall permeameter, compressibility (consolidation test) and compaction characteristics (Proctor compaction by ASTM D-1557 method). The results of all tests are presented Table B-1 in Appendix B. Results of the moisture content and most sieve analysis tests are presented on the boring or test pit logs opposite the sample location. The detailed lab data sheets and plotted results are also presented in Appendix B. All tests were performed in general accordance with the latest ASTM standards.

The description of each soil layer presented above in Section 4.3.1 also discusses some of the laboratory test data for each layer.

Pocket penetrometer tests were conducted on fine grained soils to measure the approximate unconfined compressive strength. The results are shown on the boring logs at the depth of the sample tested. The results indicate undrained shear strength values for the Stratum 1 were typically about 500 psf. In the Stratum 2 (A and B) very soft clayey SILT, the pocket penetrometer values indicated the average undrained shear strength values of about 300 psf. It should be noted that pocket penetrometer measurements listed as 0 tsf in the boring logs actually mean that the undrained shear strength of the soil is approximately 100 to 200 psf when the resolution of the device is considered.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 SOIL PROFILES AND SOIL PARAMETERS FOR DESIGN – GENERAL

In general, the soil profile in the west half of the site is dominated by the deep alluvium deposited by the Skagit River, while the soil profile in the east half of the site apparently transitions to the glacial outwash soil described in Section 4.2 Geologic Setting. Borings drilled by WSDOT in 1984 indicate that the soft or loose alluvium at the bridge location extends to at last 80 feet depth. Figure 3 shows an estimated soil profile along the future setback levee alignment, illustrating the reduced thickness of alluvium and the appearance of shallow dense glacial soils towards the eastern end.

The soil encountered within the area to be occupied by the new facility can be used for foundation support with certain precautions, and with the expectation that large total and differential settlements may occur after construction due to the soft nature of the soil (Stratum 2A and 2B).

A table of estimated soil parameters for each of the soil strata encountered at the site is provided at the end of the text (Table 1) to assist design, site preparation and construction of the proposed facility. The values provided in the table have been estimated using a combination of current measured field and laboratory data together with published data on similar soils. It should be noted that in most cases the values listed in Table 1 are intended to represent average or slightly on the conservative side of average conditions. Natural variations in stratigraphy and soil parameters are expected throughout the site, and the Table 1 values may not be strictly representative of all locations.

6.2 SEISMIC CONSIDERATIONS

The geotechnical-related parameters to be used for seismic design in accordance with 2006 IBC provisions are evaluated as described in Section 1613.5 of the 2006 IBC Code. The spectral response accelerations for the “Maximum Considered Earthquake”, which has a 2 percent probability of being exceeded in 50 years (i.e. return period of 2500 years), are obtained from the USGS Earthquake Ground Motion Parameters (PGA) Version 5.0.9 software based on the 2006 IBC Code corresponding to the site with a latitude 48.32 degrees and a longitude of –122.34 degrees. The recommended values for Site Class B are:

S_S = 112.7 % g = 1.13 g (short period, or 0.2 second spectral response)

S_1 = 38.7 % g = 0.39 g (1.0 second spectral response)

The Site Class is selected using the definitions in Table 1613.5.2 considering the average properties of soils in the upper 100 feet of the soil profile at the site. Information from the current and previous borings indicates that a Site Class E (“Soft Soil Profile”) is the generally the most appropriate for this location. A Site Class F may need to be considered for local areas where a significant thickness of potentially liquefiable Stratum 2B exists, for example near Borings B-1 and AB-4 adjacent to the existing bridge.

The site coefficient values, obtained from Section 1613.5.3 of the 2006 IBC, are used to adjust the mapped spectral response acceleration values to get the adjusted spectral response acceleration values for the site. The recommended Site Coefficient values for Site Class E are:

$F_a = 0.9$ (short period, or 0.2 second spectral response)

$F_v = 2.4$ (1.0 second spectral response)

A peak horizontal ground acceleration (PGA) of 0.27g was estimated based on guidelines in 2006 IBC. That is, the damped design spectral acceleration value S_{DS} was divided by 2.5 as directed in Section 1802.2.7 of the 2006 IBC.

The potential for seismic-induced liquefaction in some portions of the site is high because of the very loose to medium dense nature of the primarily granular soils of Stratum 2B and Stratum 3 and the shallow depth of the water table. If seismic-induced liquefaction does occur, it will be accompanied by ground settlement, the magnitude of which will depend on the thickness of liquefiable sediments and the severity of shaking. The liquefaction induced settlement will be in addition to the magnitude of settlement due to consolidation from static loads. The potentially liquefiable Stratum 2B was encountered at shallow depths (less than 5) at only two locations, at Borings B-1 near the north end of the future setback levee and further north along Pioneer Highway at AB-4. This liquefiable soil was encountered at depths greater than 9 to 12 feet at the following locations:

- along or near the north end of the future setback levee in Boring AB-1 and Test Pit ATP-3
- on the property north of Fisher Slough in wells GW-2 and GW-3 and Test Pit TP-5
- near the south end of the future setback levee in well GW-1 and Test Pit ATP-1.

The potential for significant "lateral spread" of liquefied soil appears to be low in the vicinity of the project area because a "free face" condition, as described in Youd, Hansen, and Bartlett (2002) and Bartlett and Youd (1995), is not generally present at this location. However, loss of shear strength in liquefied soils and increased pore pressures in non-liquefied soils generated by earthquake shaking can potentially reduce the stability of existing or new embankments. During the design phase of the project, stability analyses for the new setback levee should incorporate reduced shear strength values for foundation soils in areas where liquefaction is expected. The only obvious location of likely liquefaction effects on the levee is in the vicinity of Boring B-1 where Stratum 2B is present at shallow depths.

If liquefaction occurs, pipelines and subsurface chambers and vaults such as those associated with the siphon will react in a manner that depends on their position with respect to the groundwater table. Structures above the groundwater table will likely settle an amount equal to the settlement of the surrounding ground surface. Structures below the groundwater table will be subjected to upward buoyancy forces that must be resisted by the overlying backfill soil. Insufficient resistance will allow the structure to "float" to the surface. For structures not located within the liquefaction area (i.e. not in Stratum 2B), the seismic shaking could cause compressive or tensile stresses from the passage of seismic surface waves through the ground.

6.3 SETBACK LEVEE

6.3.1 SIDE SLOPES AND CUTOFF

Side slopes for the new levees should be approximately 2.5H:1V (2.5 horizontal to 1 vertical) or flatter as determined during design stability analysis. Slightly steeper slopes may be possible depending on the height of embankment selected.

Erosion and scour control measures should be adopted to reduce loss of surficial soils on the upstream face of the levee. The erosion control measures could consist of gravel, cobbles, boulders, woody debris, geotextile or welded wire-reinforced layers, and/or planted vegetation that has been selected and placed following standard soil-bioengineering practices.

A cutoff trench is recommended by the State of Washington for permanent "dams", while a cutoff is not necessarily required by FEMA levee guidance. The typical objectives of a cutoff are to control seepage quantities and effects when the foundation soil is primarily granular and permeable, and to increase the resistance to sliding at the base. Soils expected to serve as the foundation for the new levee will be somewhat mixed, with a primarily fine grained nature over most of the length, but with the sandier Stratum 2B near the north end of the levee. The State of Washington guidance is that the cutoff should be wide enough to accommodate self-propelled compaction equipment, i.e. about 8 feet. However, given the limited size of this levee, a 6-foot wide trench to a depth of 4 feet below the base of the dam is expected to provide a suitable cutoff. A cutoff deeper than 4 or 5 feet could require dewatering efforts.

Since the cutoff is being contemplated, the embankment and foundation soils are expected to consist of relatively low permeability materials, and the relocated Big Ditch will be present on the downstream side, so a toe drain is not recommended for the new setback levee.

6.3.2 FOUNDATION

The foundation for the new setback levee will be located on Stratum 1 Fill material, which is present along the proposed levee alignment. As described in Section 4.3.1, Stratum 1 is a cohesive fine grained material, soft to medium stiff in consistency, and typically 4 to 9 feet thick. Therefore, URS expects that stability and piping (exit gradient) are likely not issues. However, due to the soft nature of the soil (Strata 2A and 2B), the levee will experience considerable settlement, both during and after construction. URS roughly estimated anticipated the maximum settlements for a typical levee (11 feet height, 12 feet top width, 2H:1V slopes) at three locations, as listed below:

- parallel to Pioneer Highway between B-1 and AB-1; settlement = 4.5 feet
- along abandoned railroad embankment near B-2; settlement = 2.5 feet
- near east end of levee between GW-1 and B-4; settlement = 2.6 feet

Approximately 30 percent of the above settlements are expected to occur within 6 months following the construction of the levee, with the remainder occurring over a period of roughly 6 to 10 years or more. These values need to be re-evaluated during the design phase based on the actual levee geometry.

Preloading of the foundation area, i.e. placement of fill soil prior to the start of construction, could be used to pre-induce some of the settlement. Even if a preload of magnitude equal to the full weight of the future setback levee embankment could be placed along the levee alignment, some rebound of the ground surface would occur and subsequently a small amount of "recompression" settlement when the new embankment is placed. Use of pre-fabricated geotextile wick drains could be used to accelerate the rate of settlement by a factor of 5 or more.

It should be noted that the new proposed levee can induce stresses in and settlement of soil beneath the nearby existing structures such as the roadway embankment and bridge. As a simplified approximation, it should be assumed that the settlement magnitude will decrease to a negligible amount at a horizontal distance from the toe of the base of the new proposed levee that is approximately equal to the width of the base of the new proposed levee. If the roadway embankment is within the above influence zone, the roadway embankment will likely settle due to the proposed levee. In order to avoid roadway embankment settlement, the distance between the toe of the new proposed levee and roadway embankment toe should be at least approximately equal to the width of the base of the new proposed levee. Alternatively, installation of an appropriately designed sheet pile wall between the levee and the existing roadway embankment could reduce the magnitude of roadway settlement.

6.3.2 CONSTRUCTION CONSIDERATIONS

Levee embankment fill materials can consist of silt, clays, sands and/or gravels with a minimum of 25 percent fines, i.e. passing the #200 sieve (considering only material less than 3 inch). Levee embankment fill should be placed in lifts approximately 6 to 8 inches thick, moisture-conditioned as necessary (moisture content of soil should be within 2 percent of the optimum moisture), and compacted to 95 percent of the maximum dry density based on ASTM Test Method D-698.

Before starting earthwork, site preparation should begin with stripping any surficial grass, roots, and topsoil from within the limits of earthwork. URS expects surface stripping may typically be necessary to depths of about approximately 0.5 feet.

Fill material identified in test pits within the existing south levee (TP-1, TP-2, and ATP-1) and within the existing railroad embankment (TP-3 and TP-4) are considered suitable for construction of the new levee. The Stratum 1 soils encountered in test pits TP-5 and TP-6 in the Junquist parcel, test pit ATP-1 in the Smith B parcel, and test pit ATP-3 in TNC field are also considered suitable for use as structural fill for the new levee. It should be noted soil encountered in test pit ATP-2 in the existing south levee does not have a sufficiently high percentage of fines, and therefore is not in its present condition suitable for use as fill for the new levee. The extent of this gravelly soil in ATP-2 is not known, but its presence is believed to be related to the dredging of Fisher Slough in past years. The native Stratum 2A SILT Stratum 2B SILT/sandy SILT/silty SAND encountered at the site are generally unsuitable for use as structural fill, i.e. to support structures or construct levee. These soils are difficult to compact unless the moisture level is close to the optimum moisture content, and are difficult to moisture condition. The Stratum 1 fill is considered suitable for re-use as structural fill for levee construction. However, natural moisture content tests performed on Stratum 1 silt or clayey silt encountered in Borings B-1 and B-4 were relatively high (39 to 49 percent), and this soil will be difficult to moisture condition and compact to the required densities.

Earthwork quantities may be estimated using the following information about the on-site fill sources:

- Shallow Fill Soils Not Associated with Existing Levees (Stratum 1) - The surficial soil throughout the project area typically consists of a fill ranging in thickness from about 4 to 9 feet. This material is being referred to as Stratum 1 . It is primarily a non-plastic to low plasticity silt to clayey silt with less than 10 percent fine sand and some occasional lenses of organic material. A shrinkage factor of 0.90 is recommended when converting "bank" volume to "compacted" volume.

- Fill Soil Comprising the Existing Levee/Embankments (Stratum 1A and Stratum 1B) - Most of the fill soil encountered in the test pits on the existing levee (TP-1, TP-2 and ATP-2) and rail embankment TP-3 and TP-4) consist of a moist low plasticity clayey silt (ML/CL) with sand content ranging from negligible to roughly 20 percent. For purposes of discussing fill properties, this soil is being referred to as Stratum 1A. At one location, only in ATP-2, the fill soil consisted of a silty gravelly sand to silty gravel (SM/GM) down to 10 feet depth. The gravelly material is being referred to in this discussion as Stratum 1B. A shrinkage factor of 0.95 is recommended for both of these soil types.

To estimate the volume of soil that will be generated by the fill compaction effort using the on-site soils, multiply the "bank" volume (i.e. volume now existing in the ground) by the "shrinkage factor" recommended above.

Depending on final setback levee location, continuous monitoring of settlement of the existing roadway embankment and bridge may be required during construction.

The native Stratum 2A SILT and Stratum 2B SILT/sandy SILT/silty SAND are considered a Type C soil from the standpoint of OSHA/WISHA regulations for excavation, trenching and shoring. This means that temporary cuts greater than 4 feet deep in this deposit should be inclined at no steeper than 1.5 Horizontal to 1 Vertical (1.5H: 1V). The fill Stratum 1 is also considered a Type C soil, and may be temporarily inclined at 1.5H:1V .

The silty sand to sandy silt soils expected to be exposed at the subgrade level for the new levee (i.e. Strata 1, 2A and 2B) are considered moderately to highly erodible in a disturbed condition. Erosion control efforts during construction should be adopted, and Best Management Practices (BMP's) applied as necessary to protect the nearby creek. BMP's may include mulching of exposed surfaces, protecting drainage ditches by placing straw bales or similar sediment trapping materials, erecting check dams or silt fencing that is properly keyed into the base, and applying final seeding upon completion of construction. Protection of compacted soil embankment slopes should be selected considering the velocity of the water that may be flowing towards or along the sloping surface.

6.4 BIG DITCH

6.4.1 CHANNEL DESIGN CONSIDERATIONS

Reconnaissance of Fisher Slough, Big Ditch and the three upper creek banks indicates that the Stratum 1 SILT is present at the ground surface. As described in Section 4.3.1, Stratum 1 is a cohesive fine grained material, soft to medium stiff in consistency, and typically 4 to 9 feet thick. Accordingly, the recommended inclination of permanent slopes up to 4 feet in height is 2H:1V. Slopes from 4 to 10 feet in height should be inclined at 2.5H:1V. Slopes greater than 10 feet in height should be inclined at 3H:1V or flatter, unless specifically evaluated using standard slope stability evaluation methods.

The Stratum 1 silt is considered moderately to highly erodible. Erosion and scour control measures should be adopted to reduce loss of stream channel banks soil during high flow periods. The erosion control measures could consist of gravel, cobbles, boulders, woody debris, geotextile or welded wire-reinforced layers, and/or planted vegetation that has been selected and placed following standard soil-bioengineering practices.

6.4.2 SIPHON DESIGN – GENERAL

A preferred siphon design concept for economically carrying the Big Ditch flows beneath the Fisher Slough has not yet been selected. Potential siphon designs include:

- Continuous rigid pipe with elbows and bends as needed; constructed in shored or unshored excavations as appropriate for the depth of burial, or constructed partly by trenchless methods (pipe ramming, auger-bore-pipe jacking, or directional drilling).

- Continuous flexible pipe with bends as needed; constructed by the same methods as mentioned above for rigid pipe.

- Rigid or flexible pipe routed through precast concrete inlet and outlet chambers/vaults on either side of the Fisher Slough undercrossing; inlet and outlet pipes constructed in open cut excavations, the chambers/vaults in shored excavations, the indercrossing pipe rammed or auger-bored and jacked into place.

Both the pipe and the chamber/vault can be supported on pile foundations for limiting either downward or upward movement, or shallow foundation support can be provided on improved or unimproved subgrade soils, or a combination of shallow and deep foundations can be provided.

6.4.3 FOUNDATION SUPPORT - SHALLOW

Design of foundations for the siphon structures must consider the potential for a bearing capacity failure as well as the effect of settlements that may occur following construction. Only if the structure under consideration actually applies significantly more vertical pressure at the foundation subgrade level than originally occurred from the overburden pressure of the soil is consideration of bearing capacity and settlement necessary. For buried structures such as pipes and vaults, the bearing capacity failure is not usually a concern, since the actual pressure applied by the structure is typically less than or not much more than the pressure removed in excavating the soil. In fact flotation, i.e. uplift pressure from buoyancy, may be a greater concern and should be checked. For structures that will result in an increase in vertical downward pressure, settlement must be controlled to a magnitude that is tolerable for the structure and its connections. Alternatively the design of the structure must be modified to accommodate the settlement.

Assuming that only the chambers/vaults could result in increased applied downward pressure on the foundation subgrade, allowable bearing pressures and settlements should be considered. The foundations for the future siphon inlet and outlet structures will likely be supported on the Stratum 2B SILT/sandy SILT/silty SAND, for which an allowable soil bearing value of 1000 psf or less should be used. Depending on the design of the vault, the actual applied pressure will likely be less than 1000 psf.

The embedment depth of the chamber/vault may below the water table, i.e. greater than 6 to 8 feet below the ground surface. Therefore the subgrade is expected to be exposed by excavation using a sheet pile shoring system. Subgrade preparation should include placement of a minimum 6-inch thick layer of rockfill or crushed stone. If the actual applied pressure is 500 psf, long term settlement of approximately 6 to 8 inches is estimated if the plan dimension of the chamber/vault is approximately 6 feet by 12 feet in plan dimension. Approximately 50 percent of the settlement will occur within 2 to 3 months after the load is applied. This settlement has been estimated by ignoring the potentially beneficial effect of the presence of the inflow and outflow pipes, which will act to further spread out the load of the chamber/vault. The estimated settlement will be larger than 6 to 8 inches if the actual pressure is higher than 500 psf or the width of the chamber/vault is larger than 6 feet. Preloading of the chamber/vault location will result in final post-construction settlements of less than 1 or 2 inches, depending on the magnitude of the preload.

Recommended values of the modulus of subgrade reaction k (also commonly called the “coefficient of subgrade reaction” or the “subgrade reaction coefficient”) are presented for each existing soil layer and for a typical granular compacted fill in Table 2. These values are typical of those obtained from tests using a 30-inch diameter plate, and are consistent with values recommended for slabs and pavements by the Portland Concrete Association and the American Concrete Institute.

The siphon foundations should have an embedment depth sufficient to resist undermining by Fisher Slough bed scour, or the foundation area should be provided with scour protection in the form of rip-rap, gabions, or similar materials. Scour depths have not been estimated for this project.

The embedment depth of the proposed Siphon structure is not available at this stage of investigation. However, URS expects that shoring may be necessary to install proposed Siphon structure. Based on the nature of the soil and shallow groundwater at proposed Siphon structure locations, sheet pile shoring is recommended.

6.4.3 SIPHON FOUNDATION - DEEP

Easily installed deep foundations such as helical piles can be used to either reduce the magnitude of settlement of the chamber/vault, or to resist the uplift forces if a net buoyant situation is predicted. The “deep” foundations can consist of drilled-in helical piles (anchors) such as those manufactured by the Chance Company. A helical anchor consists of a steel shaft with one to four circular helical plates (“helix”) attached at the bottom. When the anchor is screwed into a competent soil layer, both downward and upward loads applied to the top of the shaft are resisted by the soil above and below the helices. The more helices that are attached to the shaft, the higher the resistance to applied loads. The diameter of the available helices varies from 8 to 14 inches. The load carrying capacity of the helix increases with increasing diameter of the helix. The ultimate load that can be carried by an individual helix can be estimated using expressions presented in the manufacturer’s Bulletin01-9601 dated January 2000. The expressions are similar to those used for estimating the ultimate load for a pile foundation, and have been developed using case history data.

Typical allowable downward or uplift loads in the soft soils encountered at this site would be roughly 10 kips to 15 kips for a 4-helix pile approximately 15 feet long. When load is applied to the anchor either in the downward or upward direction, some movement of the anchor should be expected.

6.4.4 SIPHON DESIGN - LATERAL EARTH PRESSURES

Lateral earth pressures are required for designing temporary excavation (shoring) support structures, permanent subsurface walls, and for estimating the resistance to lateral loads on shallow foundations.

The recommended values of earth pressure coefficients are presented in Table 1, and recommended values of equivalent fluid unit weight (earth pressure coefficient multiplied by soil unit weight) for estimating lateral earth pressures are presented in Table 2.

The active case usually applies to walls that are permitted to rotate or translate away from the retained soil by approximately 0.002H, where H is the height of the wall. This case would be appropriate for a retaining wall. The at-rest case applies to unyielding walls, such as a rigidly connected vault walls. The passive value includes a factor of safety of 1.5. Above the groundwater level, the drained condition ("above water") values can be used. If water is constantly pumped out at all times and a positive drainage system is provided to lower the groundwater table in the vicinity of the structure, drained conditions ("above water") could be used. Otherwise, undrained conditions ("below water") should be used below the groundwater level.

Earthquake shaking effects on lateral earth pressures may be ignored for relatively small subsurface structures, such as chambers and vaults that may be considered as siphon components.

For larger structures and retaining walls, the active and at-rest pressures will temporarily increase and the passive pressures will temporarily decrease, as described by Whitman (1990) using the Mononobe Okabe equation and by Sherif et al (1982) using bench-scale experimentation. For walls greater than 6 feet in height, the increase in active and at-rest components should be taken as a uniformly distributed pressure equal to 5H (in psf), where H is the height of the wall. This seismic-induced pressure acts over the full height of the subsurface portion of wall, and must be added to the static component of earth pressure. For the passive case, the equivalent fluid unit weight given in Table 2 above should be reduced by 25 percent. These recommendations were developed assuming a peak horizontal ground acceleration (PGA) of 0.27g. Note that the active and at-rest seismic earth pressures have been developed using a seismic coefficient equal to 50% of this PGA value. The value of seismic induced pressure has been estimated considering the informally-reported very favorable performance of basement walls during post earthquake inspections.

Use of heavy rolling equipment to compact fill soil directly behind subsurface walls will cause an increase in horizontal earth pressures beyond those values given above. The magnitude of additional pressures will depend on the weight and characteristics of the roller. A similar increase will occur if backhoe-mounted compaction equipment (e.g. Hoepac) is used. The increase will be negligible if the heavy equipment is kept at least 6 feet from the wall. Compaction in this 6-foot zone directly behind the wall should be accomplished using hand operated or walk-behind equipment.

The lateral earth pressures on subsurface walls will increase where loads applied to the soil from nearby structures, traffic or other sources (i.e. surcharge loads) are close enough to the new wall to exert an influence. The vertical surcharge pressure applied will result in increased lateral earth pressures on nearby vertical walls that extend below the applied load level. The magnitude of these lateral surcharge pressures are estimated by multiplying the vertical surcharge pressure by 1/3 for the active earth pressure case and ½ for the at-rest earth pressure case.

Lateral forces on the structure may be resisted by soil-to-concrete friction at the base of footings or mats. Allowable friction coefficients for soil layers that are expected to provide foundation support are listed in Table 2.

6.4.5 SHORING, DEWATERING AND OTHER CONSTRUCTION CONSIDERATIONS

Stratum 2B soil is generally considered to be poorly to moderately drained material which may yield small quantities of perched water that will flow from local sandy pockets into the excavation during construction. These sandy zones are expected to flow for short periods of time until re-charged by additional surface water inflow and infiltration. Some free-draining zones may occur within this layer, and will yield moderately high quantities of inflow if encountered. The high inflow rate encountered at test pit TP-5 is an example of one of these free draining zones. The prudent approach is to be prepared to dewater using a well installed within sheet pile shoring for foundations of the chambers/vaults (if included in the design) or for the pipe. If the pipe depth is shallow, it may be possible to employ open cut excavations with dewatering using sumps and pumping as needed. Flowing sand conditions can be expected at some locations. Shallow well points could also be used if water and ground control problems are encountered. As the current concept is that the siphon pipe inverts will be at roughly Elevation -8, which is approximately 14 to 16 feet below the ground surface and at least 10 feet below the groundwater along much of the siphon alignment, shoring by steel sheet piles is anticipated.

Near the middle of Fisher Slough, the top of the sheet pile wall is expected to be at about Elevation +7 (2 feet of freeboard), while the bottom of the trench would be at approximately Elevation -9, i.e. a sheet pile wall height of 16 feet. Where the siphon pipes pass beneath the existing north and south levees, the tops of which are at roughly Elevation 16 to 17, the pipe inverts will be up to 25 feet below the ground surface.

The width of the sheet pile shored trench should be established by providing a 1.5-foot spacing between the two siphon pipes and between the outside wall of the pipes and the adjacent sheet piles. For the two-pipe configuration in the current preliminary plan, a trench width of about 12 to 14-feet would be required. Dewatering by wells or well points inside the shoring can be used to work "in the dry". Dewatering outside of enclosed sheet pile shoring systems could result in settlement of nearby ground surfaces due to loss of buoyancy. This possibility should be considered if the siphon is constructed close to the existing Pioneer Highway. However, dewatering for the pipe installation can be eliminated if the entire installation is performed "in the wet", i.e. no attempt is made to dewater during both the excavation and pipe/backfill placement process.

Sheet pile embedment depths must consider both the potential for "piping" (soil washing into the excavation) from seepage beneath the sheet piles, and the potential for bottom heave or excessive deformation if earth pressure imbalances occur. The embedment depths can be estimated using methods presented in the U.S. Navy Design Manuals DM-7.1 and DM-7.2. The two cases are discussed separately below:

- Piping/Seepage - If installation of the inlet and outlet structures or the pipes occur in the dry, a minimum sheet pile embedment of at least 8 feet below the bottom of the excavation is recommended. For construction in the wet, where the water level in the excavations are not more than about 2 feet below the surrounding water in the slough or the surrounding groundwater, a minimum sheet pile embedment of at least 5 feet is recommended.

- Stability - The required embedment depth will be primarily influenced by whether the piles are designed as cantilever walls or alternatively if intermediate restraints from internal braces or external deadman anchors are incorporated. The limit to the excavation depth for a cantilever sheet pile shoring wall is considered to be approximately 15 feet, and somewhat less in weak soil. As the soil at the siphon location is relatively weak, an embedment of at least 2 times the depth of the excavation is recommended when cantilever walls are used (i.e. a 30 ft embedment for a cantilever wall height of 15 feet). If the sheet pile wall is properly supported using a system of internal or external braces, the embedment can be reduced to not less than 10 feet below the bottom of the excavation.

Details of the sheet pile shoring design must be developed when the final geometry and construction methods are selected.

Installation of sheet piles by vibratory methods will likely induce settlement of the Stratum 2B silty sands during both installation and withdrawal. The structural and hydraulic system should be designed to accommodate this movement, which could be up to several inches.

If an “in the wet” shored trench installation approach is used, the bedding and backfill soil for the pipes should consist of clean sand and gravel that can be placed below the water and compacted using vibrators similar to those employed for concrete placement. Not more than approximately 1.5 feet of loose backfill should be placed in each lift before vibratory compaction effort is applied.

If Stratum 2B soils predominate at the siphon location, use of an auger for trenchless installation of the undercrossing portion of the pipe may result in unacceptable amounts of flowing sands, thereby posing a risk of sinkhole formation during construction. A pipe ramming approach would be less risky, but would be considered marginally feasible for the proposed 250-foot length of installation and the relatively large 4-foot diameter pipe. A steel pipe would be needed for the pipe ramming option.

7.0 LIMITATIONS

The recommendations and descriptions presented in this report are based on the soil conditions disclosed by the field exploration conducted at the site in September and October 2008. The subsurface information referred to herein does not constitute a direct or implied warranty that the soil conditions between test pit locations can be directly interpolated or extrapolated or that subsurface conditions and soil variations different from those disclosed by the test pits will not be revealed. If, during construction, subsurface conditions different from those described herein are observed, or if the structures and loading conditions described here are modified, URS Corporation should review such conditions and the recommendations given herein should be revised, if necessary.

8.0 REFERENCES

Bartlett, S. F. and T. L. Youd. 1995. Empirical Prediction of Liquefaction-Induced Lateral Spread. Journal of Geotechnical Engineering, ASCE, Vol. 121, No. 4.

Dragovich, J. D., Logan, R. L., Schasse, H. W., Walsh, T. J, Lingley, W. S., Norman, D. K., Gerstel, W. J., Lapen, T. J., Schuster, J. E., and Meyers, K. D., 2002, Geological Map of Washington Northwest Quadrant, Washington Division of Geology and Earth Resources Geologic Map GM-50.

Youd, L. T., C.M. Hansen, and S.F. Bartlett. 2002. Revised Multilinear Regression Equations for Prediction of Lateral Spread Displacement. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, Vol. 128, No.12.

TABLES

Table 1 Summary of Recommended Soil Parameters
Table 2 Recommended Soil Parameters For Estimating Lateral Earth Pressures

TABLE 1 - Summary of Recommended Soil Parameters

ITEM	Imported Fill Sand	Stratum 1 SILT soft to medium stiff	Stratum 2A clayey SILT very soft to soft	Stratum 2B SILT/sandy SILT /silty SAND very loose to loose	Stratum 3 silty SAND loose to medium dense	Stratum 4 silty SAND/sandy SILT with gravel medium dense to very dense
Typical Uncorrected N-values (bpf)	N/A	1 to 7	0 to 10	0 to 6	8 to 17	24 to 63
Total Unit Weight γ (pcf)	130	110	95	100	110	130
Friction Angle ϕ (degrees)	36	20(*)	18(*)	18(*)	28	40
Cohesion c (psf)	0	250	125	125	0	0
Static Elastic Modulus E (ksf)	1200	200	100	100	300	1200
Poisson's Ratio v	0.35	0.35	0.35	0.35	0.3	0.3
Active Earth Pressure Coeff Ka(**)	0.26	0.49	0.53	0.53	0.36	0.22
At-Rest Earth Pressure Coeff Ko(**)	0.4	0.66	0.69	0.69	0.53	0.36
Passive Earth Pressure Coeff Kp(***)	2.6	1.36	1.26	1.26	1.85	3.1
Soil-Concrete Friction Coeffcient(****)	0.3	0.2	0.2	0.2	0.25	0.35
Modulus Subgrade Reaction k (pci)	300	160	140	140	200	225
Compression Index $C_{c\varepsilon}$	N/A	0.15	0.2	0.2	N/A	N/A
Re-compression Index $C_{r\varepsilon}$	N/A	0.015	0.02	0.02	N/A	N/A

Notes: (*) Equivalent effective friction angle of silt for drained conditions
(**) Calculated based on estimated friction angles of silt for drained condition and Rankine equations
(***) Calculated based on estimated friction angles of silt for drained condition using Rankine equations and a factor of safety of 1.5
(****) A factor of safety of 1.5 was applied to the ultimate value of friction coefficient

TABLE 2 - Recommended Soil Parameters For Estimating Lateral Earth Pressures

Soil Type	Condition	Soil Unit Weight (pcf)	Friction Angle (degree)	EQUIVALENT FLUID UNIT WEIGHT (PCF)		
				Active Case	At-Rest Case	Passive Case(***)
Granular Backfill	Above Water	130	36	34	52	320
	Below Water(**)	68	36	17	27	170
Stratum 1	Above Water	110	20(*)	54	73	150
	Below Water(**)	48	20	24	32	65
Stratum 2A	Above Water	95	18(*)	50	66	120
	Below Water(**)	33	18	17	23	42
Stratum 2B	Above Water	100	18(*)	53	69	126
	Below Water(**)	38	18	20	26	48

Notes: (*) Equivalent effective friction angle of silt for drained conditions

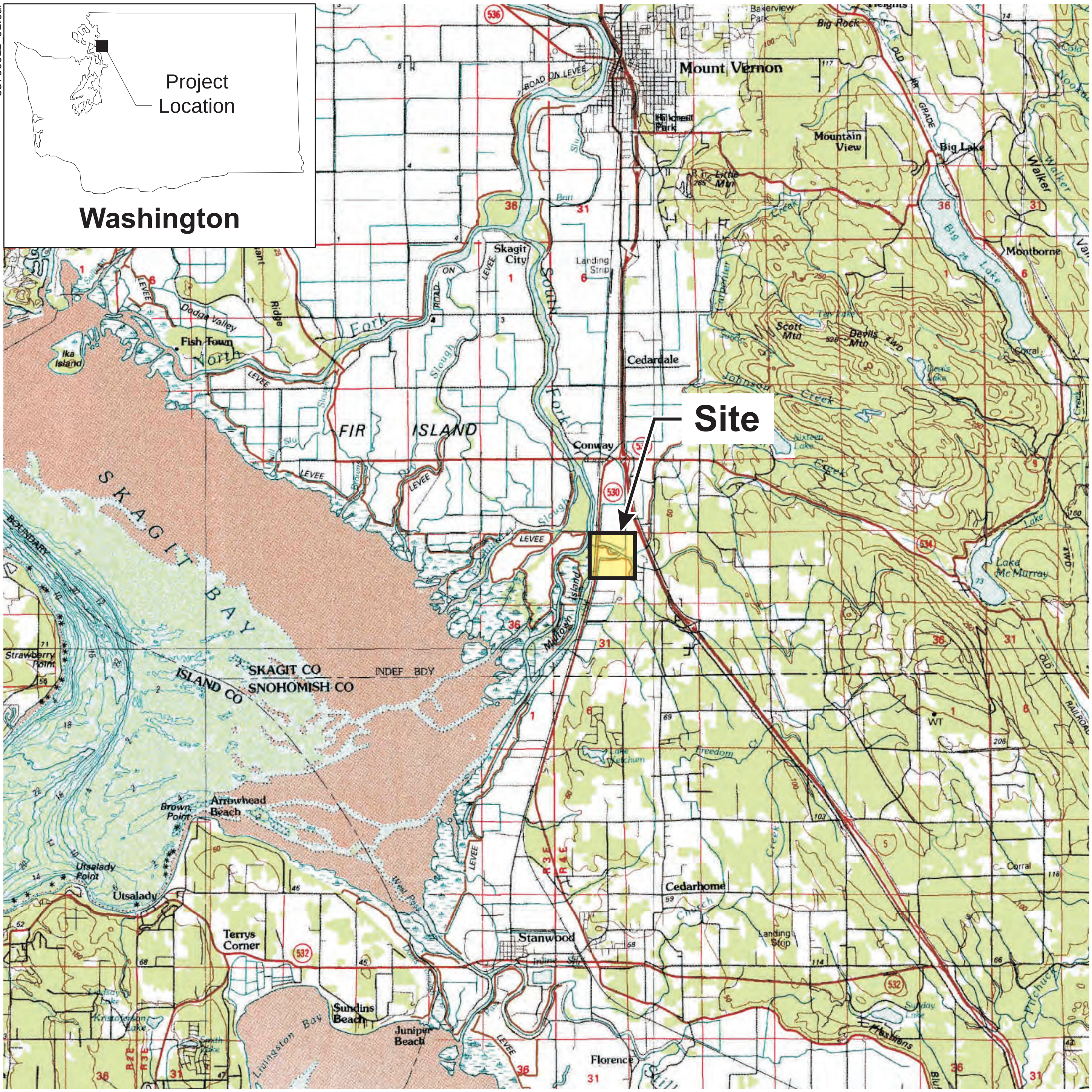
(**) Considered to be the "submerged condition", and hydrostatic pressure must be added to active and at-rest soil pressures to get total pressure.

(***) A factor of safety of 1.5 was applied to the passive earth pressure coefficient.

FIGURES

Figure 1	**Vicinity Map**
Figure 2	**Layout - Drill Hole and Test Pit Location**
Figure 3	**Profile of Soil Logs - Siphon and Proposed Levee**

33760911_01.cdr



SOURCE: USGS 1:100,000 scale topographic quadrangle, Port Townsend, Washington, 1993

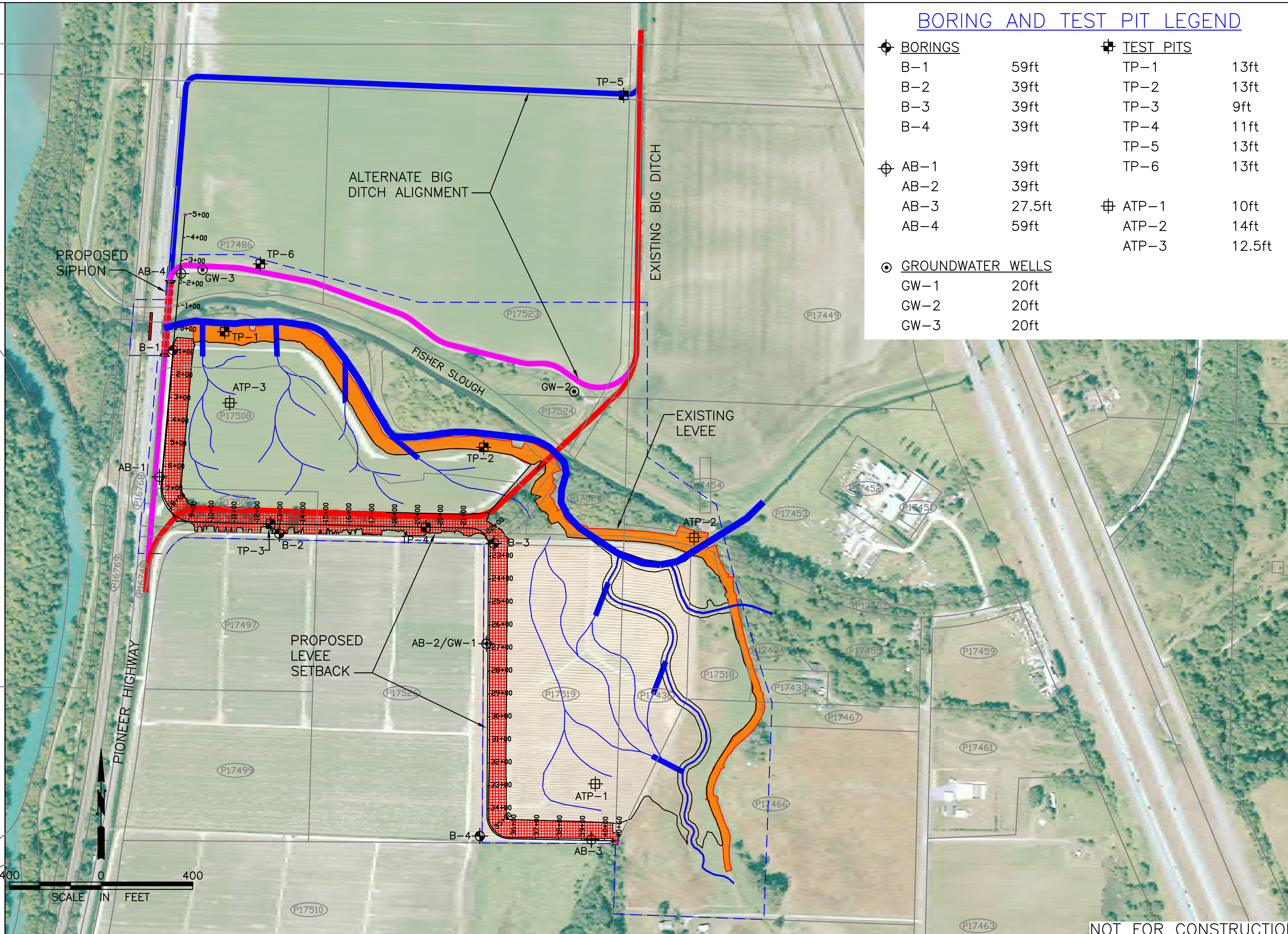
0 2 4
Scale in Miles

Job No. 33760911

Figure 1
Site Location

URS

Fisher Slough Restoration Project
Soil Investigation
Skagit County, Washington



BORING AND TEST PIT LEGEND

BORINGS	
B-1	59ft
B-2	39ft
B-3	39ft
B-4	39ft
AB-1	39ft
AB-2	39ft
AB-3	27.5ft
AB-4	59ft

GROUNDWATER WELLS	
GW-1	20ft
GW-2	20ft
GW-3	20ft

TEST PITS	
TP-1	13ft
TP-2	13ft
TP-3	9ft
TP-4	11ft
TP-5	13ft
TP-6	13ft
ATP-1	10ft
ATP-2	14ft
ATP-3	12.5ft

		Date
Designed	D. HAWK/D. CLINE/ S. BALENDRA	AUG 2008
Drawn		AUG 2008
Checked	R. DENHERDER	AUG 2008
Approved	MARTIN MC CABE	OCT 2008

Title

FISHER SLOUGH RESTORATION PROJECT

INVESTIGATION PLAN

SOIL INVESTIGATION PLAN
SKAGIT COUNTY, WASHINGTON

Tetra Tech, Inc.
1420 Fifth Avenue, Suite 550
Seattle, Washington 98101
206-728-9655 Fax: 206-728-9670

URS

File Name

Drawing No.
FIGURE 2

Sheet 1 of 1

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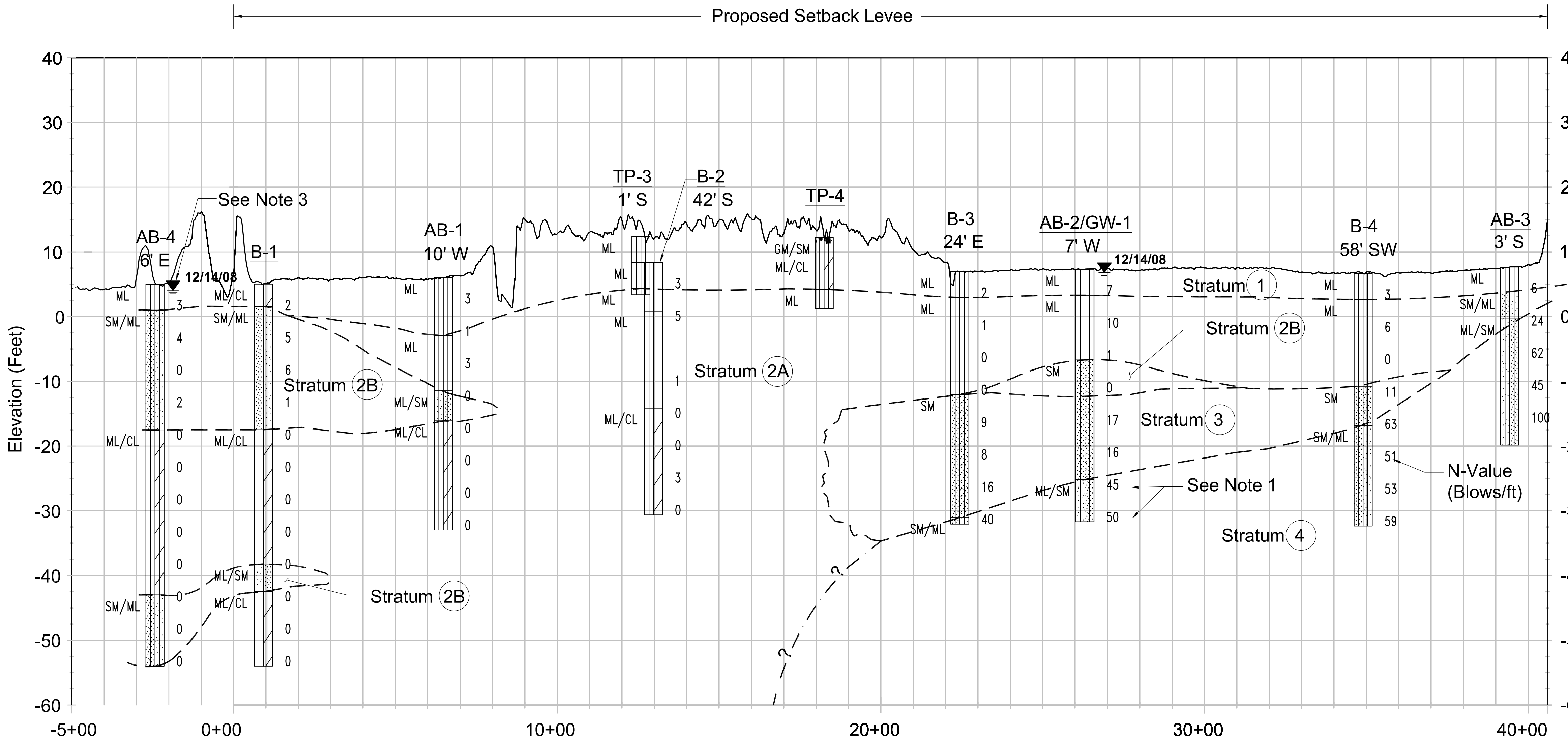

Notes:

1. N-values are not corrected to account for drilling method and effects of heaving sand. N-value of Ø indicates sampler advanced 18-inches under the weight of the rods and sampler.

2. The soil conditions are known only at the boring locations and are, therefore, accurate only at these points. The profile is based on interpolation between conditions observed at the boring locations and should be considered approximate.

3. Measured at Well GW-3.

Legend:

SM	Sand w/Silt
ML	Silt - Low Plasticity
CL	Clay - Low Plasticity
GM	Gravel w/Silt
12/14/08	Water Level and Date Measured

Key:

Stratum 1	Fill : Soft-m.stiff Silt (ML)
Stratum 2A	V.soft to soft Clayey Silt (ML)
Stratum 2B	V.loose to loose Silt and Silty Sand (ML/SM)
Stratum 3	Loose to medium dense Silty Sand (SM)
Stratum 4	Medium dense to dense Silty Sand and Sandy Silt (SM/ML)

400 0 400
Horizontal Scale in Feet
Vertical Exageration = 20x

P:\ACAD\PROJECT\Tetra Tech\Fisher Slough\Maps and Data\2008Cadd\fisher_profiles for soil samples_Profile.dwg
Mod: 12/15/2008, 15:31 | Plotted: 12/15/2008, 15:47 | Layout: A-3

NOT FOR CONSTRUCTION

Designed CLINE/S. BALENDRA Date OCT. 2008
Drawn OLMSTED/T. PHAM OCT. 2008
Checked R. DENHERDER
Approved MARTIN MC CABE
Title

FISHER SLOUGH RESTORATION PROJECT
SOIL INVESTIGATION REPORT
PROPOSED SETBACK LEVEE PROFILE
SKAGIT COUNTY, WASHINGTON

URS

Tetra Tech, Inc.
1420 Fifth Avenue, Suite 550
Seattle, Washington 98101
206-728-9655 Fax: 206-728-9670

File Name

Drawing No.
FIGURE 3

APPENDIX A

FIELD EXPLORATION

Key to Log of Boring and Descriptive Terms for Soil
Logs of Borings AB-1, AB-2/GW-1, AB-3, AB-4, B-1 to B-4, GW-2, and GW-3
Logs of Test Pits ATP-1 to ATP-3, TP-1 to TP-6

Project: Fisher Slough
Project Location: Skagit County, Washington
Project Number: 33760911

Key to Log of Boring and Descriptive Terms for Soil

Unified Soil Classification System (ASTM D2487 & D2488)

Major Divisions			Symbols: Graph	Symbols: Letter	Typical Descriptions
Coarse Grained Soils — More than 50% of No. 200 Sieve Size	Gravels — More than 50% of Coarse Fraction Retained in No. 4 Sieve	Clean Gravels (less than 5% fines)		GW	Well-Graded Gravels, Gravel-Sand Mixtures, Little or no Fines
				GP	Poorly-Graded Gravels, Gravel-Sand Mixtures, Little or no Fines
		Gravels with Fines (more than 12 % fines)		GM	Silty Gravels, Gravel-Sand-Silt Mixtures
				GC	Clayey Gravels, Gravel-Sand-Clay Mixtures
	Sands — More than 50% of Coarse Fraction Passing through No. 4 Sieve	Clean Sand (less than 5% fines)		SW	Well-Graded Sands, Gravelly Sands, Little or no Fines
				SP	Poorly Graded Sands, Gravelly Sands, Little or no Fines
		Sands with Fines (more than 12 % fines)		SM	Silty Sands, Sand-Clay Mixtures
				SC	Clayey Sands, Sand-Clay Mixtures
Fine Grained Soils — More than 50% of Material is Smaller than No. 200 Sieve Size	Silts and Clays	Liquid Limit Less than 50%		ML	Inorganic Silts and very Fine Sands, Rock Flour, Silty or Clayey Fine Sands or Clayey Silts with Slight Plasticity
				CL	Inorganic Clays of Low to Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays
				OL	Organic Silts and Organic Silty Clays of Low Plasticity
	Silts and Clays	Liquid Limit Greater than 50%		MH	Inorganic Silts, Micaceous or Diatomaceous Fine Sand or Silty Soils
				CH	Inorganic Clays of High Plasticity, Fat Clays
				OH	Organic Clays of Medium to High Plasticity, Organic Silts
Highly Organic Soils				PT	Peat, Humus, Swamp Soils with High Organic Contents (see ASTM D4427-92)

Relative Density or Consistency

Coarse-Grained Soils: Relative Density	N, SPT Blows / ft	Fine-Grained Soils: Relative Consistency	N, SPT Blows / ft
Very loose sand	0 - 4	Very soft	< 2
Loose	4 - 10	Soft	2 - 4
Medium dense	10 - 30	Medium stiff	4 - 8
Dense	30 - 50	Stiff	8 - 15
Very dense	Over 50	Very stiff	15 - 30
		Hard	Over 30

Minor Descriptors

Trace	0 - 5%
Slightly (clayey, silty, sandy, gravelly)	5 - 12%
Clayey, silty, sandy, gravelly	12 - 30%
Very (clayey, silty, sandy, gravelly)	30 - 50%

Moisture Content

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

Abbreviations

SA	Sieve Analysis
M	Moisture
DD	Dry Density
AL	Atterberg Limits
HA	Hydrometer Analysis
C	Consolidation
Pc	Constant Head Permeability
Pf	Falling Head Permeability
DS	Direct Shear
TX	Triaxial
TV	Torvane Shear
LV	Laboratory Vane Shear
PP	Pocket Penetrometer
OVA	Organic Vapor Analyzer
OC	Organic Content
N	Number of hammer blows for last 12 inches sampled

Sampler Symbols

- 3" O.D. Split Spoon Sample with brass rings
- 3" O.D. Shelby Tube Sample
- Core
- Piston Sample
- Non-standard penetration test
- Grab Sample
- 2" O.D. Split Spoon with 140lb Hammer and 30-inch drop (SPT)

Typical Well Graphic Symbols

- One pipe in bentonite pellets
- One slotted pipe in filter pack
- One pipe in filter pack
- Bentonite Seal

NOTES:

1. Descriptions and stratum lines are interpretive; field descriptions may have been modified to reflect lab test results. Descriptions on these logs apply only at the specific boring locations and at the time the borings were advanced; they are not warranted to be representative of subsurface conditions at other locations or times.
2. Dual Symbols are used to indicate borderline soil classifications

Project: Fisher Slough	Log of Boring AB-1
Project Location: Skagit County, Washington	Sheet 1 of 2
Project Number: 33760911	

Date(s) Drilled	9/29/08	Logged By	S.Balendra	Checked By	WMM
Drilling Method	Hollow Stem Auger	Drill Bit Size/Type	4.25" O.D.	Total Depth of Borehole	39.0 feet
Drill Rig Type	Mobile Drill B-61	Drilling Contractor	Environmental Drilling, Inc.	Approximate Surface Elevation	6.0 feet
Groundwater Level	Not Measured	Sampling Method(s)	SPT and/or Shelbey Tube	Hammer Data	SPT: 140-lb Auto Hammer, 30-inch Drop
Borehole Completion	Bentonite Chips	Location			

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery - Inches	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	0					ML	Brown SILT, very soft, moist [Fill]					
5												
			D-1	2 1 2 N=3	67		with stratified dark brown decomposed wood (probably peat)					PP = 0 tsf
	5											
0												
			D-2	2 1/1' N=1	22							
						ML	Dark gray SILT/sandy SILT, soft, wet					
	10											
-5												
			D-3	1 1 2 N=3	83							
	15											
-10		S	S-4		0							
			D-5	0/1.5' N=0	100	ML/ SM	dark gray sandy SILT/silty SAND with sea shell, very loose, wet to moist, rapid to slow dilatancy					
	20											
-15												
						ML/ CL	dark gray clayey SILT with sea shell, very soft, moist, slow dilatancy					
			D-6	0/1.5' N=0	100							PP = 0.15 tsf
	25								97.5	38.81	71.1	
-20		S	S-7		100							
												PP = 0 tsf PP = 0.18 tsf
			D-8	0/1.5' N=0	100							
	30											

Project: Fisher Slough
Project Location: Skagit County, Washington
Project Number: 33760911

Log of Boring AB-1

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	30												
-25													
			D-9	0/1.5' N=0	100								PP = 0.15 tsf
	35												
-30													
			D-10	0/1.5' N=0	100								PP = 0.15 tsf
								terminated at 39 feet at 1.15 Pm on Monday, 29 th September 2008 backfilled with cuttings and chips.					
	40												
-35													
	45												
-40													
	50												
-45													
	55												
-50													
	60												
-55													
	65												

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Project: Fisher Slough	Log of Boring AB-2/GW-1
Project Location: Skagit County, Washington	Sheet 1 of 2
Project Number: 33760911	

Date(s) Drilled	9/26/08	Logged By	S.Balendra	Checked By	WMM
Drilling Method	Hollow Stem Auger	Drill Bit Size/Type	4.25" O.D.	Total Depth of Borehole	39.0 feet
Drill Rig Type	Mobile Drill B-61	Drilling Contractor	Environmental Drilling, Inc.	Approximate Surface Elevation	7.0 feet
Groundwater Level	0.5 feet on 12/14/08	Sampling Method(s)	SPT	Hammer Data	SPT: 140-lb Auto Hammer, 30-inch Drop
Borehole Completion	Bentonite Chips	Location			

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	0						ML	Brown SILT, medium stiff, moist [Fill]	0.5 ft ▼				concrete and monument
5													bentonite seal
			D-1	2 3 4 N=7	100			with stratified dark brown decomposed wood (probably peat)					PP = 0.5 ~ 1.5 tsf
							ML	dark gray SILT with trace sand, very soft, moist					
	5												
0													
			D-2	5 6 4 N=10	100					98.4	42.6		riser pipe and sand pack PP = 0.15 tsf
	10												slotted (.020 in) and sand pack
-5													
			D-3	0/1' 1 N=1	100			with sea shell			27.4		PP = 0 tsf
							SM	dark gray silty SAND with sea shell, very loose, moist, slow dilatancy					
	15												
-10													
			D-4	0/1.5' N=0	100								
	20												backfill below well
-15													
			D-5	4 7 10 N=17	100			grades to medium dense		25.1	20.8		
													cuttings
	25												
-20													
			D-6	4 7 9 N=16	100			grades to medium dense and rapid dilatancy					
	30												

Project: Fisher Slough
Project Location: Skagit County, Washington
Project Number: 33760911

Log of Boring AB-2/GW-1

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	30												
-25													
			D-7	5 17 28 N=45	100		ML/ SM	dark gray sandy SILT/silty SAND with trace gravel (rounded), dense, moist					
	35												
-30													
			D-8	10 19 31 N=50	100								
	40							terminated at 39 feet at 10.45 Am on Friday, 26 th September 2008 Install well 2 inch diameter PVC Well tag: APQ791. Water level measurement (below existing ground surface): -12/14/08 at 15:00: 0.5 feet in observation well					
-35													
	45												
-40													
	50												
-45													
	55												
-50													
	60												
-55													
	65												

Project: Fisher Slough	**Log of Boring AB-3**
Project Location: Skagit County, Washington	Sheet 1 of 1
Project Number: 33760911	

Date(s) Drilled	9/26/08	Logged By	S.Balendra	Checked By	WMM
Drilling Method	Hollow Stem Auger	Drill Bit Size/Type	4.25" O.D.	Total Depth of Borehole	27.5 feet
Drill Rig Type	Mobile Drill B-61	Drilling Contractor	Environmental Drilling, Inc.	Approximate Surface Elevation	8.0 feet
Groundwater Level	Not Measured	Sampling Method(s)	SPT	Hammer Data	SPT: 140-lb Auto Hammer, 30-inch Drop
Borehole Completion	Bentonite Chips	Location			

Elevation feet	Depth, feet	Samples: Type	Samples: Number	Samples: Blows/ 6in.	Samples: Recovery - Inches	Samples: Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	0						ML	Brown SILT, medium stiff, moist [Fill]					
5			D-1	2 2 4 N=6	100			with stratified dark brown decomposed wood (probably peat)					PP = 0.25 ~ 0.5 tsf
	5						SM/ ML	dark gray silty SAND/sandy SILT with sea shell, very loose to medium dense, wet, rapid dilatancy					
0			D-2	5 9 15 N=24	89		ML/ SM	dark gray sandy SILT/silty SAND with trace gravel (rounded) , medium dense to very dense, moist					
	10												
-5			D-3	12 24 38 N=62	100								
	15												
-10			D-4	7 19 26 N=45	100								
	20												
-15			D-5	23 50/3" N>100	100								
	25												
-20								terminated at 27.5 feet at 9 Am on Friday, 26 th September 2008 backfilled with cuttings and chips.					
	30												

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Project: Fisher Slough	Log of Boring AB-4
Project Location: Skagit County, Washington	Sheet 1 of 2
Project Number: 33760911	

Date(s) Drilled	9/30/08	Logged By	S.Balendra	Checked By	WMM
Drilling Method	Hollow Stem Auger	Drill Bit Size/Type	4.25" O.D.	Total Depth of Borehole	59.0 feet
Drill Rig Type	Mobile Drill B-61	Drilling Contractor	Environmental Drilling, Inc.	Approximate Surface Elevation	5.0 feet
Groundwater Level	Not Measured	Sampling Method(s)	SPT and/or Shelbey Tube	Hammer Data	SPT: 140-lb Auto Hammer, 30-inch Drop
Borehole Completion	Bentonite Chips	Location			

Elevation feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Blows/ 6in.	SAMPLES Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
5	0						ML	Brown SILT, soft, moist [Fill]					
			D-1	1 1 2 N=3	100			with stratified dark brown decomposed wood (probably peat)					PP = 0.25 tsf
							SM/ ML	dark gray silty SAND/sandy SILT , very loose , moist					
0	5												
			D-2	0 2 2 N=4	72			clayey SILT from 8 to 9 ft, very soft					PP = 0.21 tsf
-5	10	S	S-3		29					85.2	29.63	70.4	
			D-4	0/1.5' N=0	67			from 12.5 to 22.5ft: with sea shell, wet, rapid dilatancy					
-10	15												
			D-5	0/1' 2 N=2	100			from 17.5 to 19 ft: poorly graded fine to medium SAND, loose					
-15	20												
			D-6	0/1.5' N=0	100		ML/ CL	dark gray clayey SILT/silty CLAY with sea shell, very soft, moist, slow to none dilatancy					PP = 0.05 tsf
-20	25												
			D-7	0/1.5' N=0	100								PP = 0.17 tsf
-25	30												

Project: Fisher Slough	Log of Boring AB-4
Project Location: Skagit County, Washington	Sheet 2 of 2
Project Number: 33760911	

Elevation feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Blows/ 6in.	SAMPLES: Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
-25	30												
			D-8	0/1.5' N=0	100								PP = 0.14 tsf
-30	35												
			D-9	0/1.5' N=0	100								PP = 0.18 tsf
-35	40												
			D-10	0/1.5' N=0	100								PP = 0.17 tsf
-40	45												
			D-11	0/1.5' N=0	100		SM/ ML	dark gray silty SAND/sandy SILT with sea shell, very loose , moist, rapid to slow dilatancy					PP = 0.17 tsf
-45	50												
			D-12	0/1.5' N=0	100			grades to SILT with sea shell, very soft, slow to none dilatancy					PP = 0.15 tsf
-50	55												
			D-13	0/1.5' N=0	100			moist to wet, rapid dilatancy					
								terminated at 59 feet at 10.15 Am on Tuesday, 30 th September 2008 backfilled with cuttings and chips					
-55	60												
-60	65												

Project: Fisher Slough Project Location: Skagit County, Washington Project Number: 33760911	**Log of Boring B-1** Sheet 1 of 2

Date(s) Drilled	**9/29/08 - 4/18/07**	Logged By	**S.Balendra**	Checked By	**WMM**
Drilling Method	**Hollow Stem Auger**	Drill Bit Size/Type	**4.25" O.D.**	Total Depth of Borehole	**59.0 feet**
Drill Rig Type	**Mobile Drill B-61**	Drilling Contractor	**Environmental Drilling, Inc.**	Approximate Surface Elevation	**5.0 feet**
Groundwater Level	**Not Measured**	Sampling Method(s)	**SPT and/or Shelbey Tube**	Hammer Data	**SPT: 140-lb Auto Hammer, 30-inch Drop**
Borehole Completion	**Bentonite Chips**	Location			

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/ ft	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
5	0						ML/ CL	Brown to gray clayey SILT/SILT, soft, moist [Fill]					
			D-1	1 1 1 N=2	67					98.2	39.4		PP =0.25 tsf
							SM/ ML	Dark gray silty SAND/sandy SILT, very loose to loose, wet, rapid dilatancy					PP =0.11 tsf
0	5												
			D-2	0 2 3 N=5	100								
-5	10												
			D-3	0 3 3 N=6	100					88.6	44.4		PP =0 tsf
-10	15												
			D-4	0/1' 1 N=1	100			with sea shell		45.7	30.8		
-15	20												
			D-5	0/1.5' N=0	100		ML/ CL	dark gray clayey SILT/SILT with sea shell, very soft, moist, slow dilatancy					PP =0.06 to 0.09 tsf
-20	25												
			D-6	0/1.5' N=0	100								PP =0 tsf
		S								93.1	30.59	81.9	PP =0.25 tsf
-25	30												

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Figure A-1.1

Project: Fisher Slough
Project Location: Skagit County, Washington
Project Number: 33760911

Log of Boring B-1

Elevation feet	Depth, feet	Type	Number	Blows/ ft	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
-25	30	S	S-7		100			grades to soft					
		D	D-8	0/1.5' N=0	100			grades to clayey SILT, slow to none dilatancy, soft					PP =0.25 tsf
-30	35												
		D	D-9	0/1.5' N=0	100			grades to clayey SILT, slow to none dilatancy					PP =0.25 tsf
-35	40												
		D	D-10	0/1.5' N=0	100		ML/ SM	dark gray sandy SILT/silty SAND with sea shell, very loose, wet to moist, rapid to slow dilatancy					PP =0 tsf; PP = 0.25 tsf
-40	45												
		D	D-11	0/1.5' N=0	100		ML/ CL	dark gray clayey SILT with sea shell, very soft, moist to wet, slow to none dilatancy					PP =0.18 tsf
-45	50												
		D	D-12	0/1.5' N=0	100			grades to SILT, soft, rapid to slow dilatancy					PP =0.25 tsf
-50	55												
		D	D-13	0/1.5' N=0	100			grades to SILT, very soft, slow dilatancy					PP =0.17 tsf
-55	60							terminated at 59 feet at 10.15 Am on Monday, 29 th September 2008 backfilled with cuttings and chips					
-60	65												

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Figure A-1.2

Project: Fisher Slough	Log of Boring B-2
Project Location: Skagit County, Washington	Sheet 1 of 2
Project Number: 33760911	

Date(s) Drilled	9/25/08	Logged By	S.Balendra	Checked By	WMM
Drilling Method	Hollow Stem Auger	Drill Bit Size/Type	4.25" O.D.	Total Depth of Borehole	39.0 feet
Drill Rig Type	Mobile Drill B-61	Drilling Contractor	Environmental Drilling, Inc.	Approximate Surface Elevation	8.0 feet
Groundwater Level	Not Measured	Sampling Method(s)	SPT and/or Shelbey Tube	Hammer Data	SPT: 140-lb Auto Hammer, 30-inch Drop
Borehole Completion	Bentonite Chips	Location			

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	0						ML	Brown SILT, stiff, moist [Fill]					
5			D-1	1 1 2 N=3	100			with stratified dark brown decomposed wood (probably peat)					PP = 0.5 tsf
	5												
0			D-2	0 4 1 N=5	100		ML	dark gray SILT with trace sand, very soft, wet					PP = 0 tsf
	10												
-5		S	S-3		100					53.9	33.33	79.7	PP = 0.25 ~ 0.5 tsf
	15							possible poorly graded sand layer between 14.5 to 17.5 ft					
								heave at 17 ft					
-10			D-4	0/1' 1 N=1	100								PP= 0 tsf
	20												
-15			D-5	0/1.5' N=0	100		ML/ CL	dark gray clayey SILT/SILT with sea shell, very soft, wet					PP= 0 tsf
	25												
-20			D-6	0/1.5' N=0	100								PP= 0 tsf
	30												

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Elevation feet	Depth, feet	Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	30												
-25			D-7	0 1 2 N=3	100								PP= 0 tsf
	35												
-30			D-8	0/1.5' N=0	100								PP= 0 ~ 0.25 tsf
	40							terminated at 39 feet at 10.15 Am on Thursday, 25 th September 2008 backfilled with cuttings and chips					
-35													
	45												
-40													
	50												
-45													
	55												
-50													
	60												
-55													
	65												

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Project: Fisher Slough	Log of Boring B-3
Project Location: Skagit County, Washington	Sheet 1 of 2
Project Number: 33760911	

Date(s) Drilled	**9/25/08**	Logged By	**S.Balendra**	Checked By	**WMM**
Drilling Method	**Hollow Stem Auger**	Drill Bit Size/Type	**4.25" O.D.**	Total Depth of Borehole	**39.0 feet**
Drill Rig Type	**Mobile Drill B-61**	Drilling Contractor	**Environmental Drilling, Inc.**	Approximate Surface Elevation	**7.0 feet**
Groundwater Level	**Not Measured**	Sampling Method(s)	**SPT**	Hammer Data	**SPT: 140-lb Auto Hammer, 30-inch Drop**
Borehole Completion	**Bentonite Chips**	Location			

Elevation feet	Depth, feet	Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
7	0						ML	Brown SILT, soft to medium stiff, moist [Fill]					
5		SPT	D-1	2 1 1 N=2	100			with stratified dark brown decomposed wood (probably peat)		95.4	32.5		PP = 0.75 tsf
							ML	dark gray SILT, very soft, wet					
	5												
0		SPT	D-2	0/1' 1 N=1	100						44.3		PP = 0.14 tsf
	10												
-5		SPT	D-3	0/1.5' N=0	100			grades to with trace sand					PP = 0.125 ~ 0.25 tsf
	15												
-10		SPT	D-4	0/1.5' N=0	100			grades to loose silty SAND with sea shell, wet					PP = 0.18 tsf
							SM	dark gray silty SAND with sea shell, loose, wet, rapid dilatancy					
	20												
-15		SPT	D-5	4 4 5 N=9	100					27.8	19.4		PP = 0.25 tsf
	25												
-20		SPT	D-6	0 3 5 N=8	100								
	30												

Project: Fisher Slough
Project Location: Skagit County, Washington
Project Number: 33760911

Log of Boring B-3

Elevation feet	Depth, feet	Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	30												
-25													
			D-7	4 7 9 N=16	100			grades to medium dense					
	35												
-30													
			D-8	15 20 20 N=40	100		SM/ ML	dark gray silty SAND/sandy SILT with trace gravel (rounded), dense, moist					
								terminated at 39 feet at 12.45 Pm on Thursday, 25 th September 2008 backfilled with cuttings and chips					
	40												
-35													
	45												
-40													
	50												
-45													
	55												
-50													
	60												
-55													
	65												

Project: Fisher Slough	Log of Boring B-4
Project Location: Skagit County, Washington	Sheet 1 of 2
Project Number: 33760911	

Date(s) Drilled	**9/25/08**	Logged By	**S.Balendra**	Checked By	**WMM**
Drilling Method	**Hollow Stem Auger**	Drill Bit Size/Type	**4.25" O.D.**	Total Depth of Borehole	**39.0 feet**
Drill Rig Type	**Mobile Drill B-61**	Drilling Contractor	**Environmental Drilling, Inc.**	Approximate Surface Elevation	**7.0 feet**
Groundwater Level	**Not Measured**	Sampling Method(s)	**SPT**	Hammer Data	**SPT: 140-lb Auto Hammer, 30-inch Drop**
Borehole Completion	**Bentonite Chips**	Location			

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	0						ML	Brown SILT, soft, moist [Fill]					
5													
			D-1	3 2 1 N=3	100			with stratified dark brown decomposed wood (probably peat)			48.9		PP = 0.25 ~ 0.5 tsf
							ML	dark gray SILT, very soft, moist					
	5												
0													
			D-2	0 3 3 N=6	100					95.3	37.5		PP = 0.15 ~ 0.21 tsf
	10												
-5													
			D-3	0/1.5' N=0	100			grades to very loose silty SAND with sea shell					PP = 0.25 ~ 0.5 tsf
	15												
-10													
			D-4	5 6 5 N=11	100		SM	dark gray silty SAND with sea shell, medium dense, moist, none dilatancy					
	20							driller indicated dense at 20 feet					
-15													
			D-5	15 28 35 N=63	100								
							SM/ ML	dark gray silty SAND/sandy SILT with trace gravel (rounded), very dense, moist					
	25												
-20													
			D-6	10 25 26 N=51	100					78.9	15.9		
	30												

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Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	30												
-25													
			D-7	12 21 32 N=53	100								
	35												
-30													
			D-8	16 22 37 N=59	100								
	40							terminated at 39 feet at 3.15 Pm on Thursday, 25 th September 2008 backfilled with cuttings and chips.					
-35													
	45												
-40													
	50												
-45													
	55												
-50													
	60												
-55													
	65												

Project: Fisher Slough	Log of Boring GW-2
Project Location: Skagit County, Washington	Sheet 1 of 1
Project Number: 33760911	

Date(s) Drilled	**9/26/08**	Logged By	**S.Balendra**	Checked By	**WMM**
Drilling Method	**Hollow Stem Auger**	Drill Bit Size/Type	**4.25" O.D.**	Total Depth of Borehole	**20.0 feet**
Drill Rig Type	**Mobile Drill B-61**	Drilling Contractor	**Environmental Drilling, Inc.**	Approximate Surface Elevation	**6.0 feet**
Groundwater Level	**3.0 feet on 12/14/08**	Sampling Method(s)	**SPT**	Hammer Data	**SPT: 140-lb Auto Hammer, 30-inch Drop**
Borehole Completion	**Bentonite Chips**	Location			

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	0						ML	Brown SILT, stiff, moist [Fill]					
5													concrete and monument bentonite seal
			D-1	2 2 2 N=4	100				3.0 ft				PP = 1.25 tsf
								with stratified dark brown decomposed wood (probably peat)					
							ML/ CL	dark gray clayey SILT/SILT, very soft, wet					
	5												
0													
			D-2	0 2 2 N=4	100								PP = 0.09 tsf riser pipe and sand pack
	10												
-5													slotted (.020 in) and sand pack
			D-3	0/1.5' N=0	100		SM	gray to dark gray silty SAND with trace gravel, very loose, moist, rapid dilatancy					
	15												
-10													
			D-4	2 3 4 N=7	100			grades to loose silty SAND with gravel and sea shell, wet					
	20							terminated at 20 feet at 1.45 Pm on Friday, 26 th September 2008 Install well 2 inch diameter PVC Well tag: APQ792 Water level measurement (below existing ground surface): -12/14/08 at 15:45: 3.0 feet in observation well					
-15													
	25												
-20													
	30												

Project: Fisher Slough	Log of Boring GW-3
Project Location: Skagit County, Washington	Sheet 1 of 1
Project Number: 33760911	

Date(s) Drilled	9/29/08	Logged By	S.Balendra	Checked By	WMM
Drilling Method	Hollow Stem Auger	Drill Bit Size/Type	4.25" O.D.	Total Depth of Borehole	20.0 feet
Drill Rig Type	Mobile Drill B-61	Drilling Contractor	Environmental Drilling, Inc.	Approximate Surface Elevation	5.0 feet
Groundwater Level	1.0 feet on 12/14/08	Sampling Method(s)	SPT	Hammer Data	SPT: 140-lb Auto Hammer, 30-inch Drop
Borehole Completion	Bentonite Chips	Location			

Elevation feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Blows/ 6in.	SAMPLES Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
5	0						ML	Brown SILT, medium stiff, moist [Fill]	1.0 ft				concrete and monument
													bentonite seal
			D-1	1 2 3 N=5	100			with stratified dark brown decomposed wood (probably peat)					PP = 0.75 tsf
							ML	dark gray SILT, very soft, moist, rapid to slow dilatancy					
0	5												
													riser pipe and sand pack
			D-2	0/1.5' N=0	100								PP = 0.15 tsf
							SM/ SP	gray to dark gray silty SAND/poorly graded fine SAND, loose, wet, rapid dilatancy					
-5	10												slotted (.020 in) and sand pack
			D-3	5 2 2 N=4	100								
-10	15												
			D-4	0/1' 2 N=2	100			with sea shell					
-15	20							terminated at 20 feet at 2.30 Pm on Monday, 29 th September 2008 Install well 2 inch diameter PVC Well tag: APQ793 Water level measurement (below existing ground surface): -12/14/08 at 16:15: 1.0 feet in observation well					
-20	25												
-25	30												

Project: Fisher Slough
Project Location: Skagit County, Washington
Project Number: 33760911

Log of Boring ATP-1

Date(s) Drilled	**10/6/08**	Logged By	**S.Balendra**	Checked By	**WMM**
Drilling Method		Drill Bit Size/Type		Total Depth of Borehole	**10.0 feet**
Drill Rig Type	**120 Excavator**	Drilling Contractor	**Catapult Heavy Construction**	Approximate Surface Elevation	**8.0 feet**
Groundwater Level	**Not Observed**	Sampling Method(s)	**Grab Sample**	Hammer Data	
Borehole Completion		Location			

Elevation feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Blows/ 6in.	SAMPLES Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	0						ML/ CL	Brown clayey SILT/SILT with/with out trace sand, Medium stiff to stiff, moist to dry [Fill]					PP = 2.0 tsf PP = 1.5 tsf
5													
	5												
0							SM/ ML	Gray silty SAND/ sandy SILT, loose, moist to wet					
	10							@ 10 feet: gray silty SAND/sandy SILT with gravel, moist, dense to very dense					
								terminated at 10 feet at 3.00 Pm on Monday, 6 th October 2008. No groundwater was encountered during excavation.					
-5													
	15												
-10													
	20												
-15													
	25												
-20													
	30												

Project: Fisher Slough	Log of Boring ATP-2
Project Location: Skagit County, Washington	Sheet 1 of 1
Project Number: 33760911	

Date(s) Drilled	10/6/08	Logged By	S.Balendra	Checked By	WMM
Drilling Method		Drill Bit Size/Type		Total Depth of Borehole	14.0 feet
Drill Rig Type	120 Excavator	Drilling Contractor	Catapult Heavy Construction	Approximate Surface Elevation	16.0 feet
Groundwater Level	Not Observed	Sampling Method(s)	Grab Sample	Hammer Data	
Borehole Completion		Location			

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	0						SM/ GM	Dark brown silty SAND with gravel/silty GRAVEL with sand, dense, moist [Fill]		10.5	2.92		
15													
	5												
10													
	10						ML	Dark gray SILT with trace sand, soft to medium stiff, moist					
5													
								terminated at 14 feet at 2.00 Pm on Monday, 6 th October 2008. No groundwater was encountered during excavation.					
	15												
0													
	20												
-5													
	25												
-10													
	30												

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Project: Fisher Slough	Log of Boring ATP-3
Project Location: Skagit County, Washington	Sheet 1 of 1
Project Number: 33760911	

Date(s) Drilled	10/6/08	Logged By	S.Balendra	Checked By	WMM
Drilling Method		Drill Bit Size/Type		Total Depth of Borehole	12.5 feet
Drill Rig Type	120 Excavator	Drilling Contractor	Catapult Heavy Construction	Approximate Surface Elevation	5.0 feet
Groundwater Level	11.5 feet on 10/0/08	Sampling Method(s)	Grab Sample	Hammer Data	
Borehole Completion		Location			

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
5	0						ML	Brown SILT , medium stiff to very stiff, moist [Fill]					PP = 2.5 tsf PP = 0.5 tsf
0	5						ML	Gray SILT , very soft, moist					
-5	10							11.5 ft					
							SP	Gray poorly graded fine to medium SAND, loose, wet heaving at 11.5 feet					
								terminated at 12.5 feet at 11.30 Am on Monday, 6 th October 2008. Groundwater was encountered at 11.5' below ground surface (large inflow rate).					
-10	15												
-15	20												
-20	25												
-25	30												

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Project: Fisher Slough	**Log of Boring TP-1**
Project Location: Skagit County, Washington	Sheet 1 of 1
Project Number: 33760911	

Date(s) Drilled	**10/6/08**	Logged By	**S.Balendra**	Checked By	**WMM**
Drilling Method		Drill Bit Size/Type		Total Depth of Borehole	**13.0 feet**
Drill Rig Type	**120 Excavator**	Drilling Contractor	**Catapult Heavy Construction**	Approximate Surface Elevation	**17.0 feet**
Groundwater Level	**Not Observed**	Sampling Method(s)	**Grab Sample**	Hammer Data	
Borehole Completion		Location			

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	0						ML/ SM	Brown sandy SILT/silty SAND with gravel, very dense, dry to moist [Fill]		32.4	4.45		
15													
							ML	Brown SILT, medium stiff, moist [Fill]					
	5												
10										73.5	5.66		PP = 0.5 tsf
	10												
5													
								terminated at 13 feet at 12.30 Pm on Monday, 6 th October 2008. No groundwater was encountered during excavation.					
	15												
0													
	20												
-5													
	25												
-10													
	30												

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Project: Fisher Slough	Log of Boring TP-2
Project Location: Skagit County, Washington	Sheet 1 of 1
Project Number: 33760911	

Date(s) Drilled	10/6/08	Logged By	S.Balendra	Checked By	WMM
Drilling Method		Drill Bit Size/Type		Total Depth of Borehole	13.0 feet
Drill Rig Type	120 Excavator	Drilling Contractor	Catapult Heavy Construction	Approximate Surface Elevation	17.0 feet
Groundwater Level	Not Observed	Sampling Method(s)	Grab Sample	Hammer Data	
Borehole Completion		Location			

Elevation feet	Depth, feet	SAMPLES: Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	0						ML	Brown SILT with sand and trace gravel, stiff to very stiff, dry [Fill]					
15							ML	Brown SILT, stiff, moist [Fill]					PP = 1.5 tsf
	5												
10													
	10						ML/ CL	Gray clayey SILT, medium stiff to stiff, moist					PP = 1 tsf
5													
								terminated at 13 feet at 1.00 Pm on Monday, 6 th October 2008. No groundwater was encountered during excavation.					
	15												
0													
	20												
-5													
	25												
-10													
	30												

Project: Fisher Slough	Log of Boring TP-3
Project Location: Skagit County, Washington	Sheet 1 of 1
Project Number: 33760911	

Date(s) Drilled	**10/6/08**	Logged By	**S.Balendra**	Checked By	**WMM**
Drilling Method		Drill Bit Size/Type		Total Depth of Borehole	**9.0 feet**
Drill Rig Type	**120 Excavator**	Drilling Contractor	**Catapult Heavy Construction**	Approximate Surface Elevation	**12.5 feet**
Groundwater Level	**Not Observed**	Sampling Method(s)	**Grab Sample**	Hammer Data	
Borehole Completion		Location			

Elevation, feet	Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	0						ML	Brown SILT , very stiff to hard, dry [Fill]					PP =4.0 tsf
10													
								Locally: Well graded GRAVEL with sand, rounded, medium dense, moist					
							ML	Brown SILT with/with out trace sand, stiff, moist [Fill]					PP = 2.0 tsf
	5												
5													
							ML	Gray SILT, very soft, moist					
								terminated at 9 feet at 3.30 Pm on Monday, 6 th October 2008. No groundwater was encountered during excavation.					
	10												
0													
	15												
-5													
	20												
-10													
	25												
-15													
	30												

Project: Fisher Slough	Log of Boring TP-4
Project Location: Skagit County, Washington	Sheet 1 of 1
Project Number: 33760911	

Date(s) Drilled	10/6/08	Logged By	S.Balendra	Checked By	WMM
Drilling Method		Drill Bit Size/Type		Total Depth of Borehole	11.0 feet
Drill Rig Type	120 Excavator	Drilling Contractor	Catapult Heavy Construction	Approximate Surface Elevation	12.0 feet
Groundwater Level	Not Observed	Sampling Method(s)	Grab Sample	Hammer Data	
Borehole Completion		Location			

Elevation feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Blows/ 6in.	SAMPLES Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	0						GM/SM	Brown silty GRAVEL with sand/ silty SAND with gravel, dense, dry to moist [Fill]					
10							ML/CL	Brown clayey SILT, stiff to hard, moist [Fill]		81.5	20.18		PP = 2 to 4 tsf
	5												
5							ML	Gray SILT, very soft, moist					
	10												
0								terminated at 11 feet at 5.30 Pm on Monday, 6 th October 2008. No groundwater was encountered during excavation.					
	15												
-5													
	20												
-10													
	25												
-15													
	30												

Project: Fisher Slough **Project Location: Skagit County, Washington** **Project Number: 33760911**	# Log of Boring TP-5 Sheet 1 of 1

Date(s) Drilled	**10/6/08**	Logged By	**S.Balendra**	Checked By	**WMM**
Drilling Method		Drill Bit Size/Type		Total Depth of Borehole	**13.0 feet**
Drill Rig Type	**120 Excavator**	Drilling Contractor	**Catapult Heavy Construction**	Approximate Surface Elevation	**4.0 feet**
Groundwater Level	**10.5 feet on 10/06/08**	Sampling Method(s)	**Grab Sample**	Hammer Data	
Borehole Completion		Location			

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
	0						ML/ CL	Brown clayey SILT with/with out trace sand, soft to stiff, moist [Fill]					PP = 2 tsf PP = 0.25 to 0.5 tsf
0							ML	Gray SILT, very soft, moist					
	5												
-5													
	10							10.5 ft					
							SP	Gray poorly graded fine to medium SAND, loose heaving at 11 feet					
-10								terminated at 13 feet at 10.00 Am on Monday, 6 th October 2008. Ground water was encountered at 10.5' below ground surface (large inflow rate).					
	15												
-15													
	20												
-20													
	25												
-25													
	30												

Project: Fisher Slough
Project Location: Skagit County, Washington
Project Number: 33760911

Log of Boring TP-6

Date(s) Drilled	**10/6/08**	Logged By	**S.Balendra**	Checked By	**WMM**
Drilling Method		Drill Bit Size/Type		Total Depth of Borehole	**13.0 feet**
Drill Rig Type	**120 Excavator**	Drilling Contractor	**Catapult Heavy Construction**	Approximate Surface Elevation	**5.0 feet**
Groundwater Level	**5 feet on 10/06/08**	Sampling Method(s)	**Grab Sample**	Hammer Data	
Borehole Completion		Location			

Elevation feet	Depth, feet	SAMPLES Type	Number	Blows/ 6in.	Recovery - Inches	Graphic Log	USCS	MATERIAL DESCRIPTION	Well Completion Schematic	Fines Content (%<#200 Sieve)	Moisture Content, %	Dry Density, (pcf)	REMARKS AND OTHER TESTS
5	0						ML/ CL	Brown clayey SILT/SILT with/with out trace sand, Medium stiff to stiff, moist [Fill]		77.2	3.61		PP = 2.0 tsf; PP = 1.5 tsf; PP = 0.5 tsf
0	5							water perched at 5 feet (5 ft)					
							ML	Gray SILT, very soft, moist					
-5	10												
								terminated at 13 feet at 10.30 Am on Monday, 6 th October 2008. Perched water was encountered at 5' below ground surface (slight inflow rate).					
-10	15												
-15	20												
-20	25												
-25	30												

APPENDIX B

LABORATORY TESTING

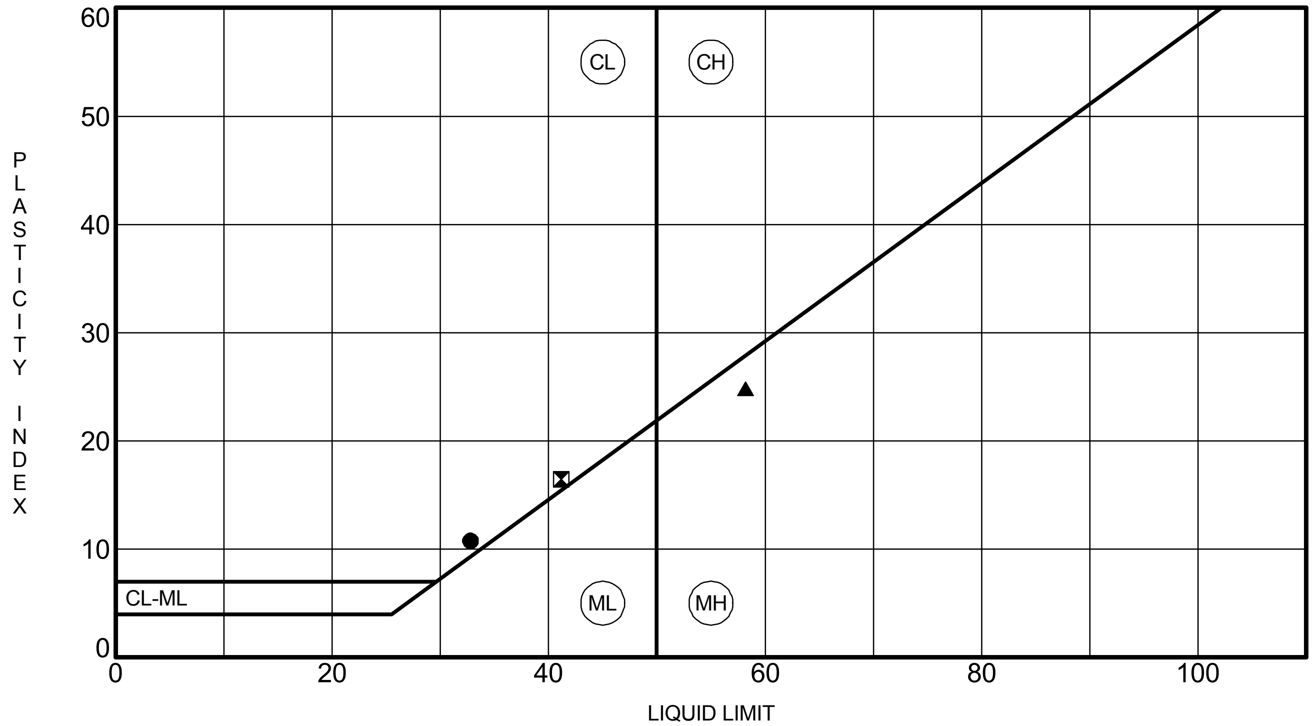
Table B-1: Summary of Laboratory Test Results
URS Atterberg Limits' Results of AB-2/GW-1, B-3, and B-4
URS Sieve Analysis Results of AB-2/GW-1 and GW-2
Analytical Resources' Consolidation etc Results of AB-1, AB-4, B-1, and B-2
Analytical Resources' Modified Proctor Testing Results of ATP-2, TP-1, TP-4, and TP-6

Table B-1: Summary of Laboratory Test Results

Boring Number	Sample Depth (ft)	USCS Soil Classification	Stratum No.	Moisture Content (%)	% Fines	% Gravel	Dry Unit Weight (pcf)	Liquid Limit	Plastic Limit	Plasticity Index	Modified Proctor Maximum Density (pcf)	Modified Proctor Optimum Moisture (%)	Modified Proctor Maximum Density (pcf) (Corrected[2])	Modified Proctor Optimum Moisture (%) (Corrected[2])	Compression Index Cc (strain)	Coefficient of Consolidation Cv (ft^2/day)	Hydraulic Conductivity (cm/s)
B-1	2.5	ML/CL	1	39.4	98.2												
	12.5	SM/ML	2B	44.4	88.6												
	17.5	SM/ML	2B	30.8	45.7												
	29-31	ML/CL	2A	30.6	93.1		81.9	43	26	17					0.10	0.19	
B-2	12.5-14.5	ML/CL	2A	33.3	53.9		79.7	25	20	5					0.09	18.0	3.61E-07
B-3	2.5	ML	1	32.5	95.4												
	7.5	ML	2A	44.3				41	25	16							
	22.5	SM	2B	19.4	27.8												
B-4	2.5	ML	1	48.9				58	33	25							
	7.5	ML	2A	37.5	95.3												
	27.5	SM/ML	4	15.9	78.9												
AB-1	25-27	ML/CL, CH	2A	38.8	97.5		71.1	51	27	24					0.14	0.28	
AB-2/GW-1	7.5	ML	2A	42.6	98.4												
	12.5	ML	2A	27.4				33	22	11							
	17.5	SM	2B		38.8	1											
	22.5	SM	3	20.8	25.1												
AB-4	10-12	SM/ML	2B	29.6	85.2	0.9	70.4										3.58E-07
GW-2	12.5-14	SM	3		30.3	12.5											
TP-1	0-4	ML/SM	Fill	4.5	32.4						133.5	8.4					
	7.5	ML	Fill	5.7	73.5						95.8	25.3					
TP-4	2-4	ML/CL	Fill	20.2	81.5						102.3	20.9					
TP-6	0-2	ML/CL	Fill	3.6	77.2						94.1	18.1					
ATP-2	0-4	SM/GM	Fill	2.9	10.5	58.9					138.9	6.5	147.2	4.7			

Notes:

1. Consolidation C_V is at a vertical stress of 1,000 psf.
2. Modified MDD and OMC for Sample ATP-2 at 0-4 feet was corrected for gravel content.



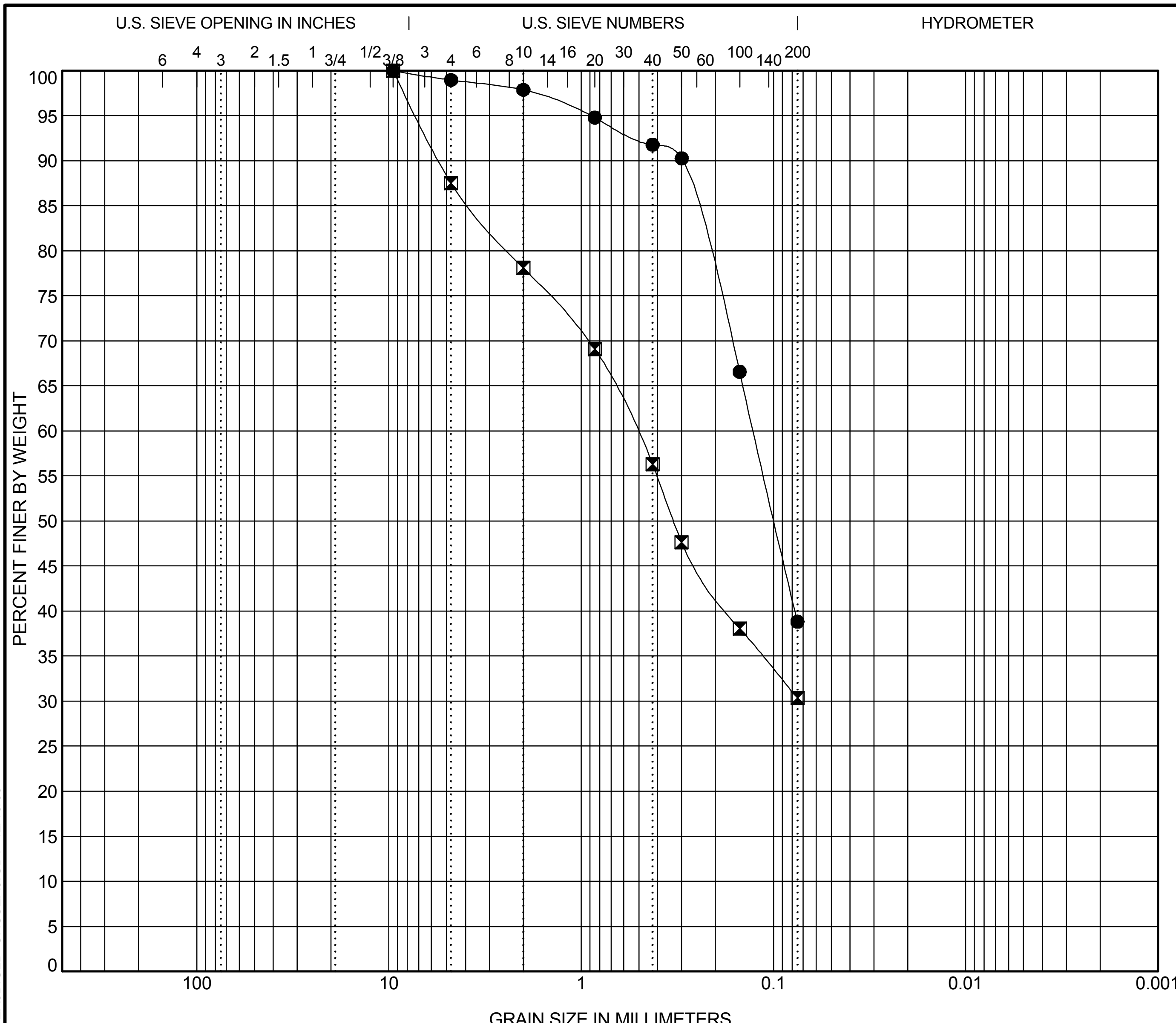
	Specimen Identification		LL	PL	PI	Moisture	Classification
●	**AB-2/GW-1**	**12.5 ft**	**33**	**22**	**11**	**27.4**	**[CL] silty CLAY**
⧗	**B-3**	**7.5 ft**	**41**	**25**	**16**	**44.3**	**[CL] silty CLAY**
▲	**B-4**	**2.5 ft**	**58**	**33**	**25**	**48.9**	**[MH] SILT**

ATTERBERG LIMITS' RESULTS

Project: Fisher Slough
Project Location: Skagit County, Washington
Project Number: 33760911

URS

Figure B-1



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● AB-2/GW-1	17.5 ft.	[SM] silty SAND					
☒ GW-2	12.5 ft.	[SM] silty SAND					

Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● AB-2/GW-1	17.5 ft.	9.5	0.127			1.0	60.2	38.8	
☒ GW-2	12.5 ft.	9.5	0.519			12.5	57.2	30.3	

GRAIN SIZE DISTRIBUTION

Project: Fisher Slough
Project Location: Skagit County, Washington
Project Number: 33760911

Figure B-2

URS

Analytical Resources, Incorporated
Analytical Chemists and Consultants

November 2, 2008

Mr. Suren Balendra, P.E.
URS Corporation
Century Square
1501 – 4th Avenue, Suite 1400
Seattle, WA 98101-1616

RE: Client Project: Fisher Slough
ARI Project: NS66

Dear Mr. Balendra;

The following pages provide the information you requested. Please call me to discuss any questions or comments you may have on the data or its presentation.

Best Regards,

Analytical Resources, Inc.

Harold Benny

Harold Benny
Geotechnical Laboratory Manager
206-695-6246
haroldb@arilabs.com

Enclosures

cc: Files NS66

Analytical Resources, Incorporated
Analytical Chemists and Consultants

Client: URS Corporation	Project No.: NS66
Client Project: Fisher Slough	

Case Narrative

1. Four samples were submitted for testing. They were received on October 3, 2008, in good condition.
2. The moisture content was measured according to ASTM D2216.
3. The samples were extruded and visually examined. Samples for consolidation and permeability were taken and set up. Soil for the other tests were taken from the trimmings and unused portions of the tube.
4. The consolidation testing was conducted using a GeoTAC Sigma-1 automated testing system and associated software. The samples were trimmed into a test ring and placed in the loading device. The loads were applied according to the test schedule, and the next load was applied after reaching 100 percent of primary consolidation, plus a delay factor based on the time to reach this point, or after 4 hours, whichever was less. For some loads the automated system had trouble calculating the end of primary consolidation. On these loads, the data was downloaded and manual calculations were performed based on ASTM D2435, method B.
5. The Atterberg limits were conducted according to ASTM D4318.
6. Flexible wall hydraulic conductivity tests were run according to ASTM D5082. The samples had low conductivity.
7. The grain size analysis was run according to ASTM D422. Only the sieve portion of the analysis was run.
8. The percent fines were measured according to ASTM D1140.
9. The data is provided in summary tables and plots.
10. There were no other noted anomalies in the samples or methods on this project.

Approved by: [signature] Date: 11/2/08
Title: Geotechnical Division Manager

Par 866 ~~4~~95 5288

Chain of Custody Record & Laboratory Analysis Request

Analytical Resources, Incorporated
Analytical Chemists and Consultants
4611 South 134th Place, Suite 100
Tukwila WA 98168
206-695-6200 206-695-6201 (fax)

ARI Assigned Number: NS66	Turn-around Requested:	Date: 10/2/08	
ARI Client Company: URS, Seattle	Phone: 206 438 2333	Page: 1	of 1
Client Contact: Suren Balendra		No. of Coolers:	Cooler Temps:
Client Project Name: Fisher Slough			
Client Project #: 33760911	Samplers:		

Sample ID	Date	Time	Matrix	No. Containers	Consolidation ASTM D2435	Permeability	Torvane Shear	Atterberg Limit ASTM D4318	# 200	Sieve			Notes/Comments
B-1 @ 29-31'	9/29/08		Soil	1	X		X	X	X				
AB-1 @ 25-27'	9/29/08		"	1	X		X	X	X				
AB-4 @ 10'-12'	9/30/08		"	1		X				X			
B-2 @ 12.5-14.5'	9/25/08		"	1	X	X	X	X	X				

Comments/Special Instructions	Relinquished by:	Received by:	Relinquished by:	Received by:
sea shell encountered in most of the shelbys.	(Signature) B Suren	(Signature) [signature]	(Signature)	(Signature)
	Printed Name: Suren Balendra	Printed Name: Gook Kasanda	Printed Name:	Printed Name:
	Company: URS, Seattle	Company: ARI	Company:	Company:
	Date & Time: 10/2/08	Date & Time: 10/03/08 9:54	Date & Time:	Date & Time:

Limits of Liability: *ARI will perform all requested services in accordance with appropriate methodology following ARI Standard Operating Procedures and the ARI Quality Assurance Program. This program meets standards for the industry. The total liability of ARI, its officers, agents, employees, or successors, arising out of or in connection with the requested services, shall not exceed the Invoiced amount for said services. The acceptance by the client of a proposal for services by ARI release ARI from any liability in excess thereof, not withstanding any provision to the contrary in any contract, purchase order or co-signed agreement between ARI and the Client.*

Sample Retention Policy: All samples submitted to ARI will be appropriately discarded no sooner than 90 days after receipt or 60 days after submission of hardcopy data, whichever is longer, unless alemate retention schedules have been established by work-order or contract.

URS Corporation

Fisher Slough

Sample Identification	Percent Fines (-#200 Sieve)
B-1 @ 29-31	93.1
AB-1 @ 25-27	97.5
B-2 @ 12.5-14.5	53.9

URS Corporation
Fisher Slough

Percent Finer Than Indicated Size, By ASTM D422

Sample ID	Depth (ft)	Moisture Content (%)	3"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#10	#20	#40	#60	#100	#200
AB-4	10'-12'	29.63	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.1	96.9	94.5	92.0	90.1	88.3	85.2

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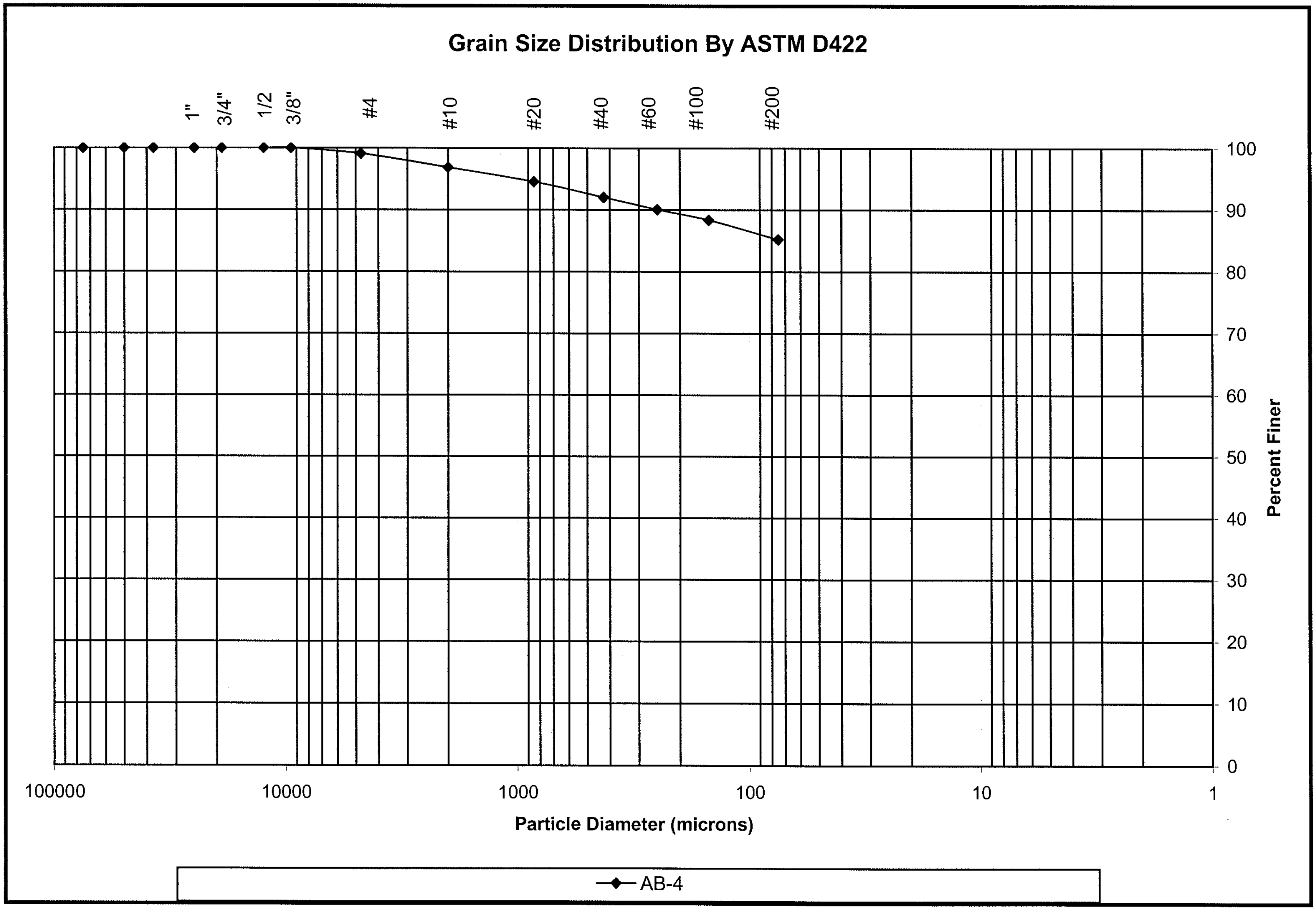
Percent Retained in Each Size Fraction, By ASTM D422

Sieve Size (microns)	3-2"	2-1.5"	1.5-1"	1-3/4"	3/4-1/2"	1/2-3/8"	3/8-#4	4750-2000	2000-850	850-425	425-250	250-150	150-75	<75
AB-4	0.0	0.0	0.0	0.0	0.0	0.0	0.9	2.2	2.3	2.5	2.0	1.7	3.2	85.2

NS66


Grain Size Distribution By ASTM D422
1"
3/4"
1/2
3/8"
#4
#10
#20
#40
#60
#100
#200
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100000
10000
1000
100
10
1
Particle Diameter (microns)
AB-4

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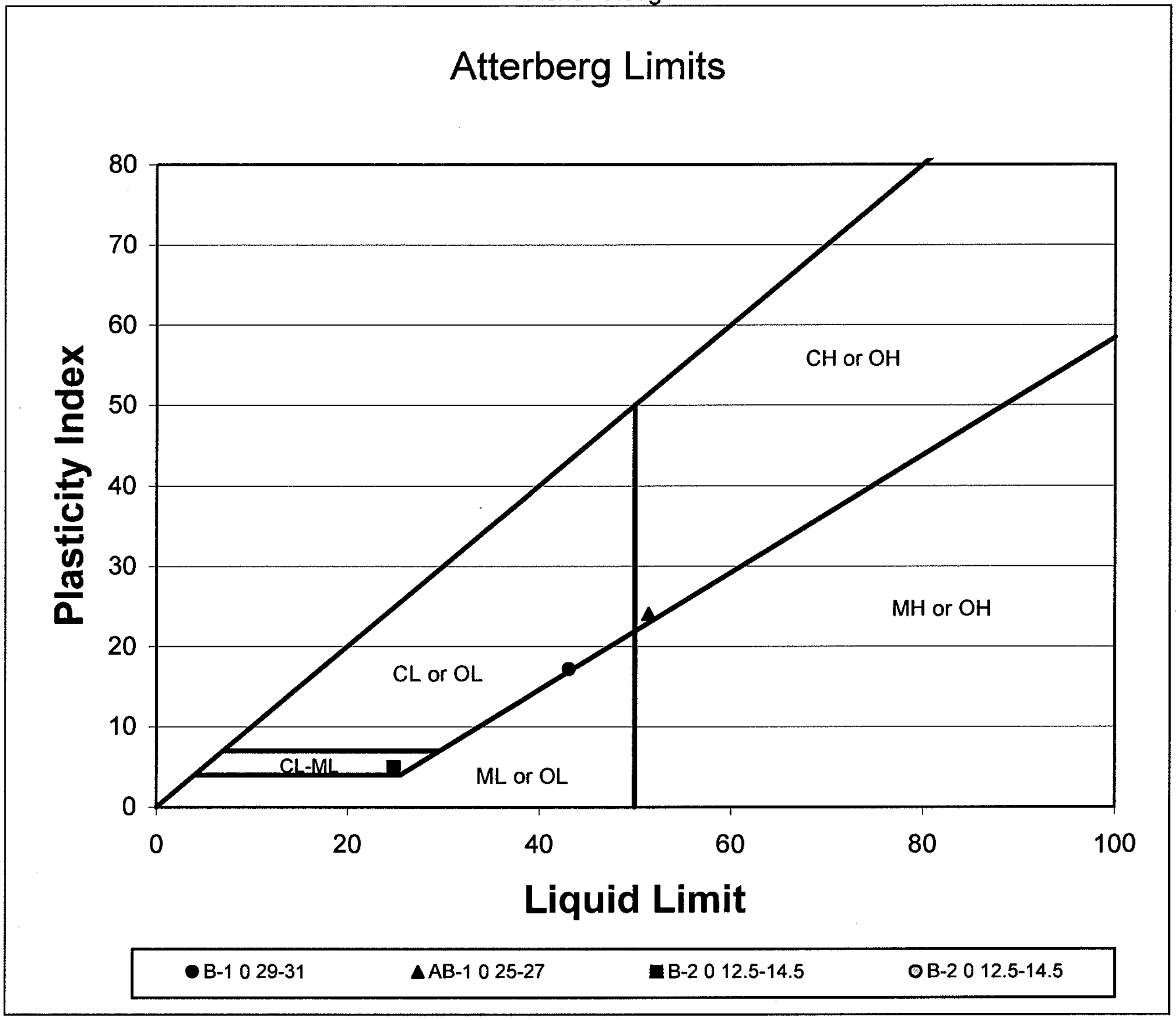

Boring Number	Sample Number	Depth (ft)	As-Received Moisture Content	Plasticity Index	Liquid Limit	Plastic Limit	USCS
B-1	0	29-31	30.59	17.2	43.2	26.0	CL
AB-1	0	25-27	38.81	24.0	51.4	27.4	CH
B-2	0	12.5-14.5	33.33	4.9	24.8	19.9	CL

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Test Results for Flexible Wall Hydraulic Conductivity Testing

Sample Identification	Depth (ft)	As Received Sample Parameters				After Test Sample Parameters				Gradient (h/l)	Hydraulic Conductivity (cm/s)
		Wet Density (lbs/ft^3)	Total Porosity	Saturation	Moisture Content (%)	Wet Density (lbs/ft^3)	Total Porosity	Saturation	Moisture Content (%)		
Sample AB-4	10-12	100.6	0.574	0.842	42.8	124.2	0.435	1.131	32.8	1.82	3.58E-07
Sample B-2	12.5-14.5	108.6	0.514	0.879	35.1	112.4	0.488	0.911	32.8	1.76	3.61E-07

Notes:

1. The samples were tested in accordance with ASTM D-5084.
2. The tests were performed using tap water for the permeant.
3. The porosity and the saturation were calculated using an assumed specific gravity value of 2.65.

Sample Description and Dimensions

Sample ID	Depth (ft)	Visual Description	Confining Pressure (psi)	Initial Average Length (cm)	Initial Average Diameter (cm)	Final Average Length (cm)	Final Average Diameter (cm)
Sample AB-4	10-12	Silty Clay	5.0	8.48	7.56	8.08	6.72
Sample B-2	12.5-14.5	Silty Clay	5.0	11.33	7.36	10.62	7.41

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Moisture and Density of Consolidation Samples

Sample ID	Wet Density (pcf)	Moisture Content (%)	Dry Density (pcf)
B-1 @ 29-31 ft	107.0	30.6	81.9
AB-1 @ 25-27 ft	98.7	38.8	71.1
B-2 @ 12.5-14.5 ft	106.3	33.3	79.7

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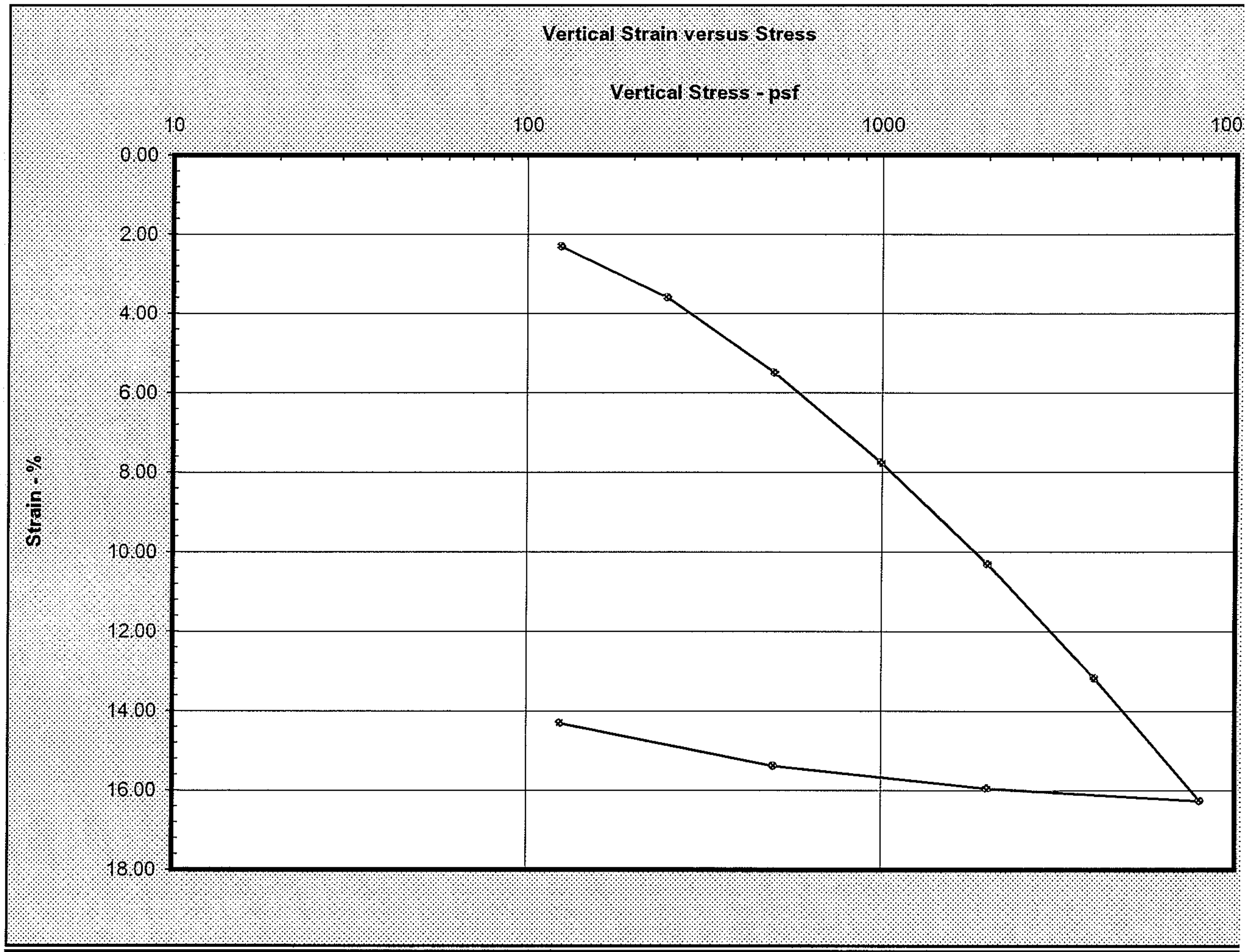
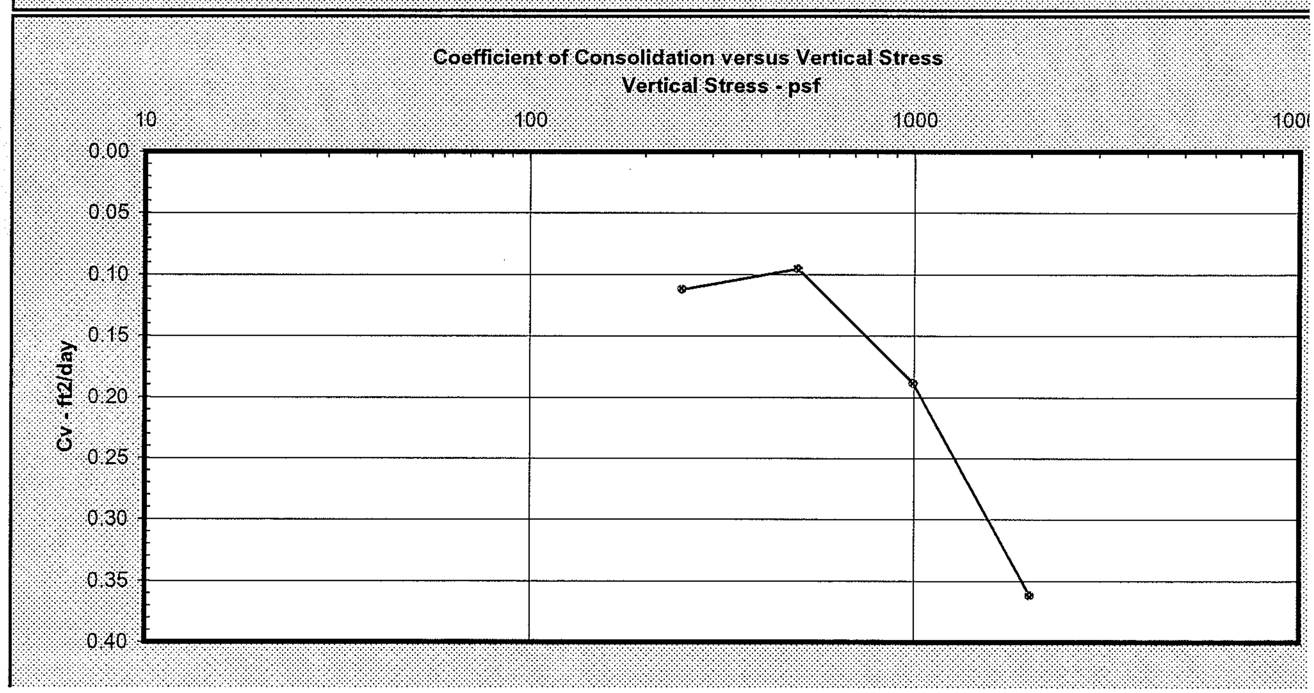
B-1 @ 29'-31'

Step No.	Vertical Stress (psf)	Machine Deflections (in.)	H_0 (in) 0.900 S_{100} (in.)	H_{100} (in.)	Vertical Strain (%)	H_{50} (in.)	t_{50} (min.)	c_v (ft^2/day)
1	100	0.0000						#N/A
2	125	0.0000	0.0209	0.8791	2.32			#N/A
3	250	0.0002	0.0086	0.8707	3.61	0.8750	3.34	0.11
4	500	0.0006	0.0168	0.8511	5.52	0.8595	3.78	0.10
5	1000	0.0016	0.0179	0.8334	7.79	0.8424	1.85	0.19
6	2000	0.0033	0.0218	0.8098	10.33	0.8207	0.92	0.36
7	4000	0.0050	0.0275	0.7813	13.19			#N/A
8	8000	0.0077	0.0305	0.7534	16.28			#N/A
9	2000	0.0036	-0.0068	0.7563	15.97			#N/A
10	500	0.0010	-0.0073	0.7610	15.40	0.7573	0.56	0.51
11	125	0.0000	-0.0107	0.7711	14.33			#N/A

URS Corporation

Fisher Slough
B-1 @ 29-31





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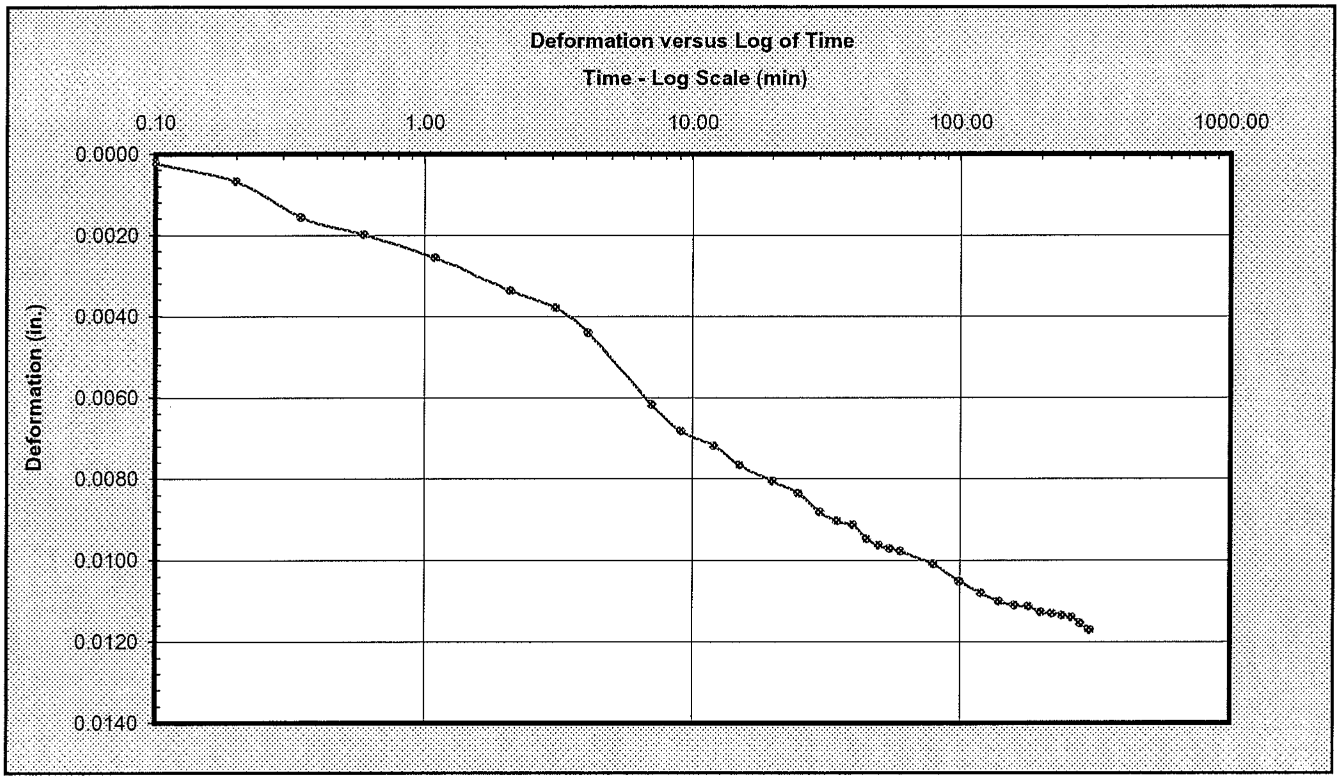
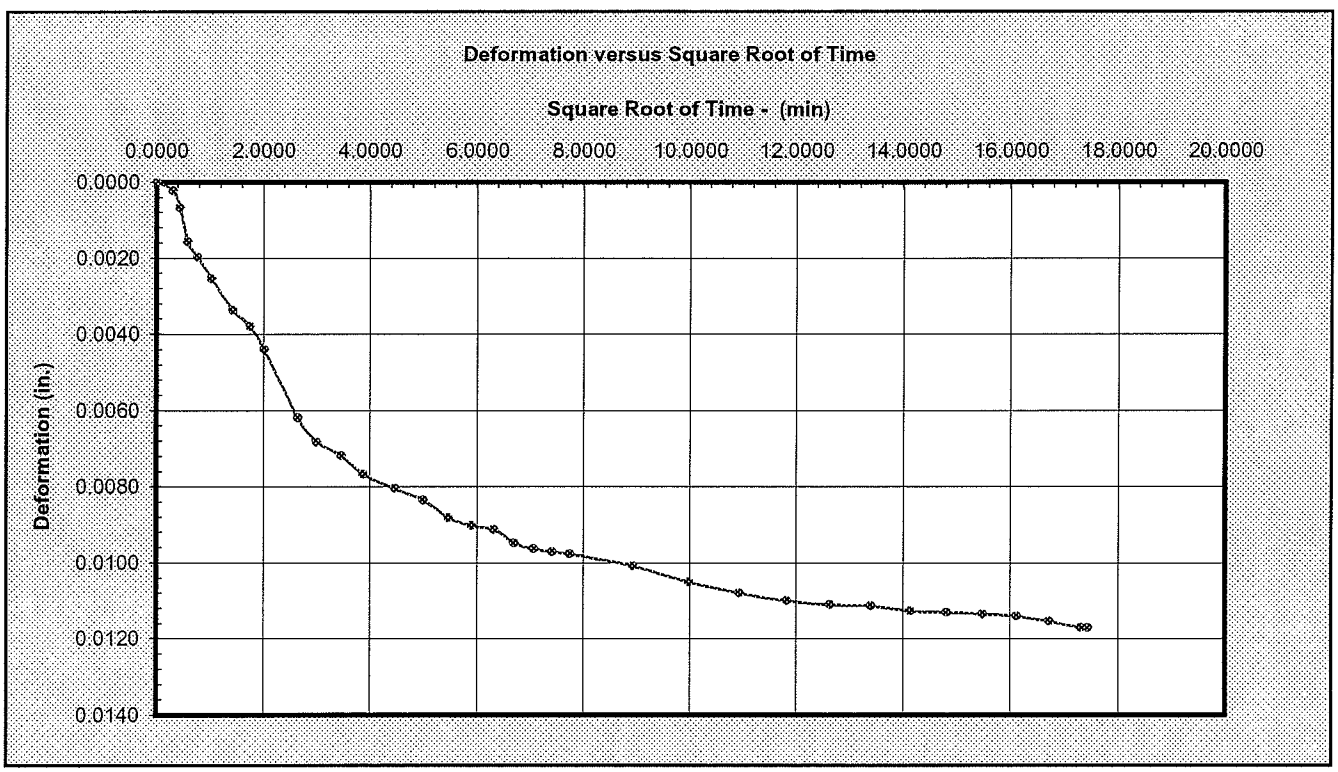
Fisher Slough
B-1 @ 29-31
250 psf Load





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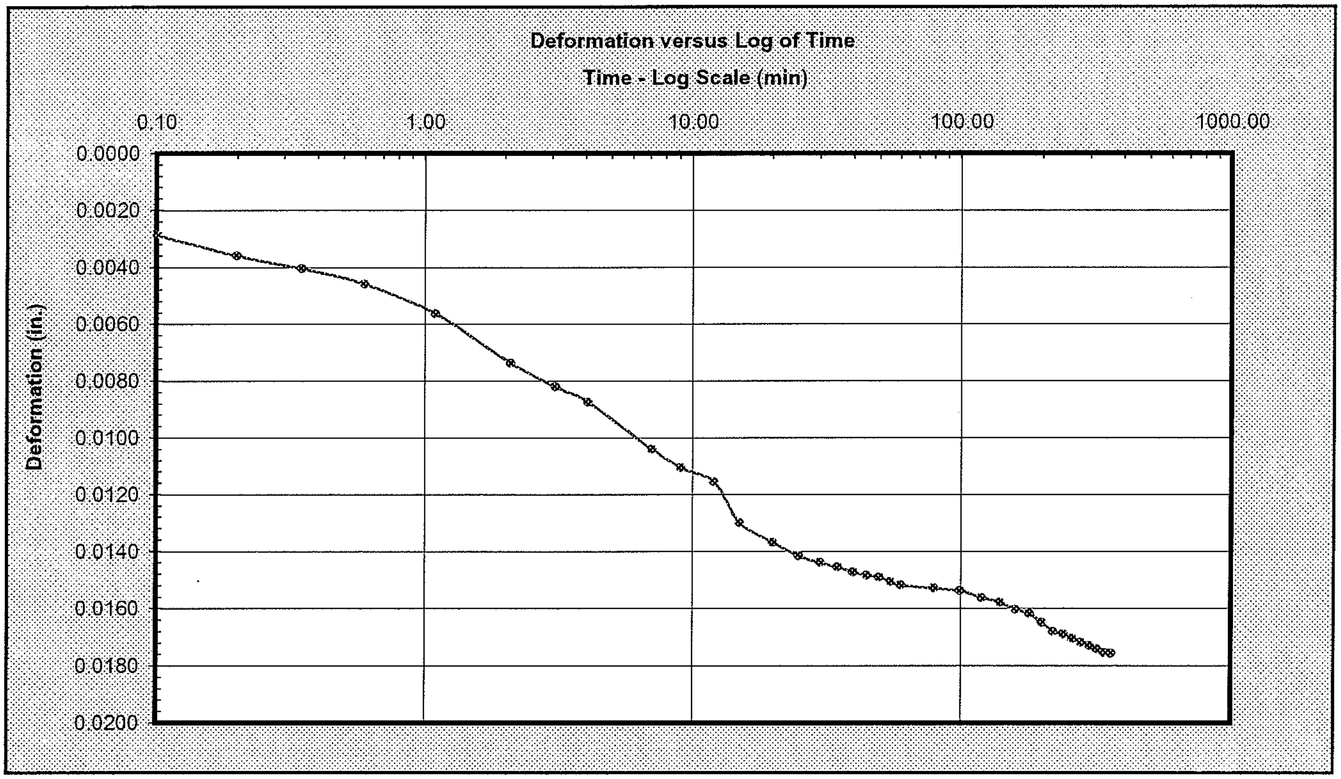
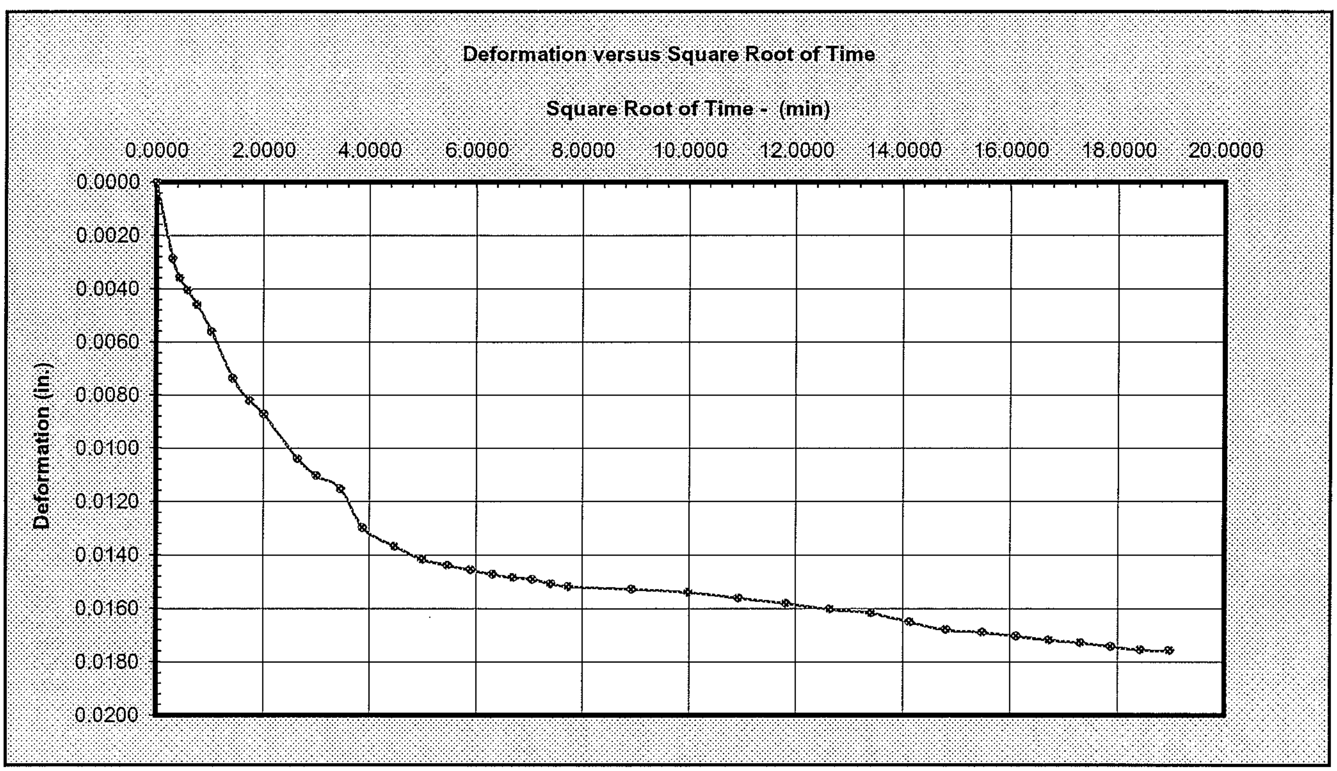
Fisher Slough
B-1 @ 29-31
500 psf Load





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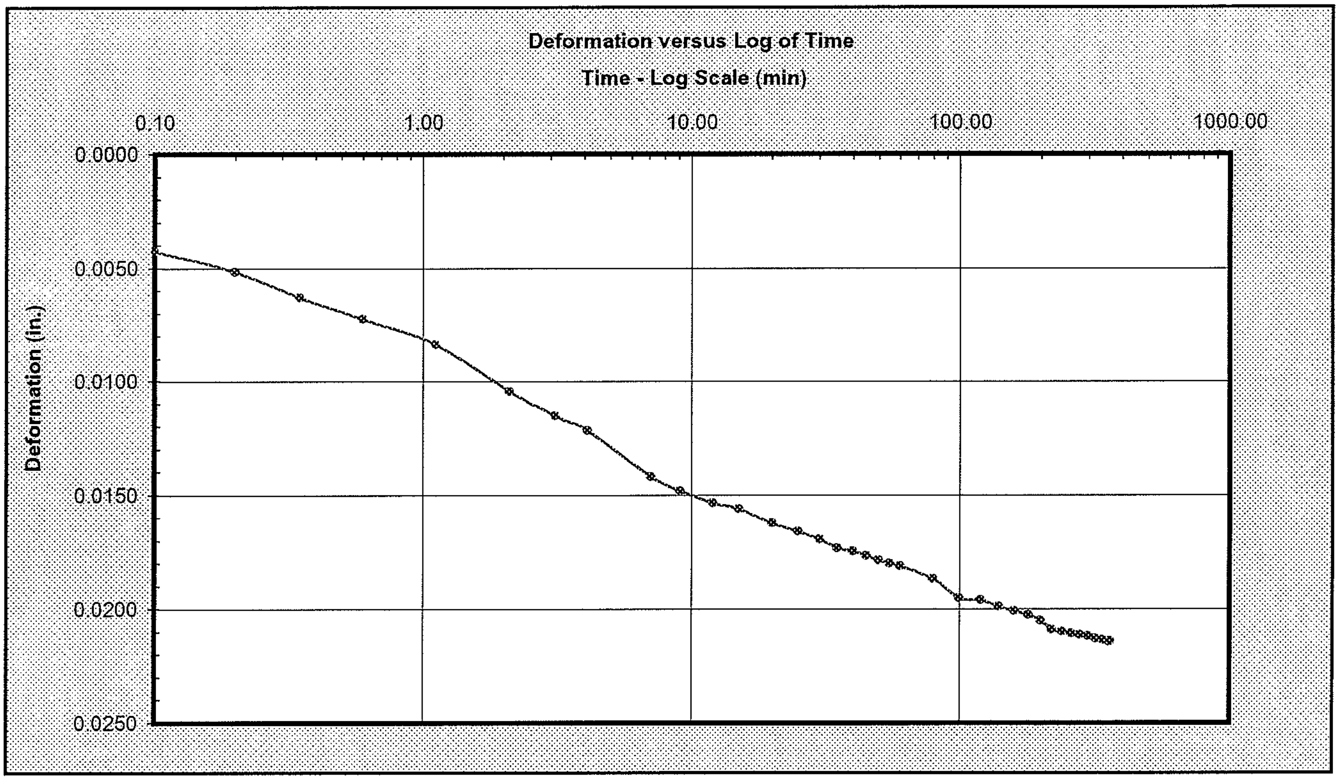
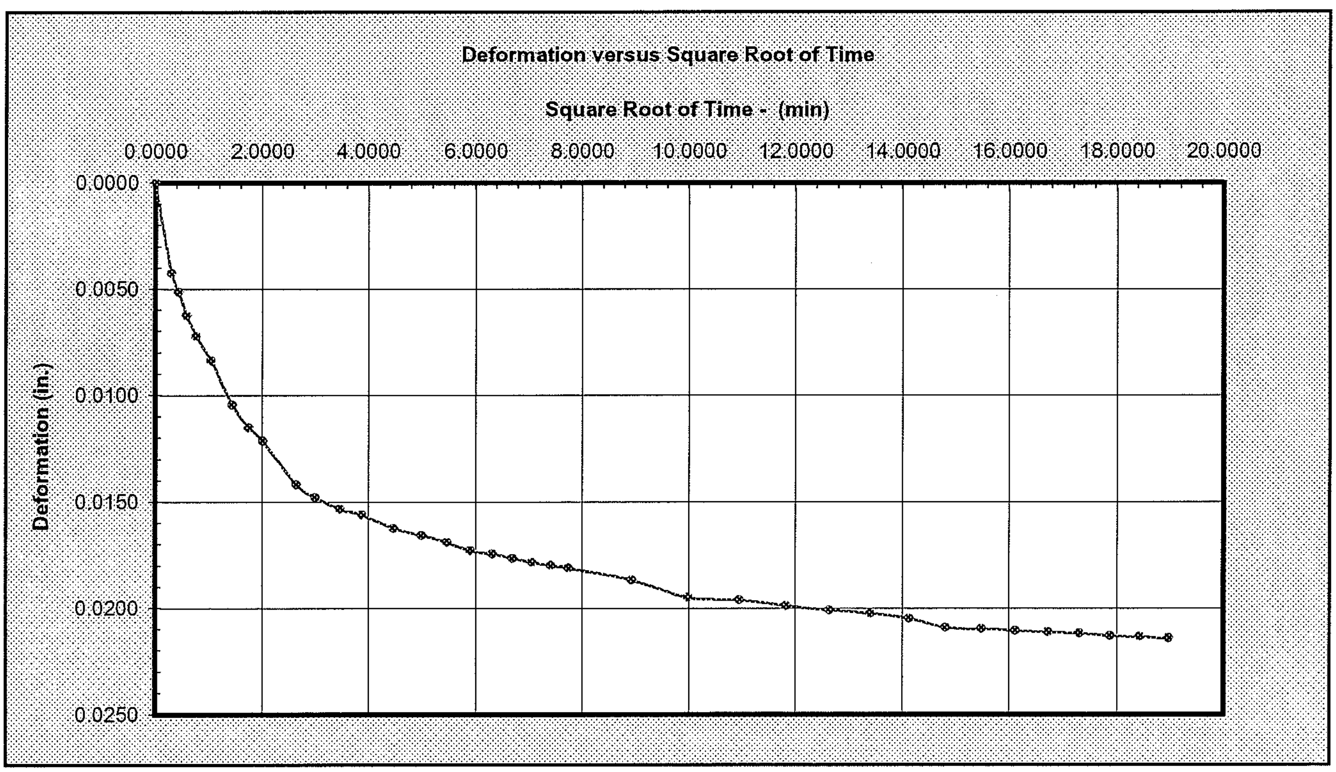
Fisher Slough
B-1 @ 29-31
1,000 psf Load





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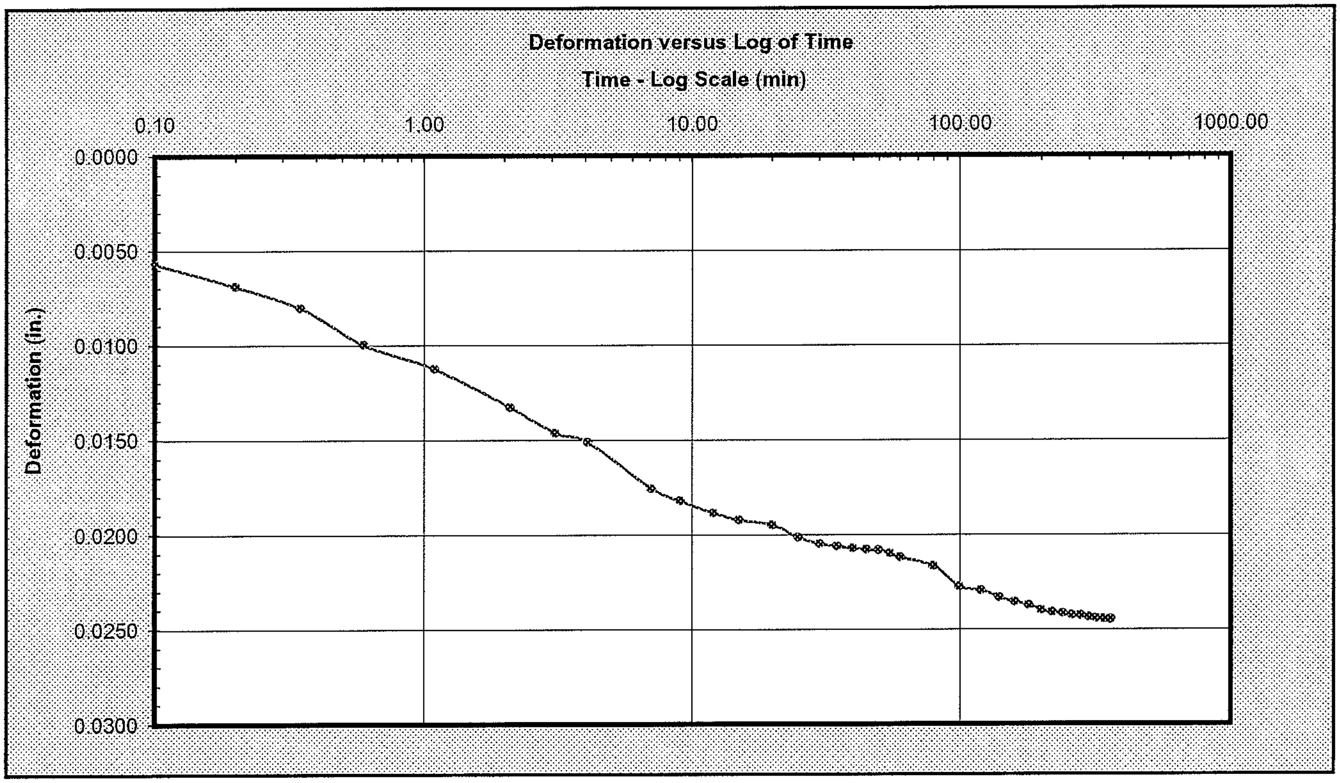
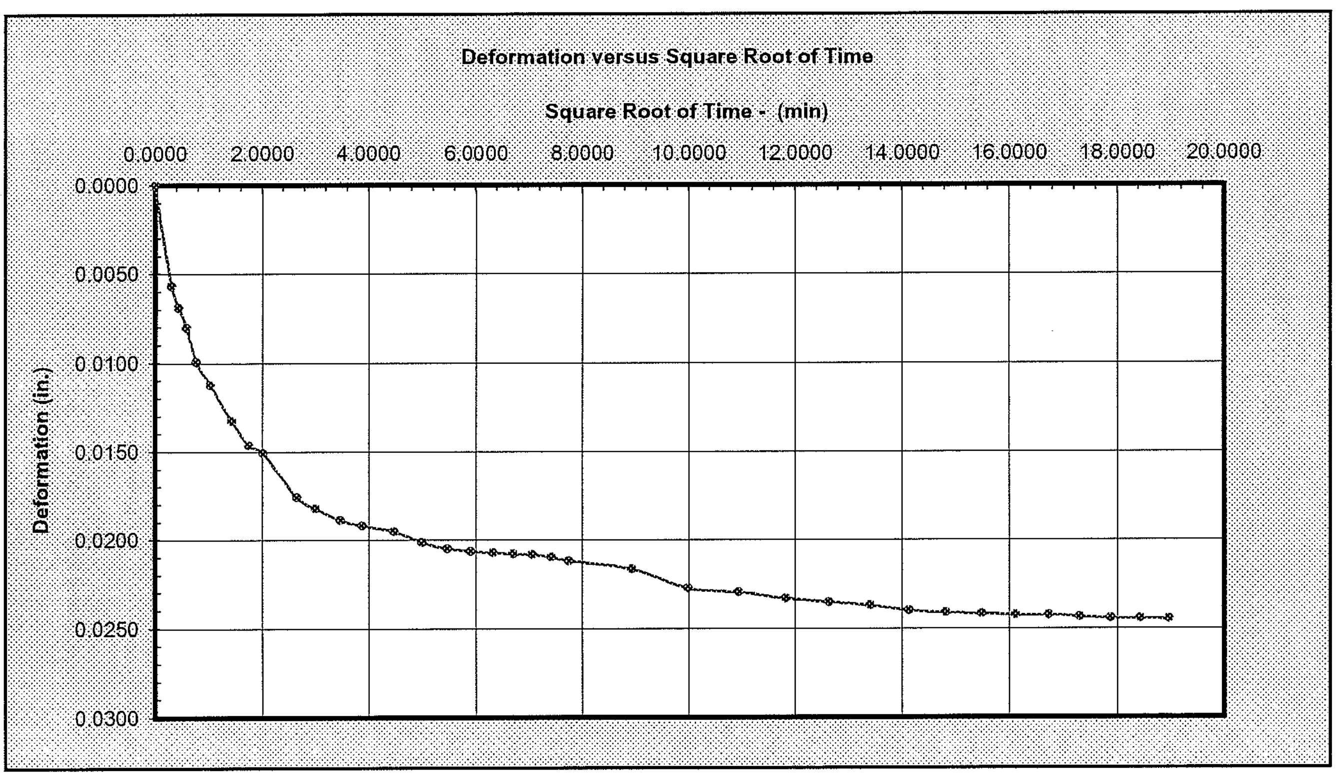
Fisher Slough
B-1 @ 29-31
2,000 psf Load





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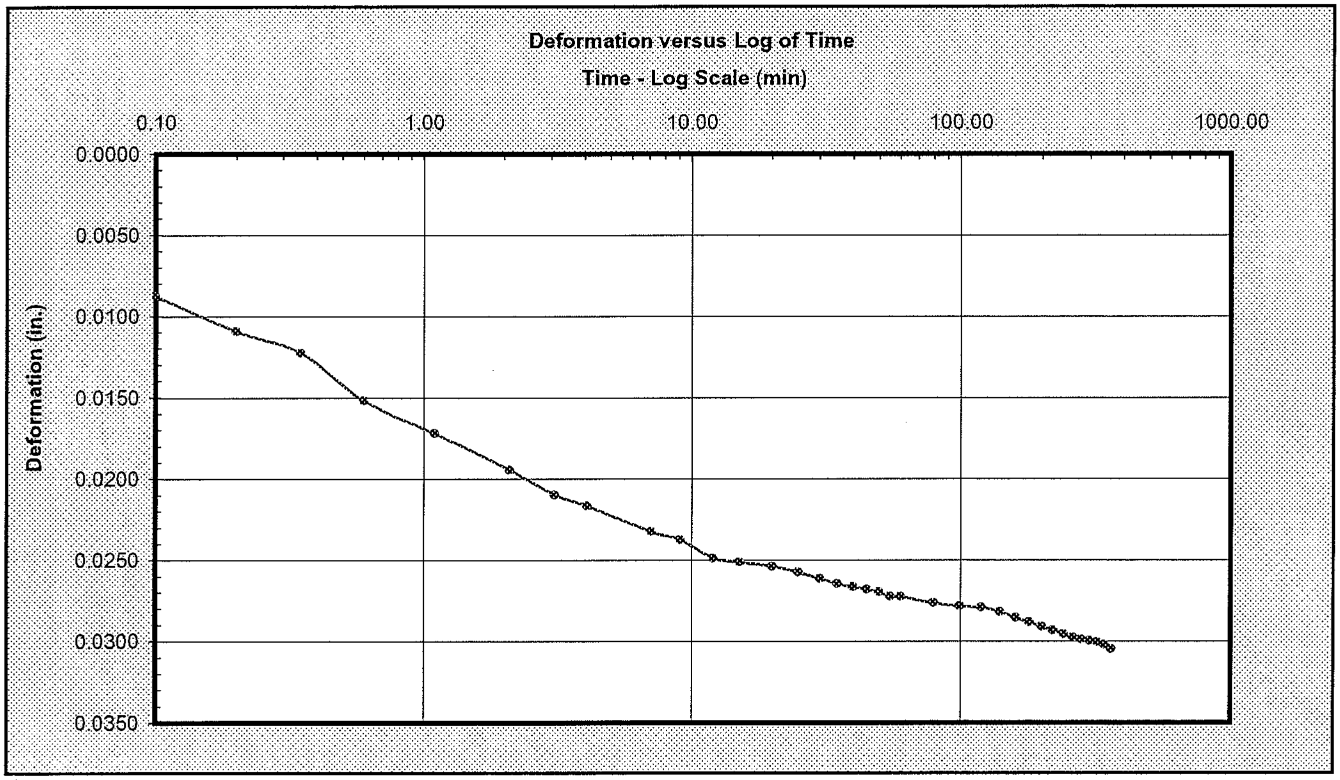
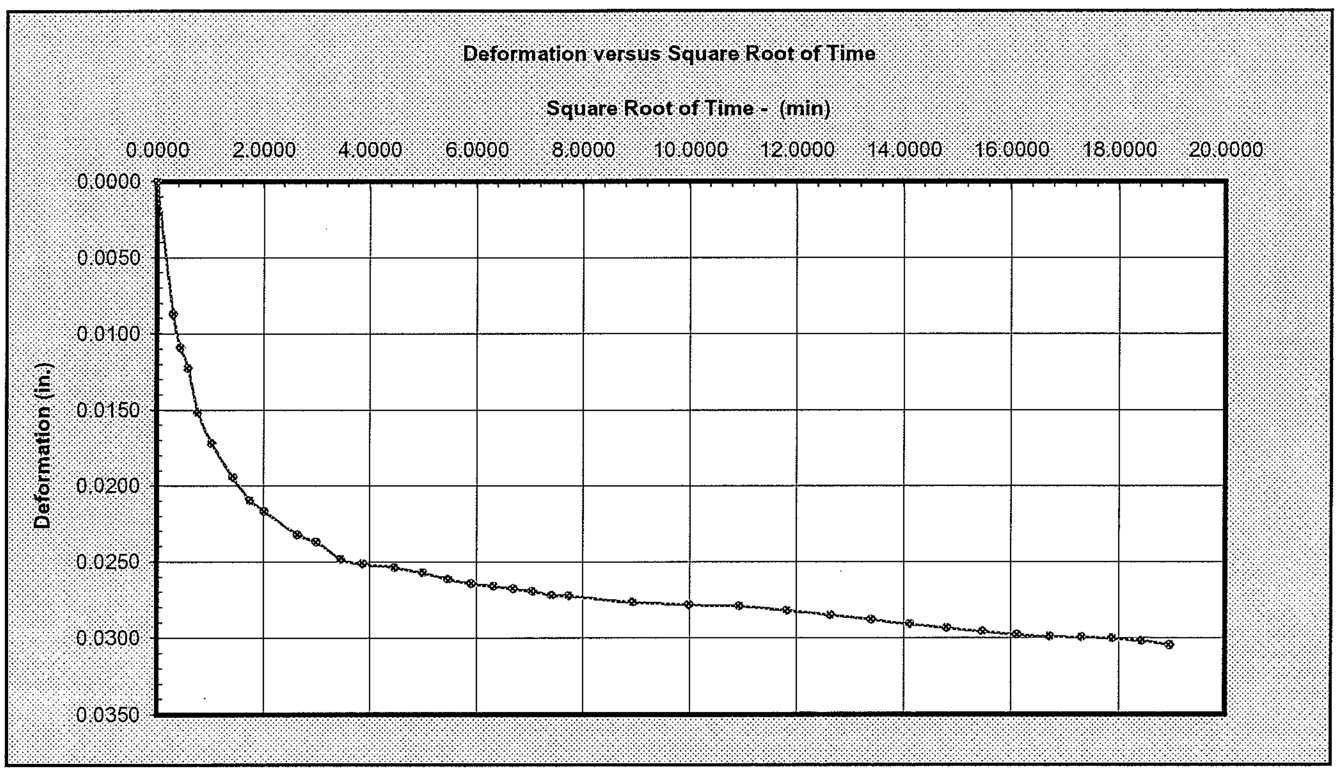
Fisher Slough
B-1 @ 29-31
8,000 psf Load





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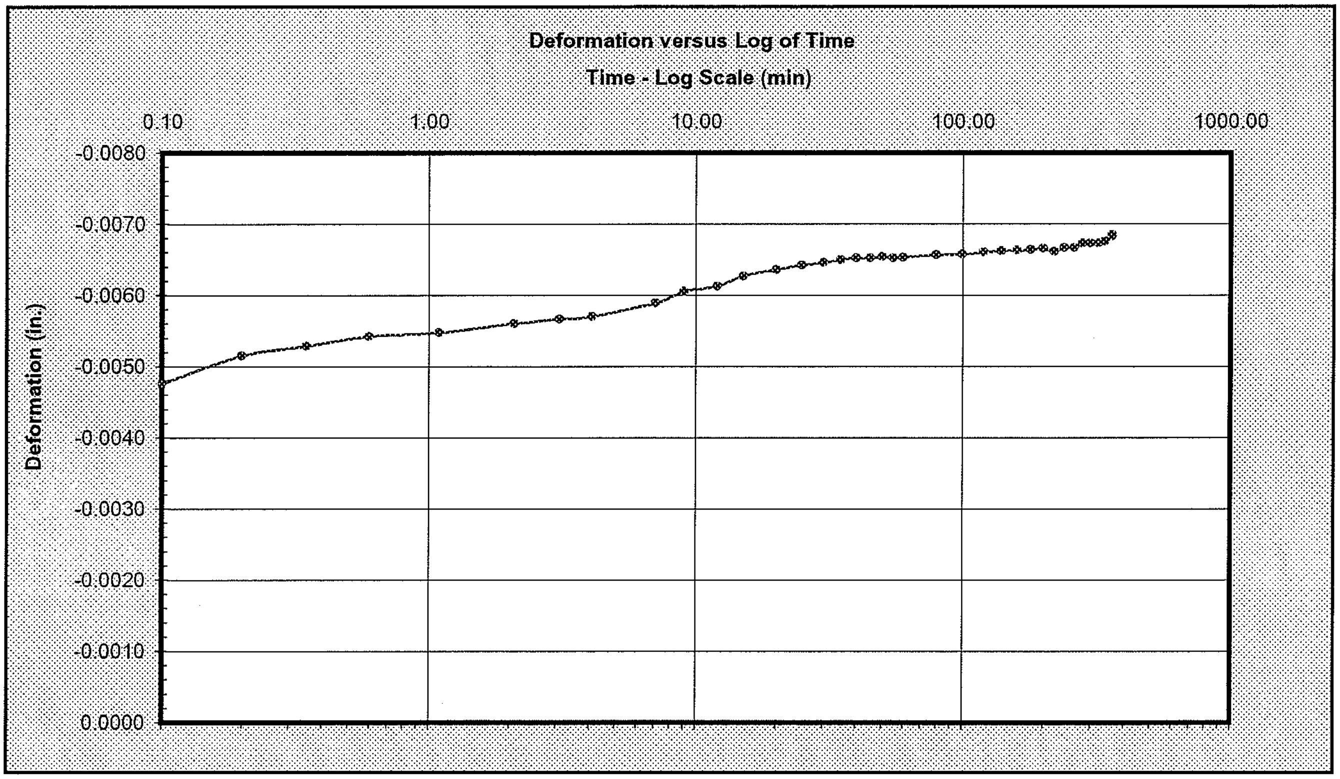
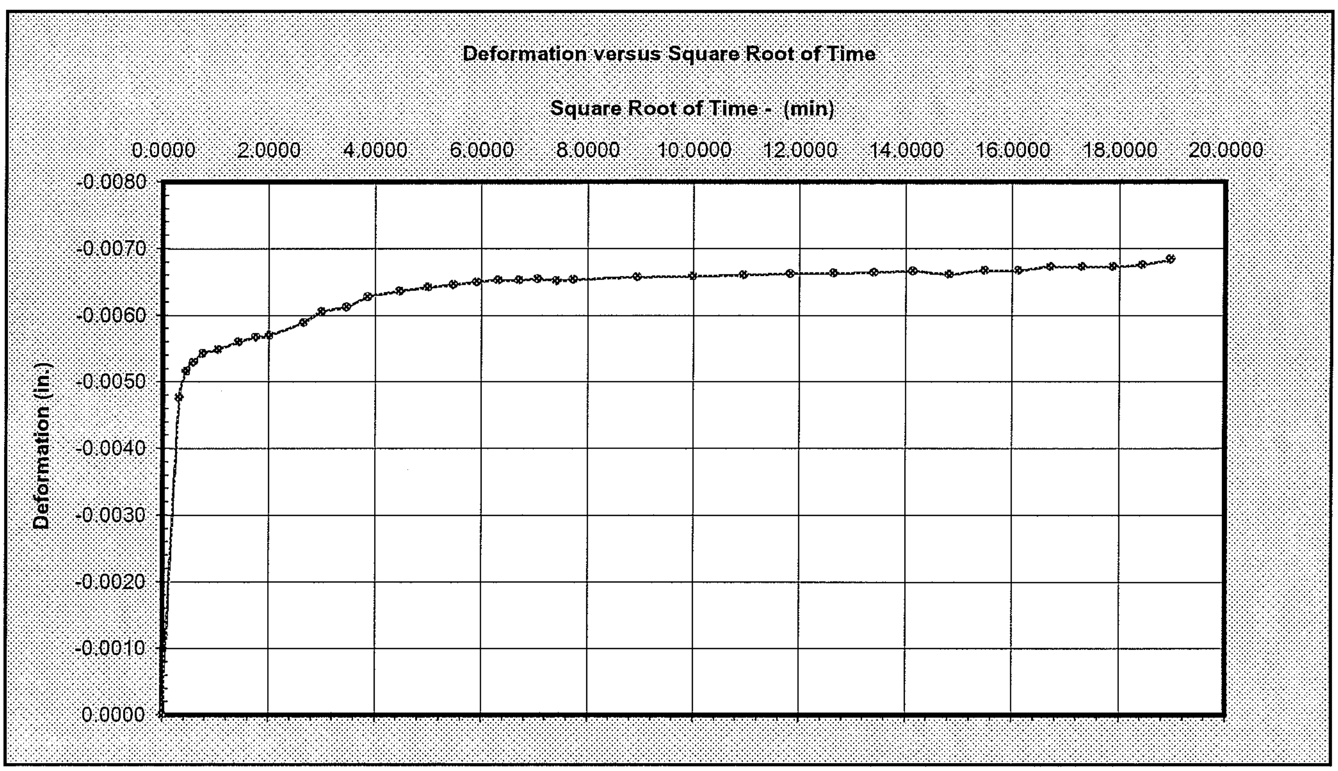
Fisher Slough
B-1 @ 29-31
2,000 psf Load (rebound)





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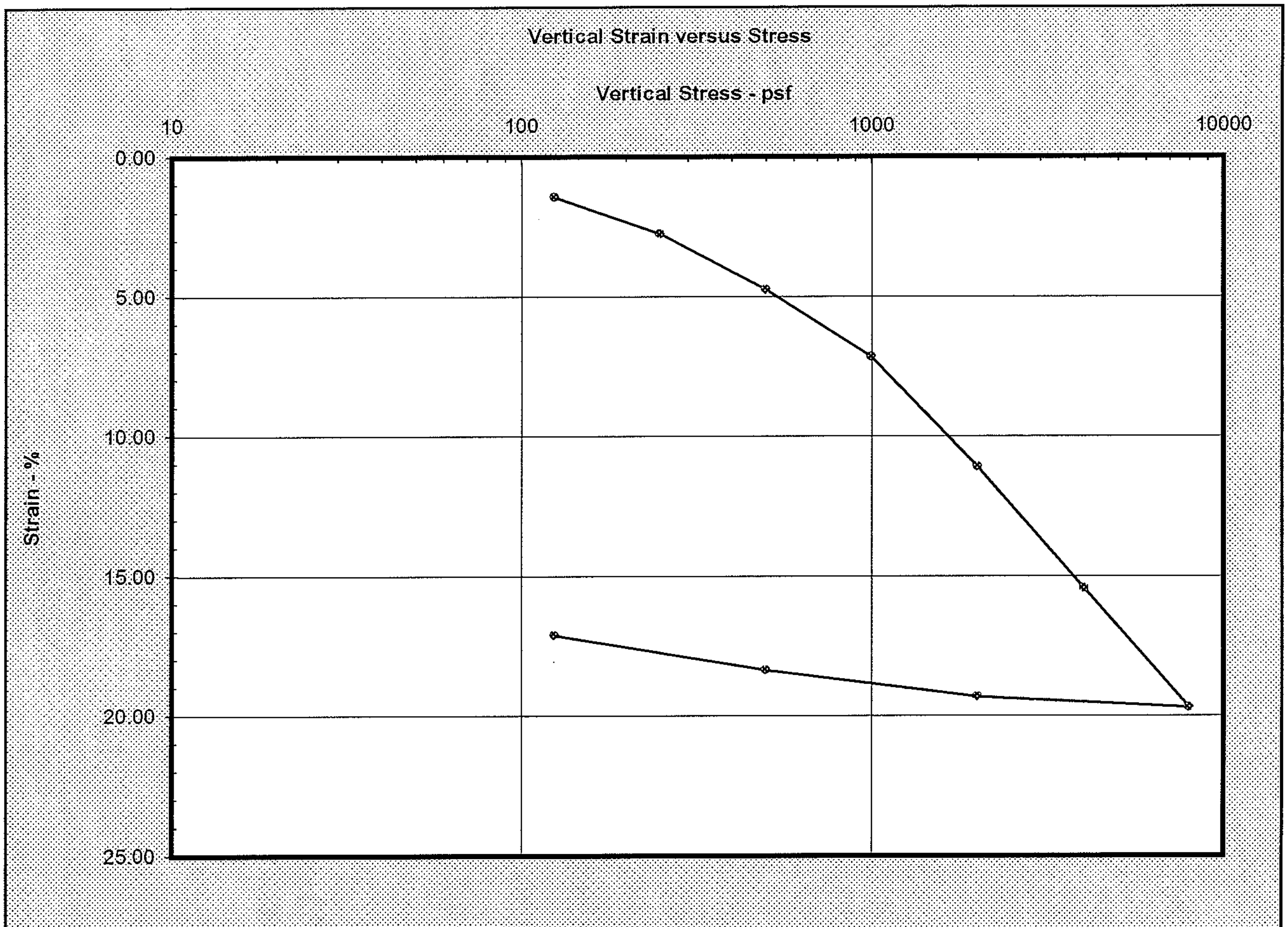
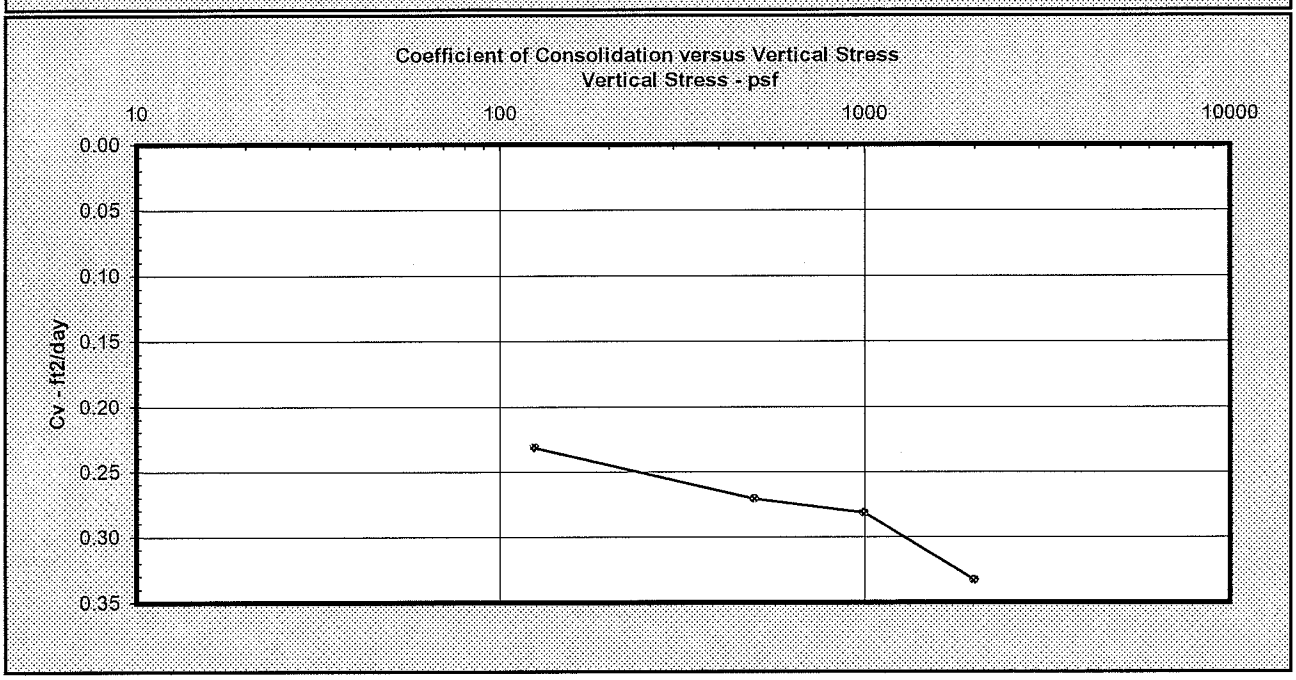
Fisher Slough
AB-1 @ 25-27

Step No.	Vertical Stress (psf)	Machine Deflections (in.)	H_0 (in) S_{100} (in.)	0.900 H_{100} (in.)	Vertical Strain (%)	H_{50} (in.)	t_{50} (min.)	c_v (ft^2/day)
1	100	0.0000						#N/A
2	125	0.0000	0.0115	0.8887	1.45	0.8944	1.70	0.23
3	250	0.0002	0.0121	0.8750	2.78			#N/A
4	500	0.0006	0.0116	0.8637	4.78	0.8695	1.37	0.27
5	1000	0.0016	0.0229	0.8351	7.19	0.8465	1.25	0.28
6	2000	0.0033	0.0290	0.8079	11.12	0.8224	1.00	0.33
7	4000	0.0050	0.0408	0.7609	15.46			#N/A
8	8000	0.0077	0.0411	0.7224	19.73			#N/A
9	2000	0.0036	-0.0075	0.7259	19.35			#N/A
10	500	0.0010	-0.0113	0.7346	18.38			#N/A
11	125	0.0000	-0.0098	0.7433	17.14	0.7384	3.17	0.08

URS Corporation

Fisher Slough
AB-1 @ 25-27





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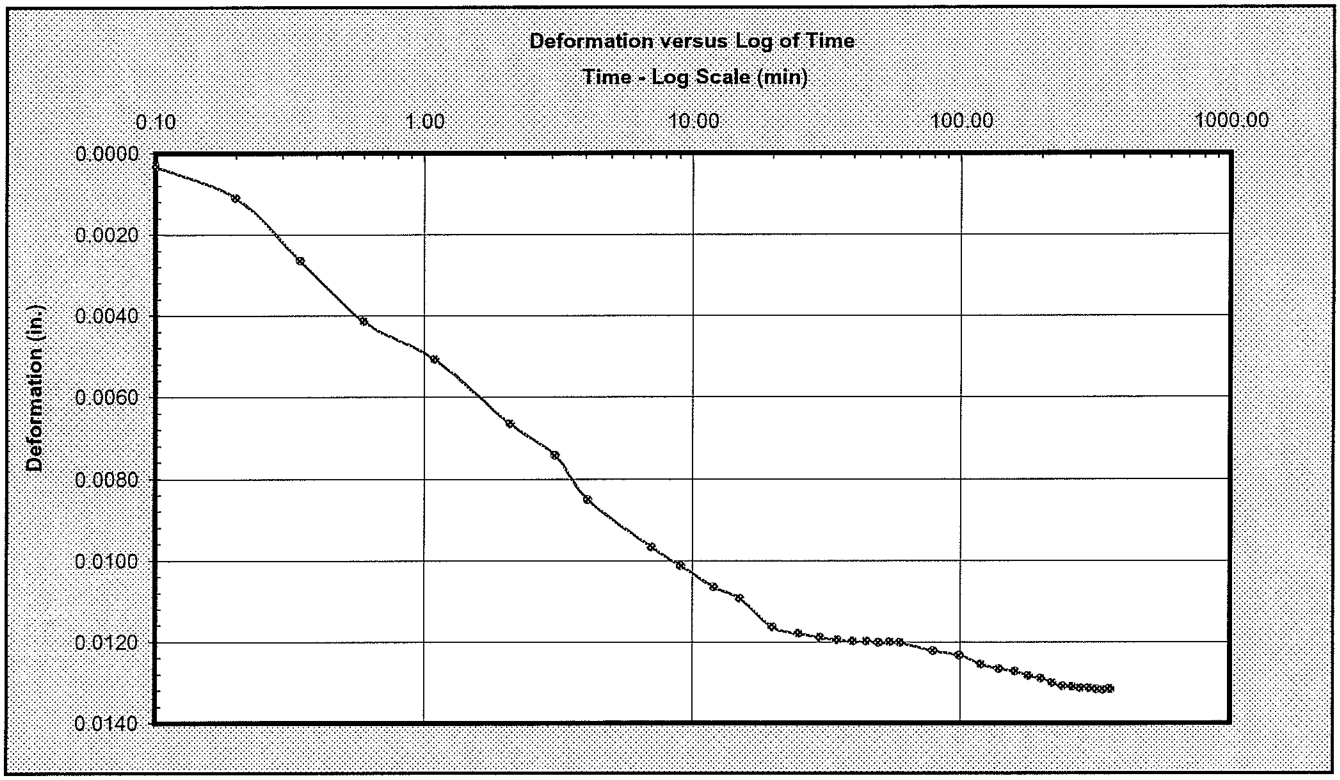
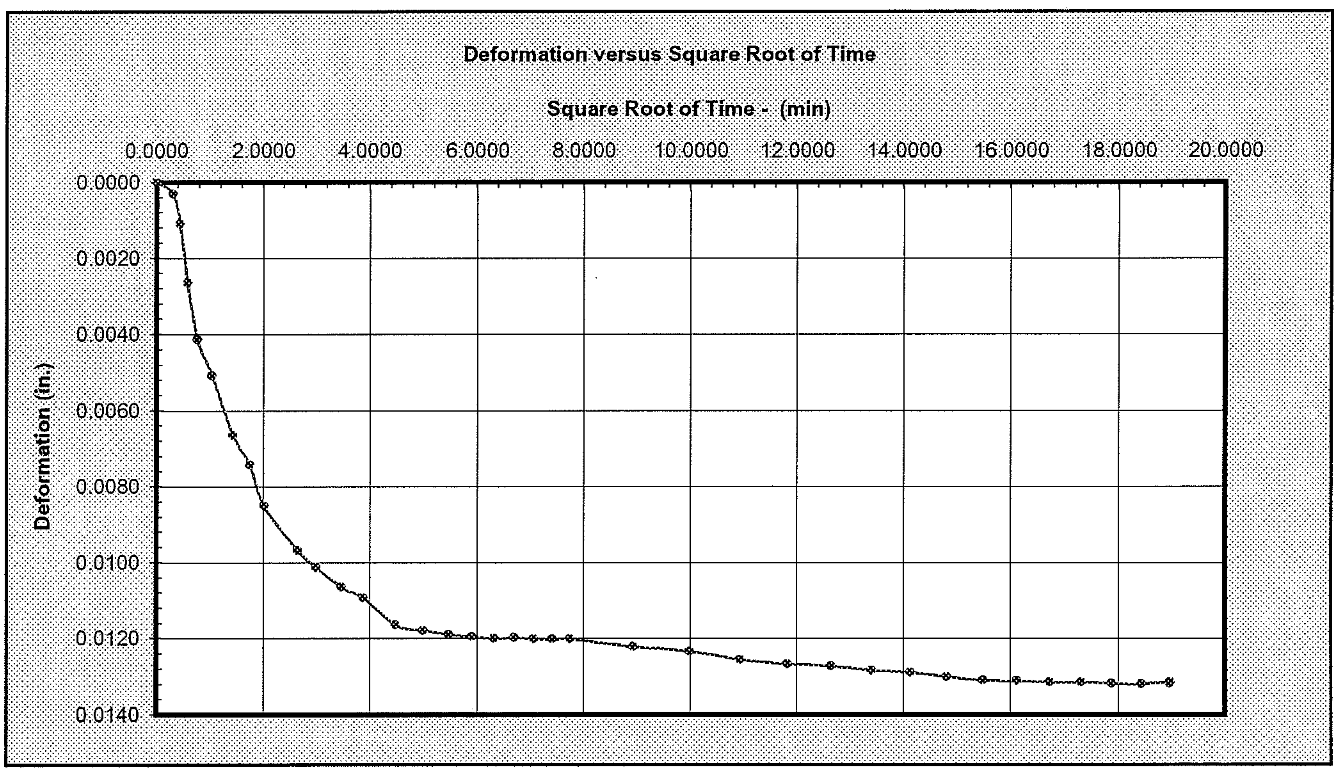
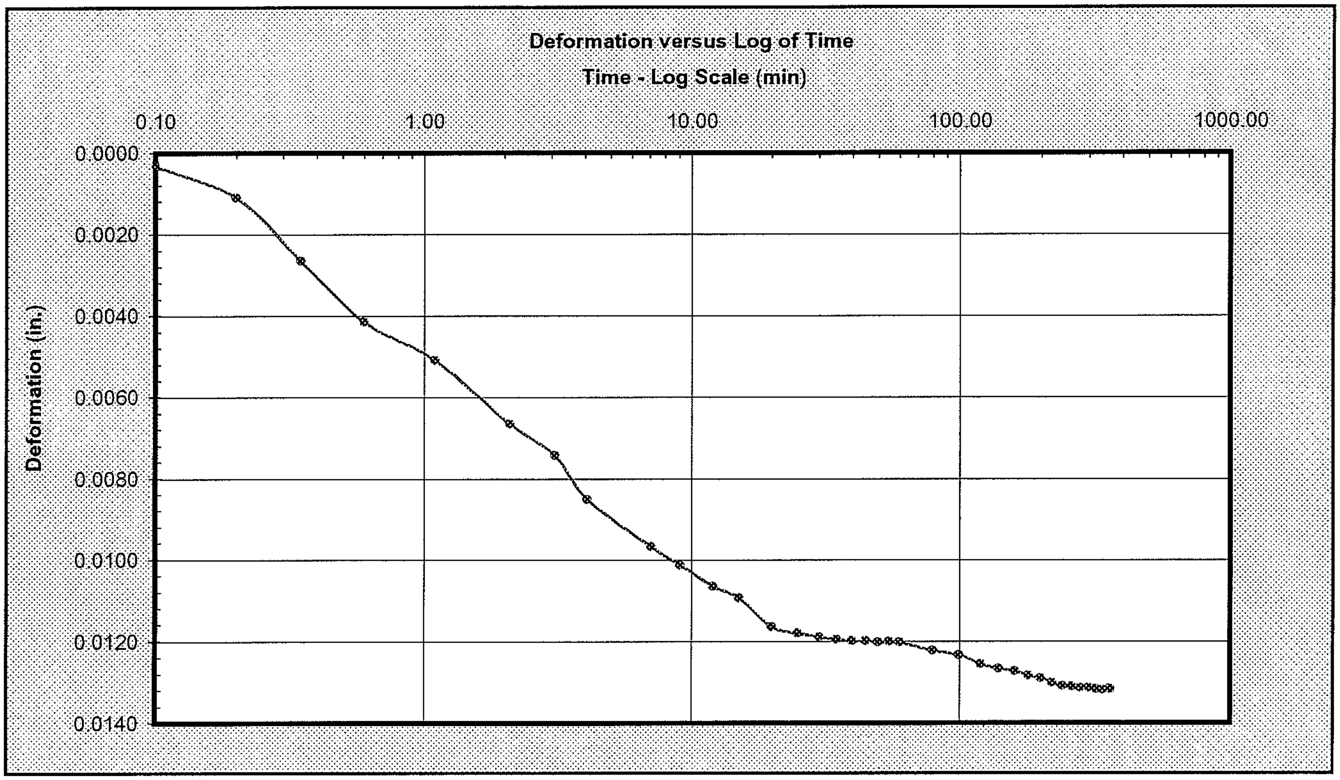
Fisher Slough
AB-1 @ 25-27
125 psf Load

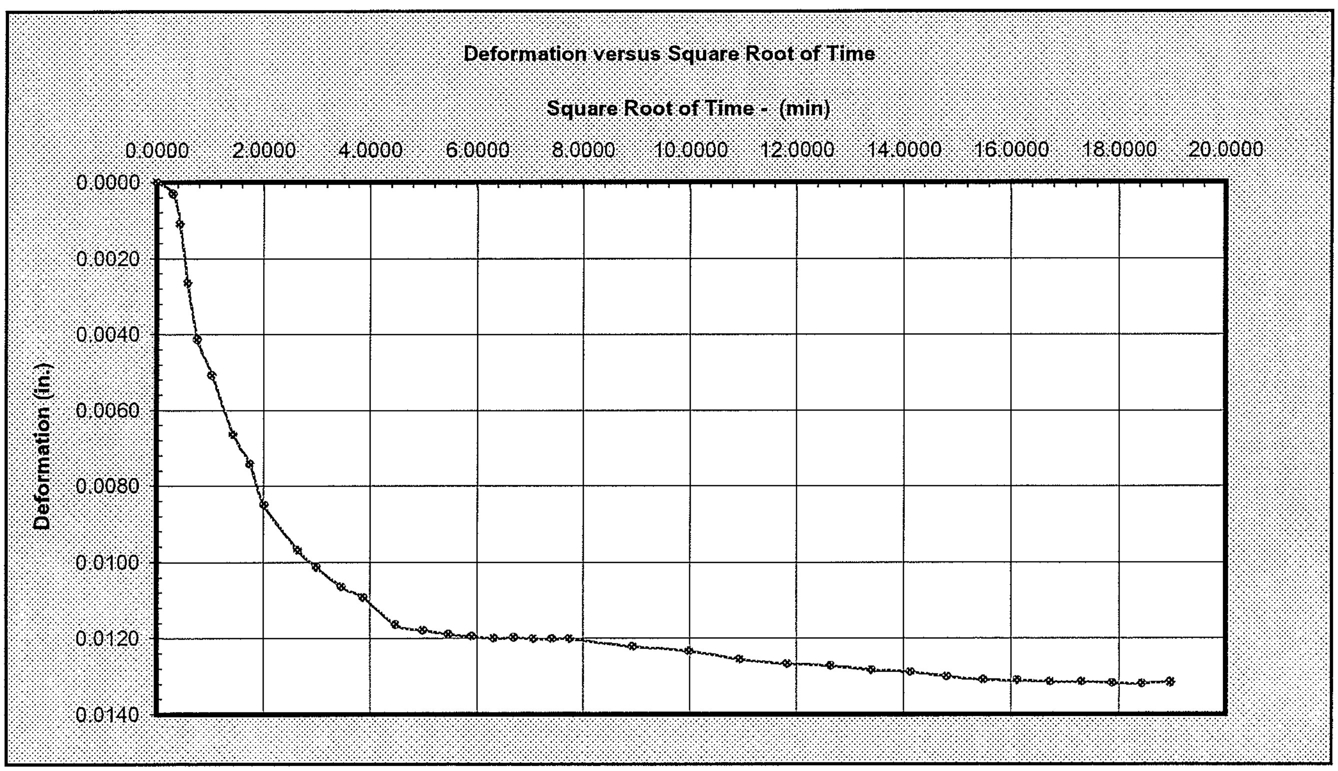




URS Corporation

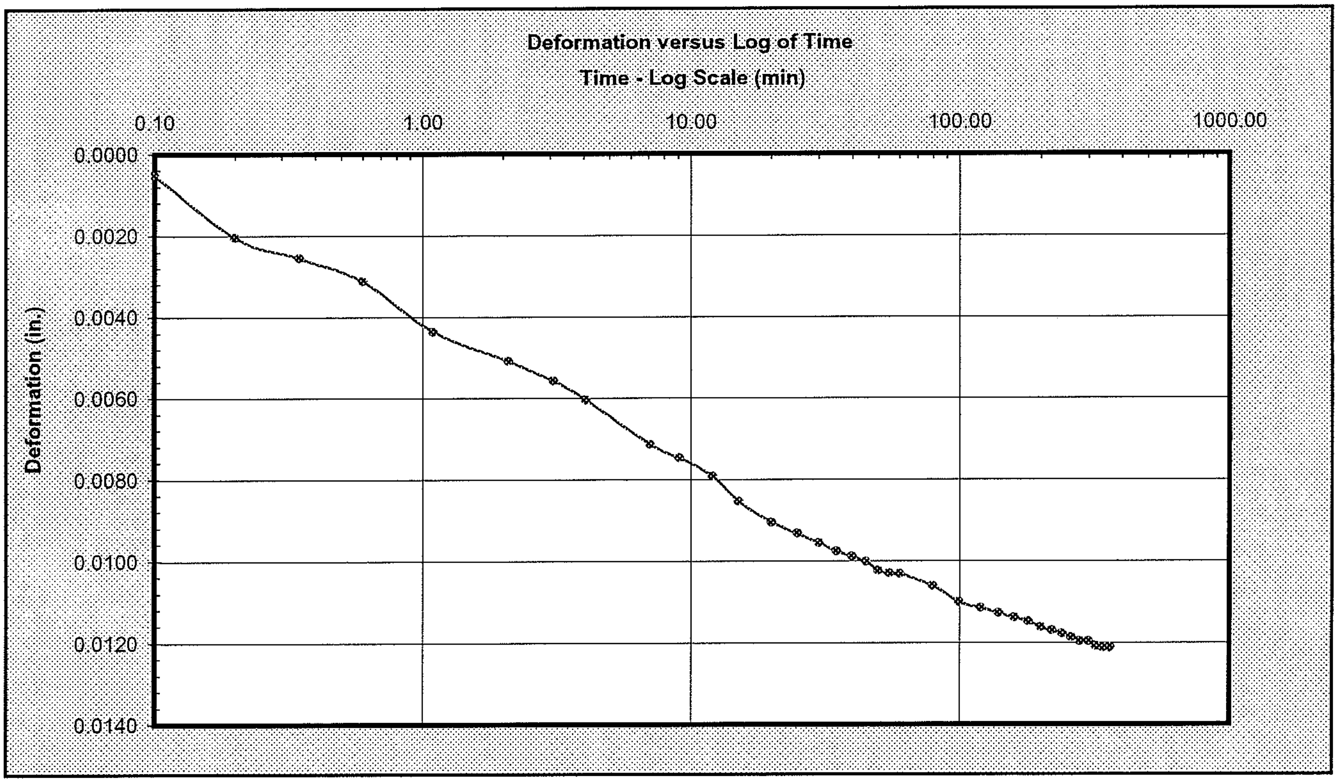
Fisher Slough
AB-1 @ 25-27
125 psf Load

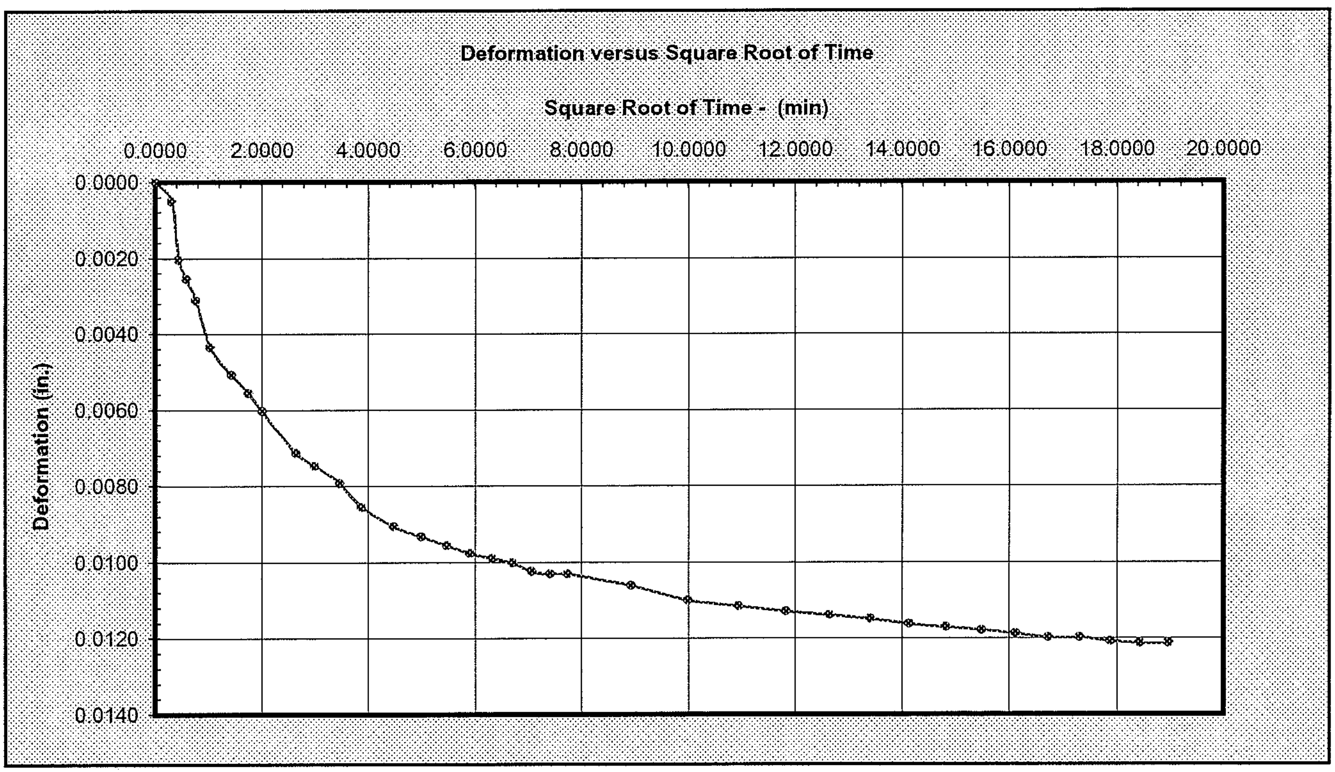




URS Corporation

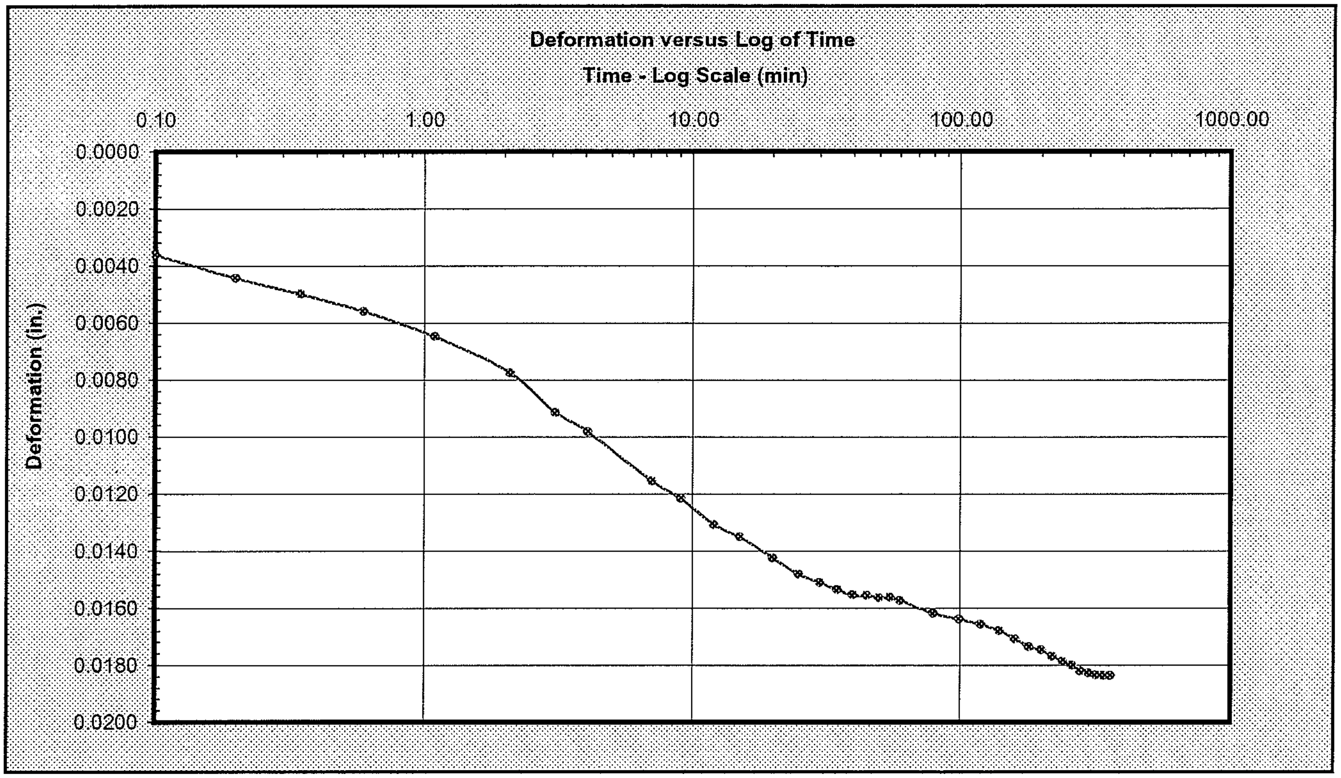
Fisher Slough
AB-1 @ 25-27
250 psf Load

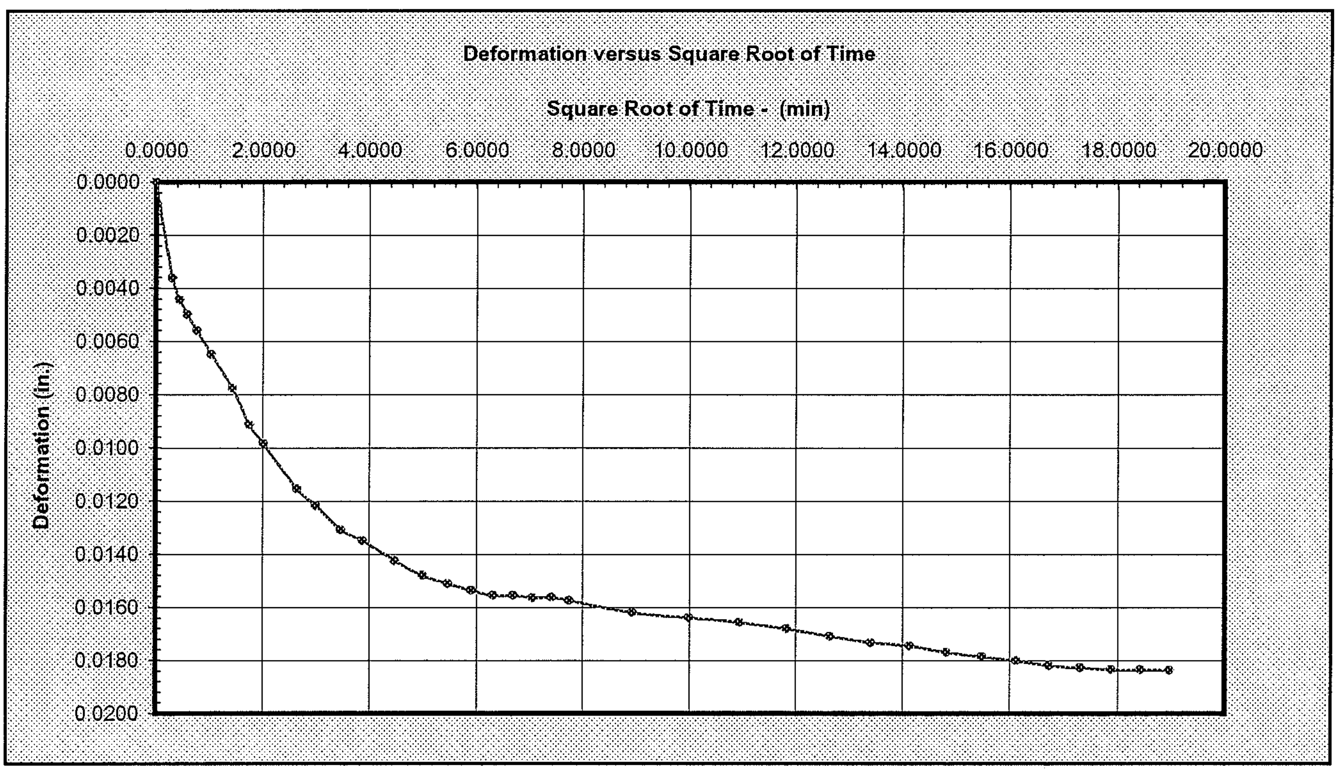




URS Corporation

Fisher Slough
AB-1 @ 25-27
500 psf Load





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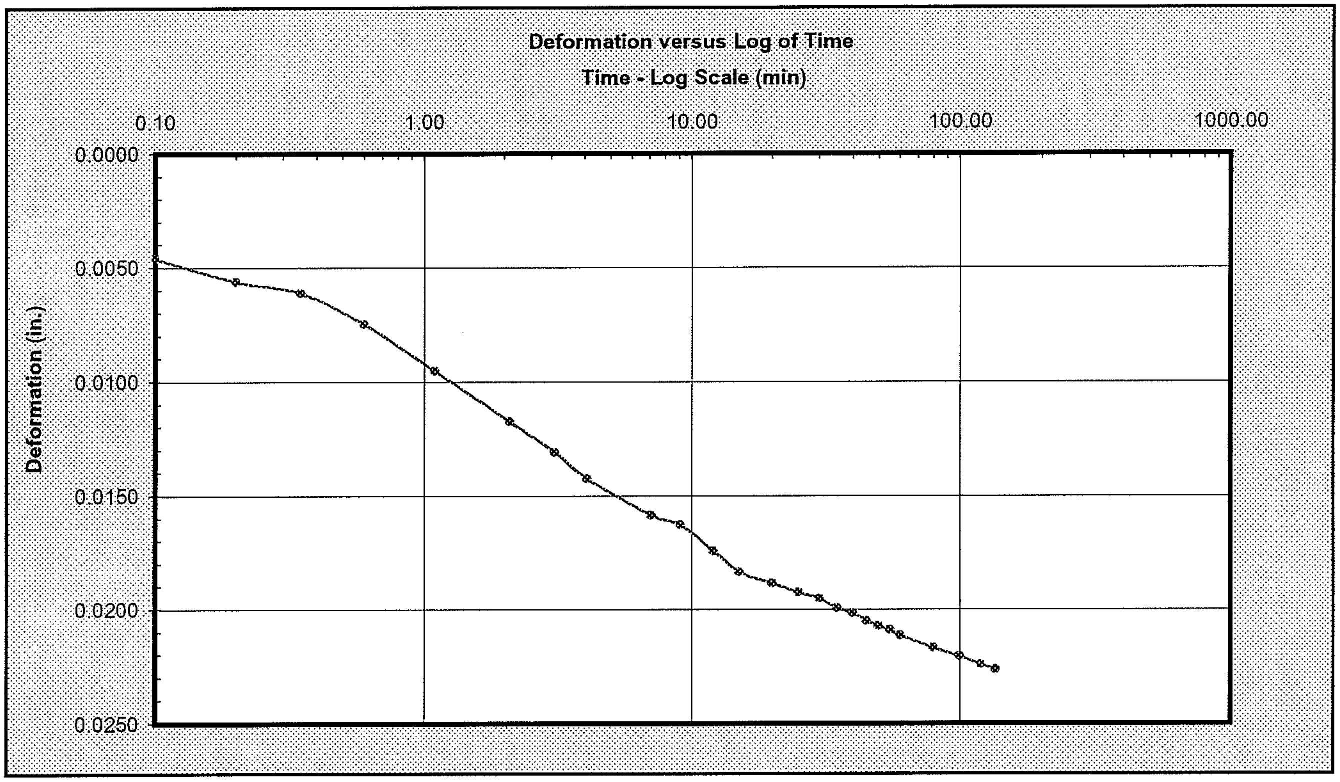
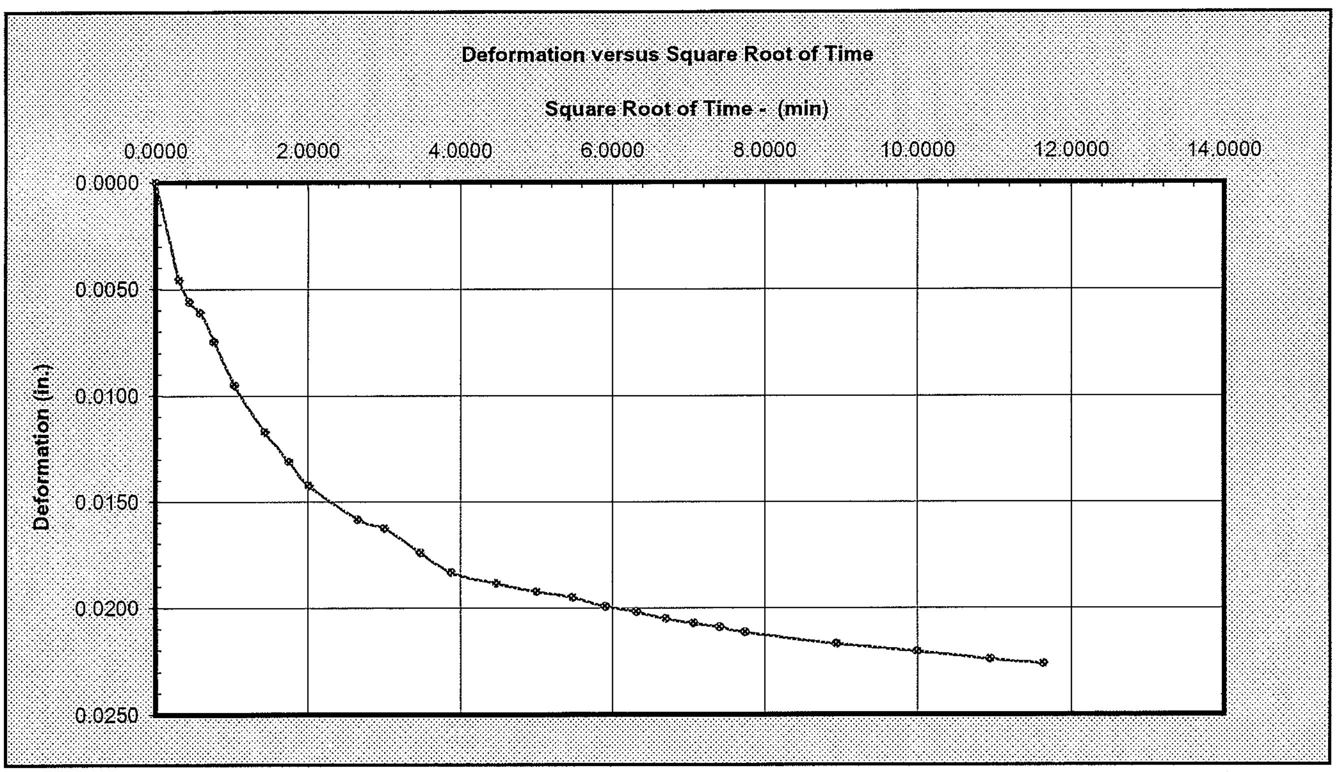
Fisher Slough
AB-1 @ 25-27
1,000 psf Load





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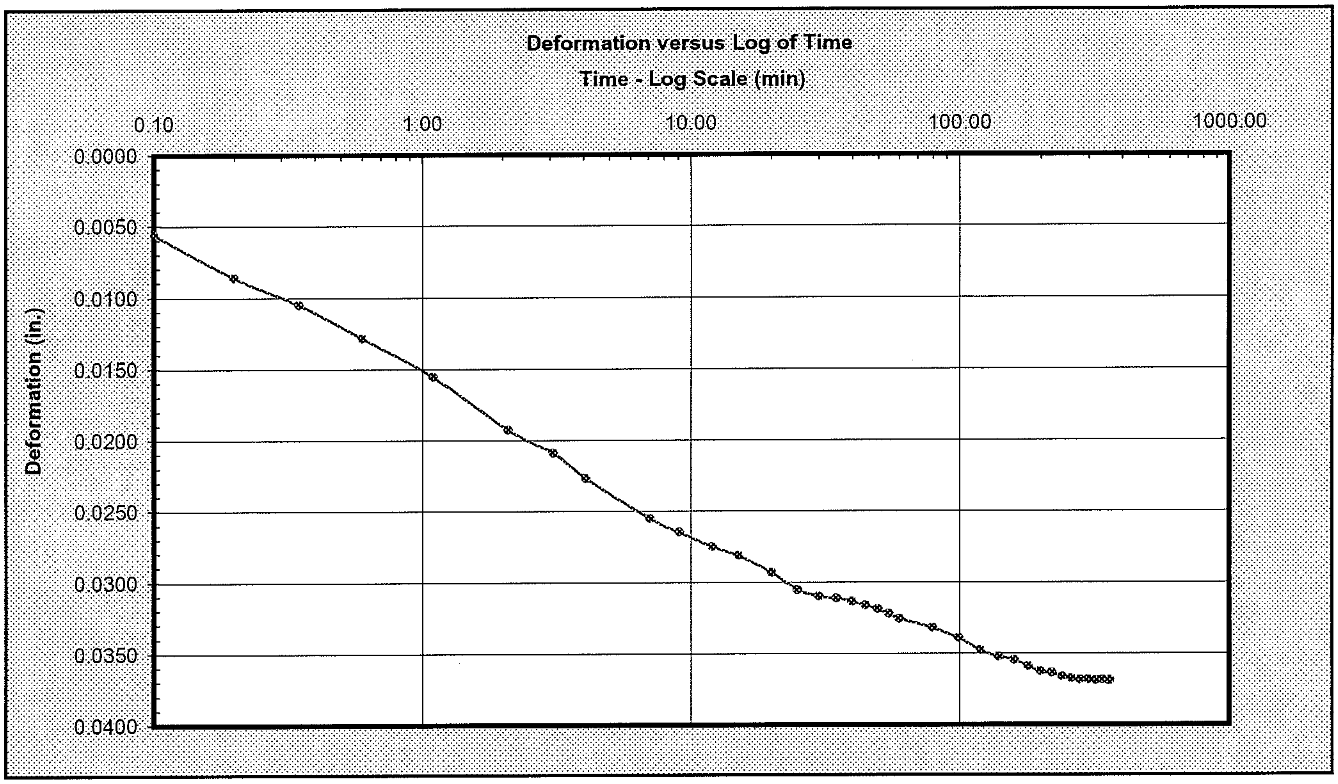
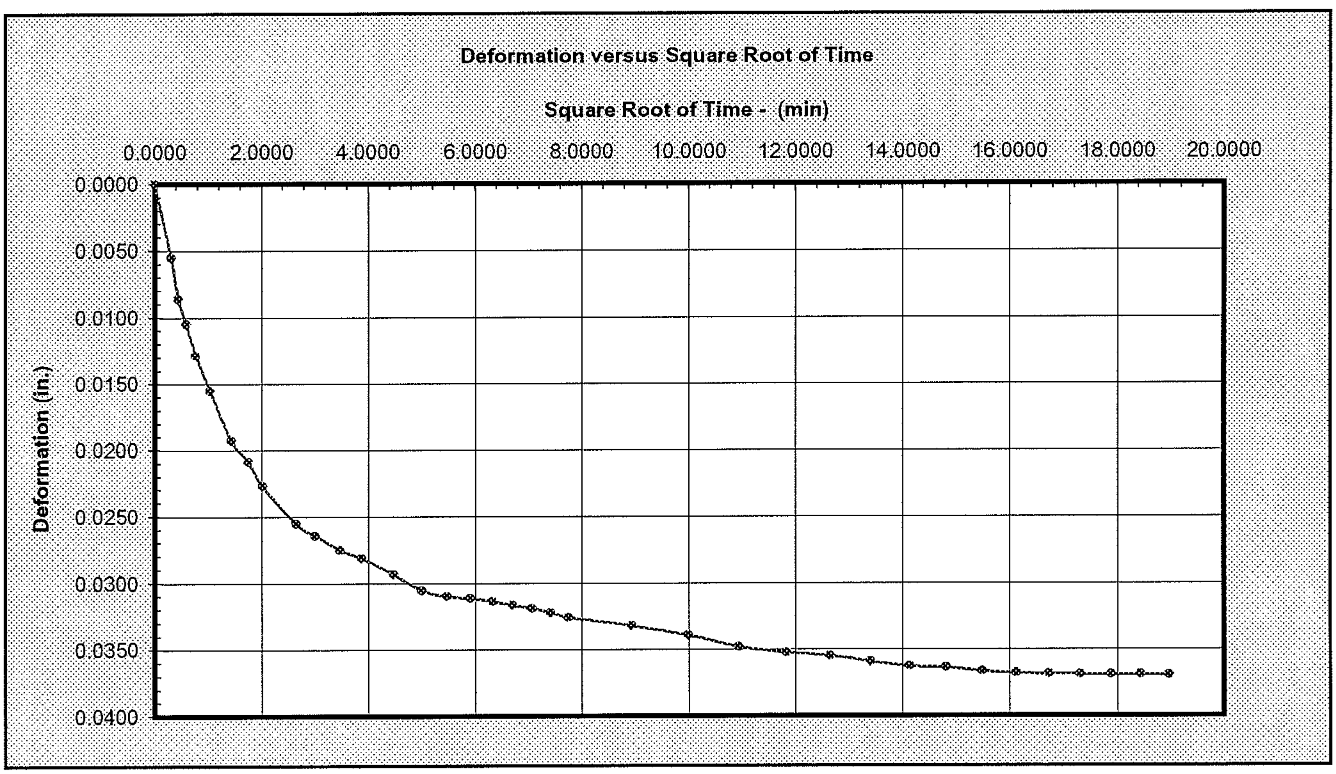
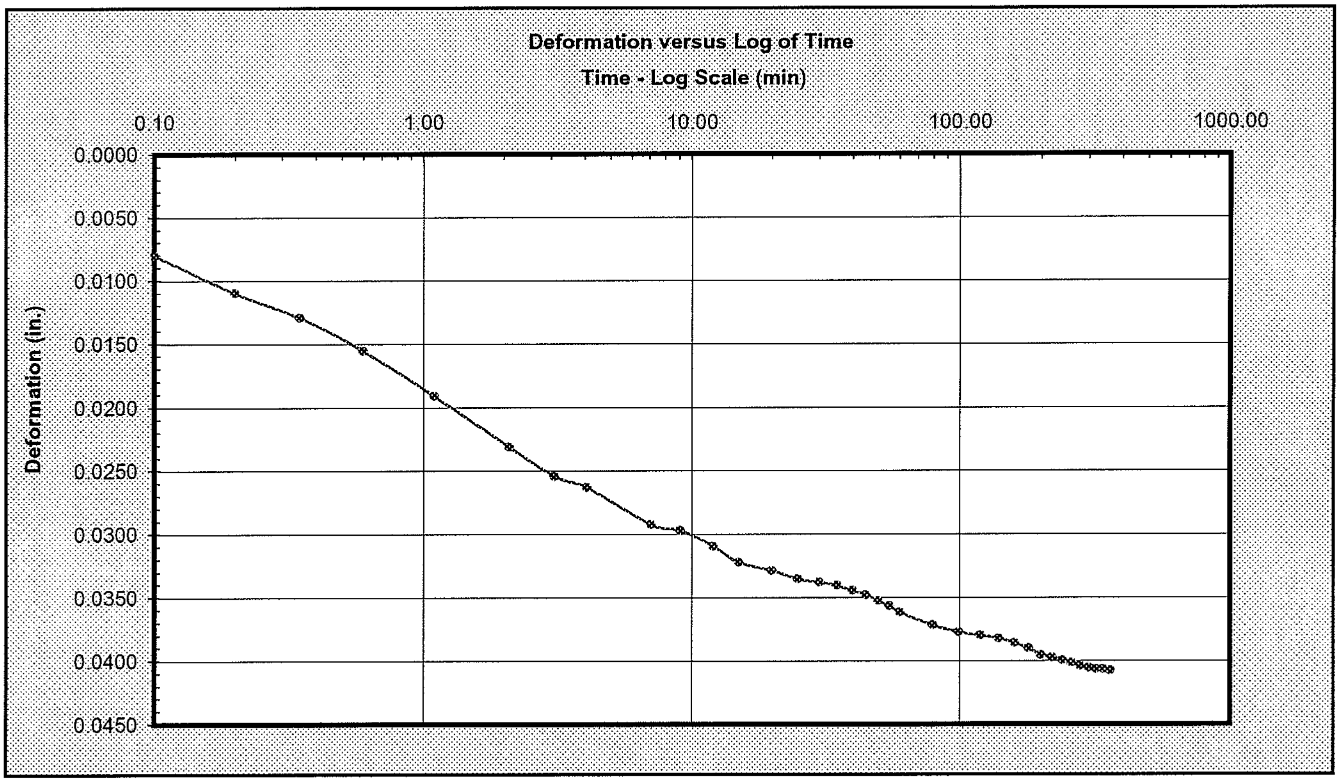
Fisher Slough
AB-1 @ 25-27
2,000 psf Load

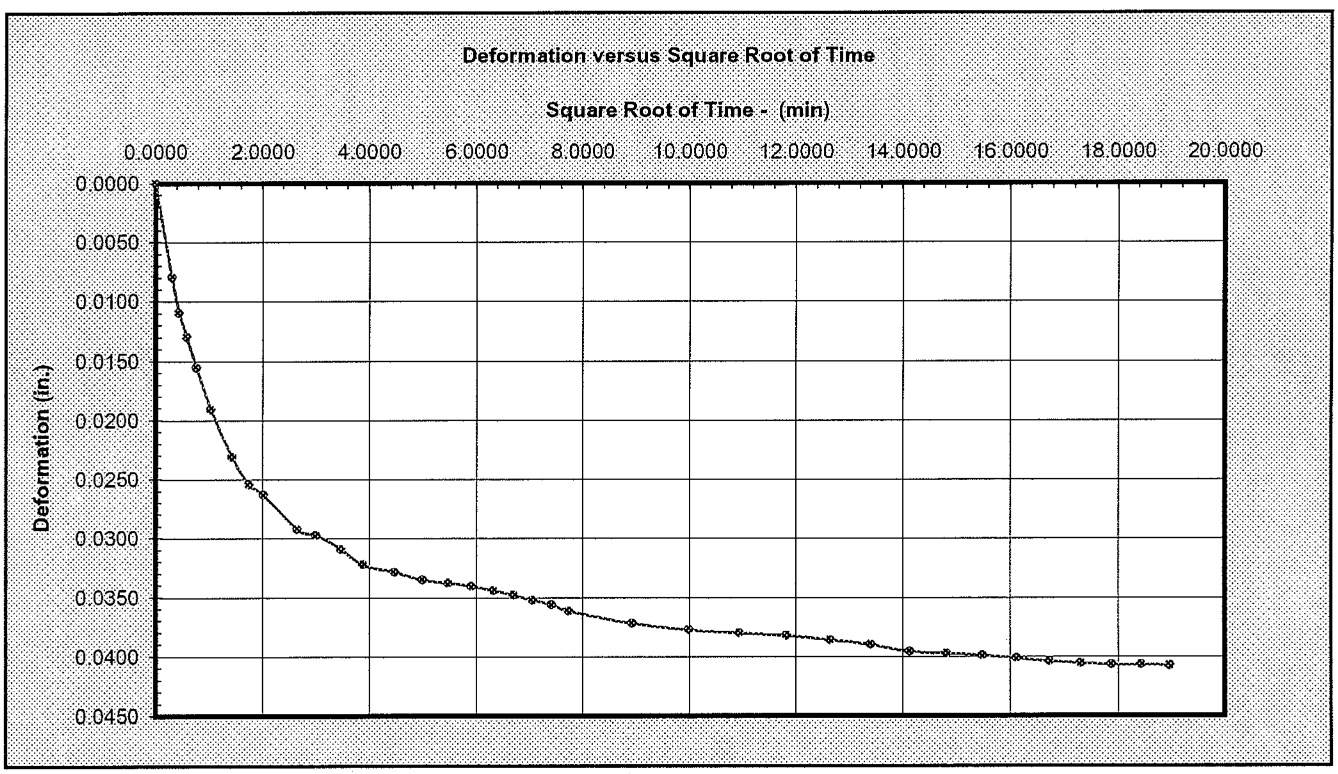




URS Corporation

Fisher Slough
AB-1 @ 25-27
4,000 psf Load





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Fisher Slough
B-2 @ 12.5-14.5

Step No.	Vertical Stress (psf)	Machine Deflections (in.)	H_0 (in)	0.900	Vertical Strain (%)	H_{50} (in.)	t_{50} (min.)	c_v (ft^2/day)
			S_{100} (in.)	H_{100} (in.)				
1	100	0.0000						#N/A
2	125	0.0000	0.0146	0.8853	1.95	0.8926	1.38	0.28
3	250	0.0002	0.0096	0.8731	2.99	0.8779	0.04	10.54
4	500	0.0006	0.0179	0.8555	4.95	0.8645	0.05	7.67
5	1000	0.0016	0.0179	0.8386	6.82	0.8476	0.02	18.05
6	2000	0.0033	0.0215	0.8187	9.03	0.8295	0.03	13.24
7	4000	0.0050	0.0236	0.7969	11.45	0.8087	0.22	1.46
8	8000	0.0077	0.0259	0.7737	14.04	0.7867	0.03	9.52
9	2000	0.0036	-0.0068	0.7763	13.74	0.7729	0.02	15.01
10	500	0.0010	-0.0072	0.7809	13.23	0.7773		#N/A
11	125	0.0000	-0.0071	0.7870	12.55	0.7835		#N/A
								#N/A
								#N/A
								#N/A
								#N/A
								#N/A
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								#N/A
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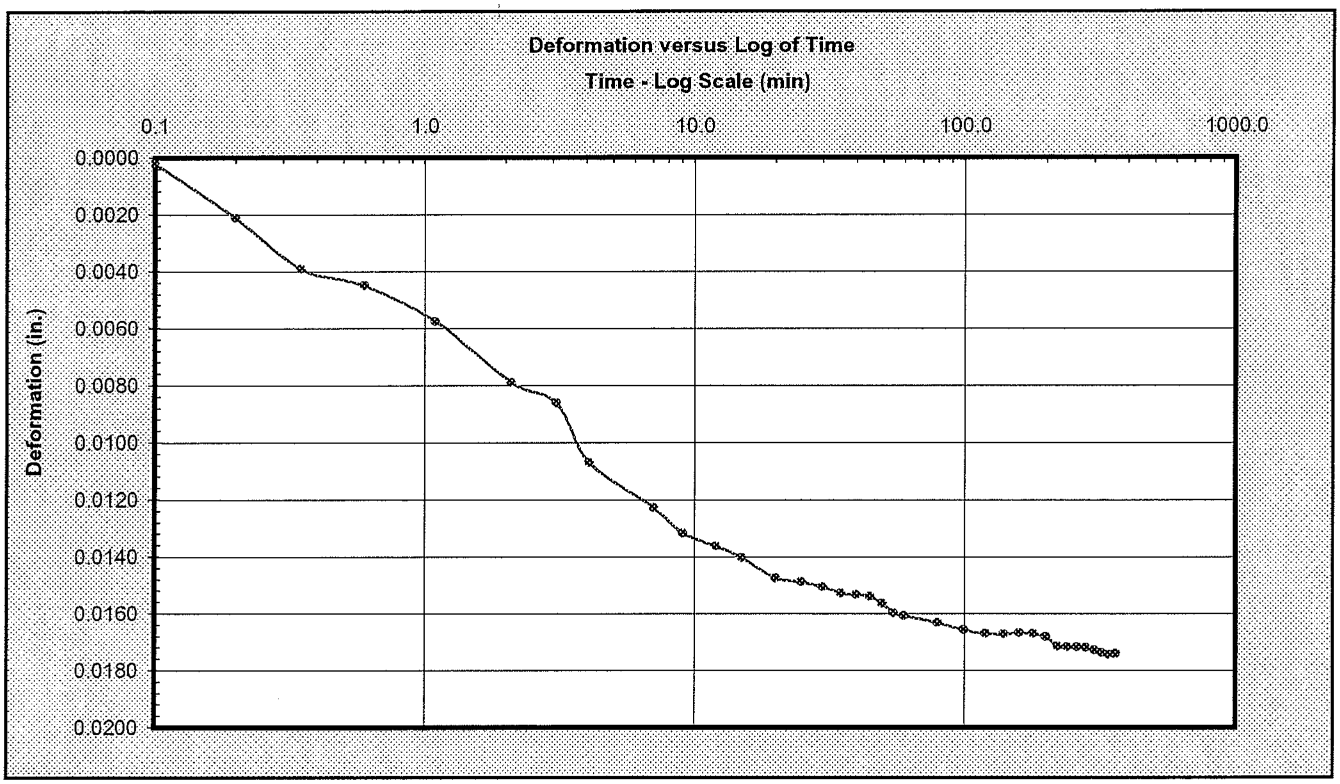
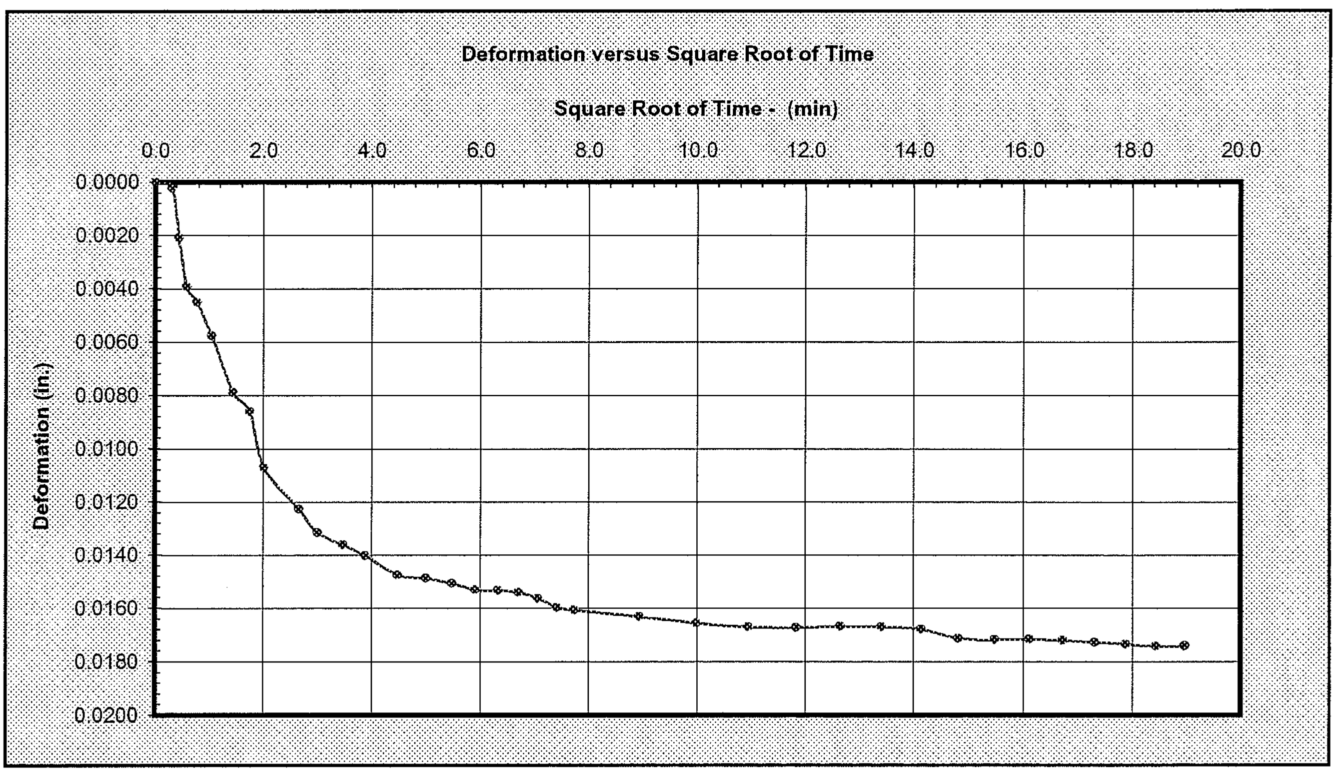
								#N/A

URS Corporation

Fisher Slough
B-2 @ 12.5-14.5
250 psf Load





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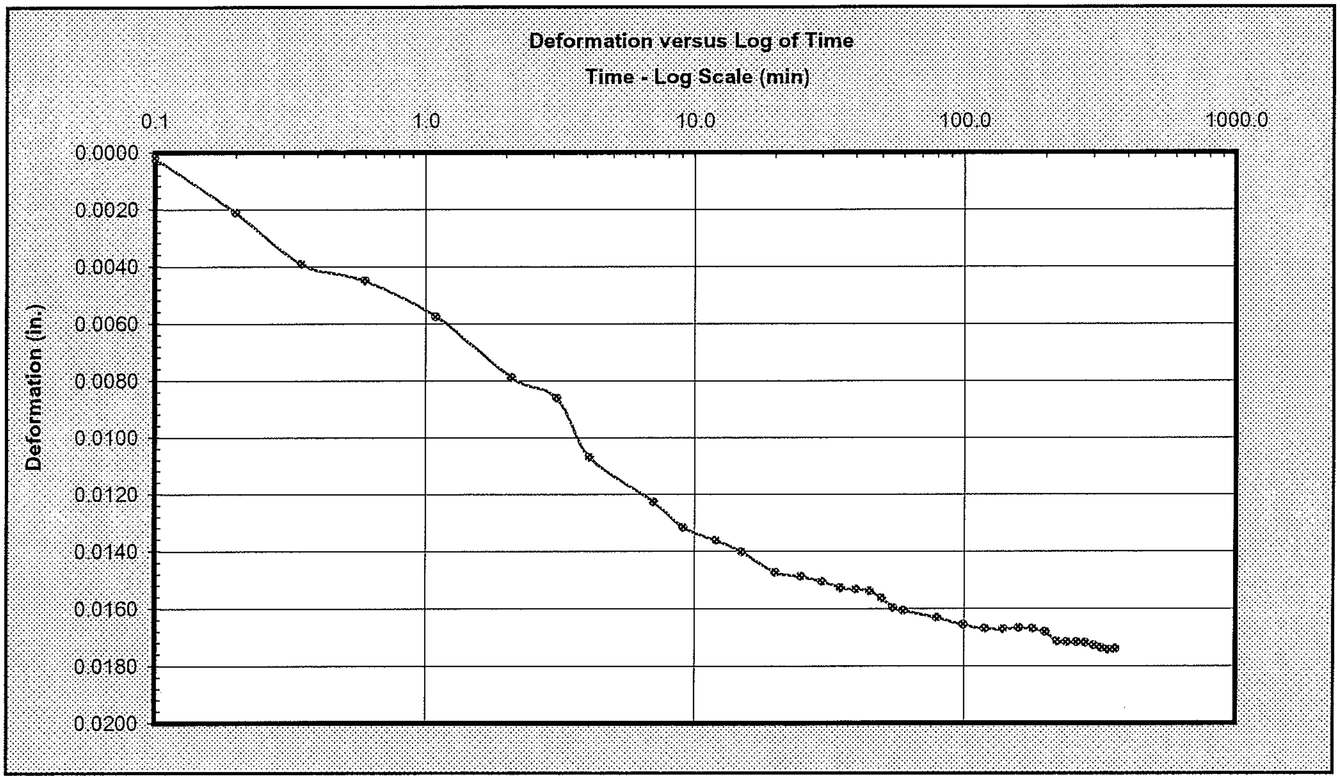
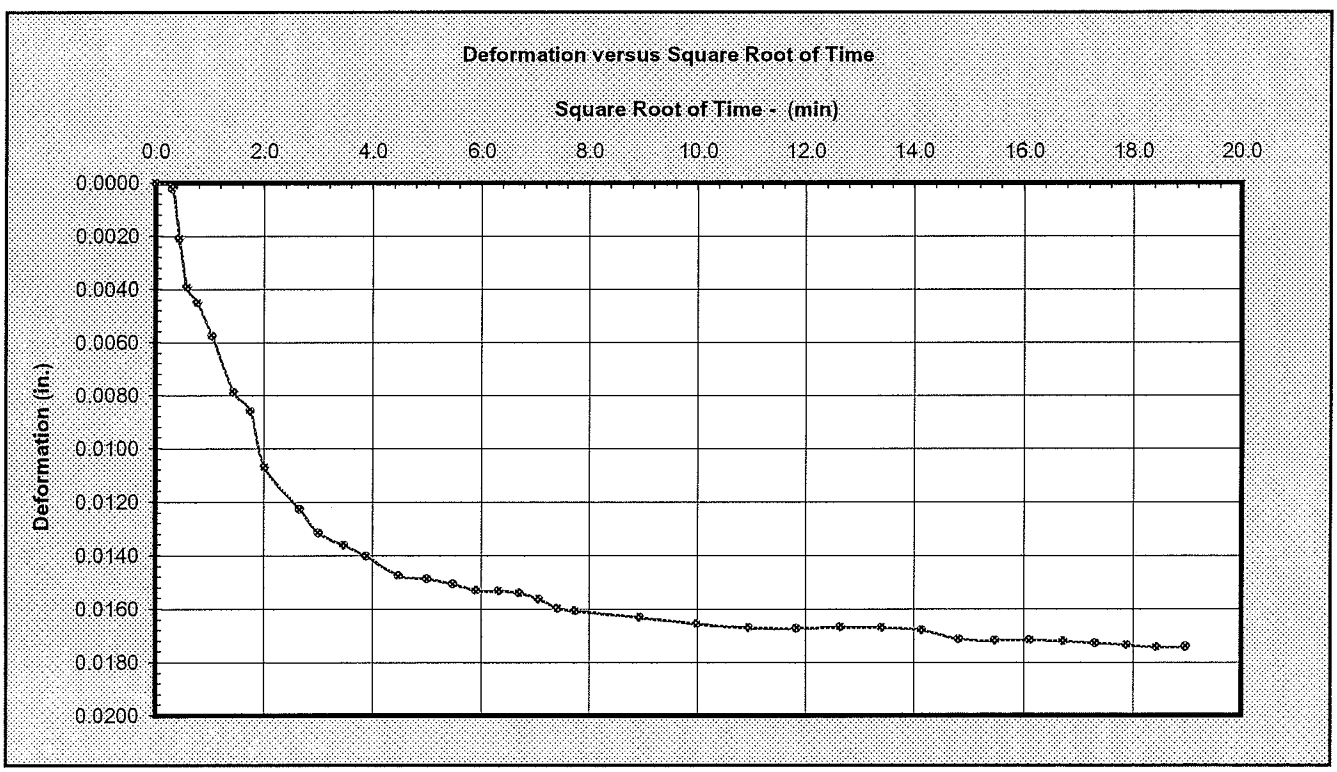
Fisher Slough
B-2 @ 12.5-14.5
125 psf Load





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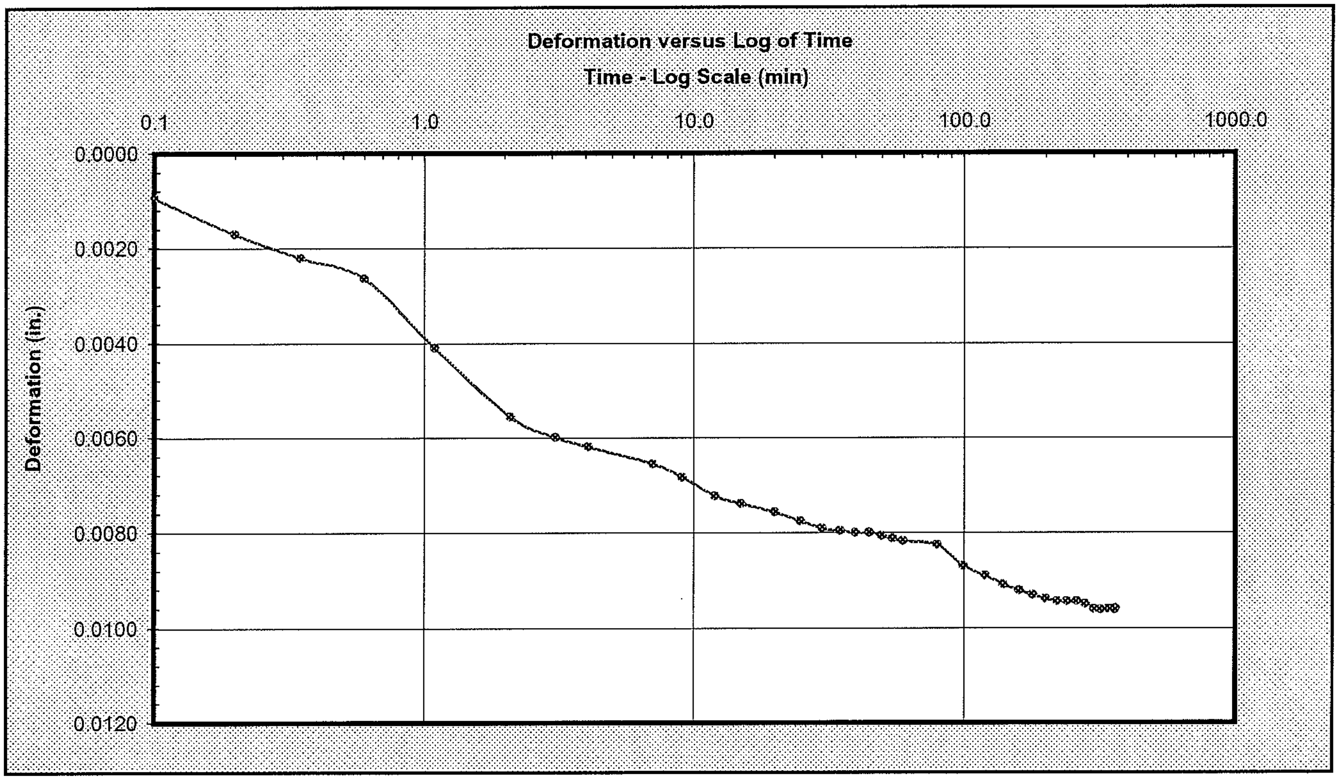
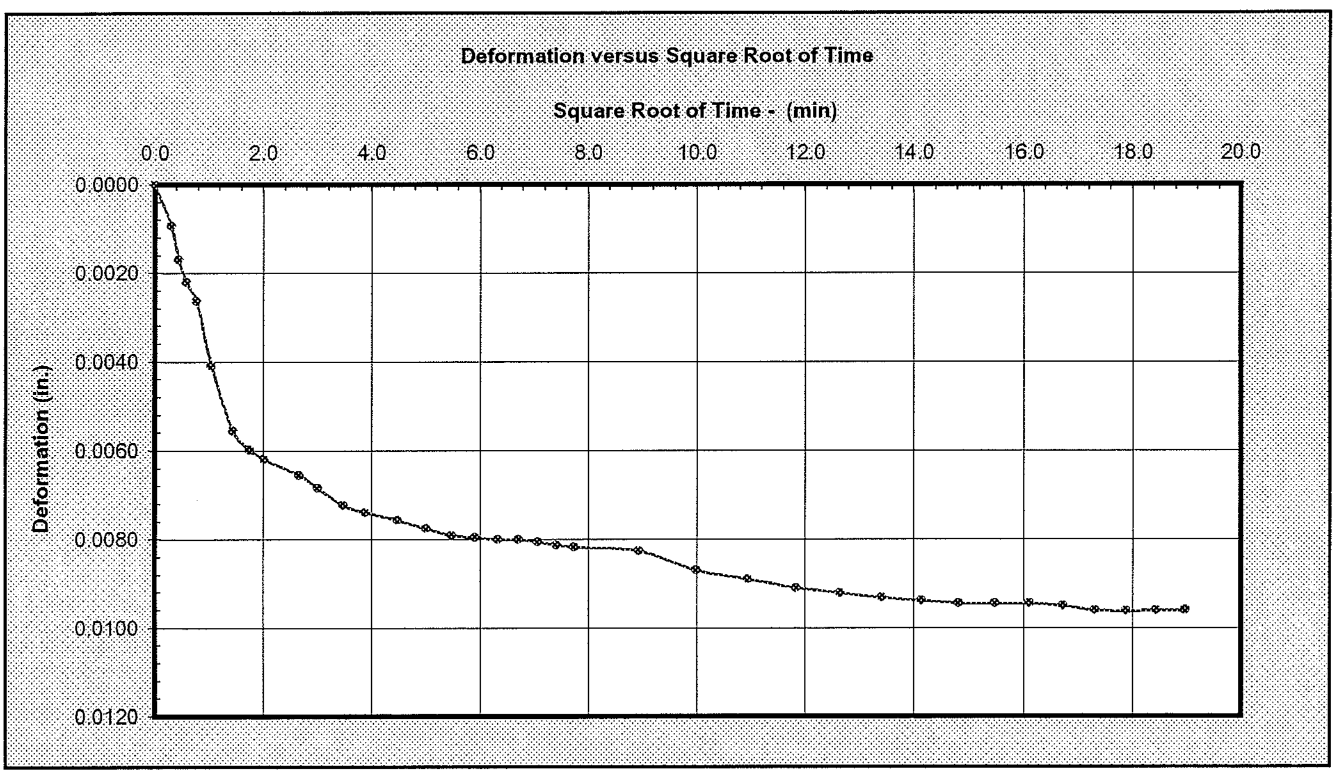
Fisher Slough
B-2 @ 12.5-14.5
250 psf Load





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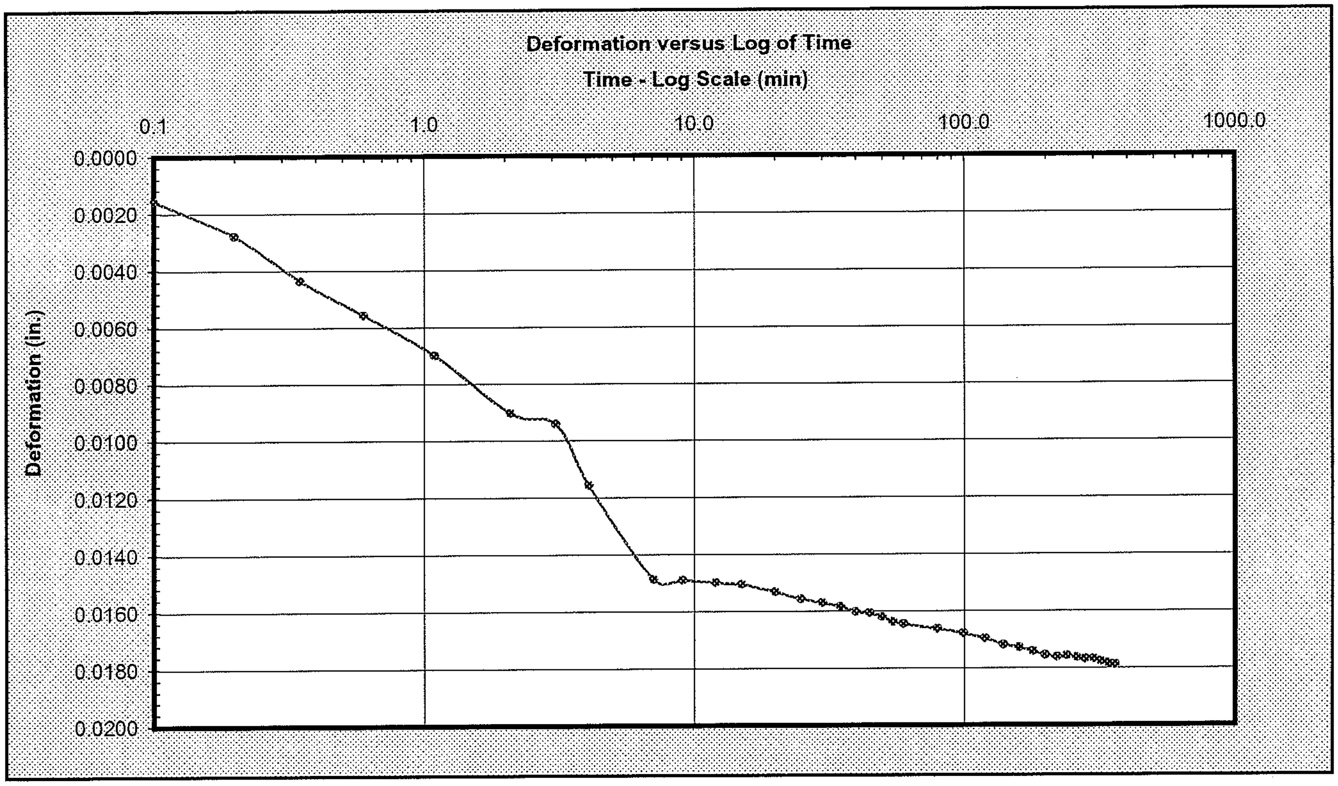
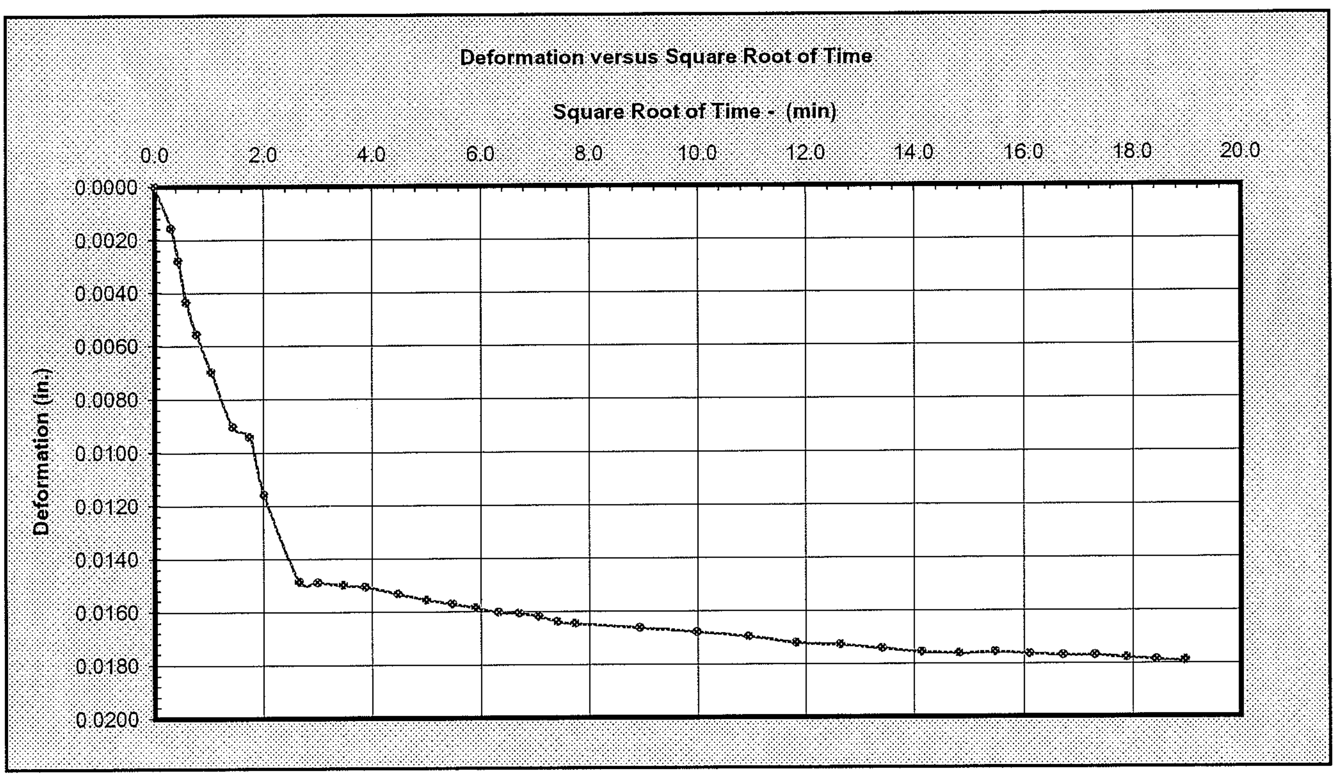
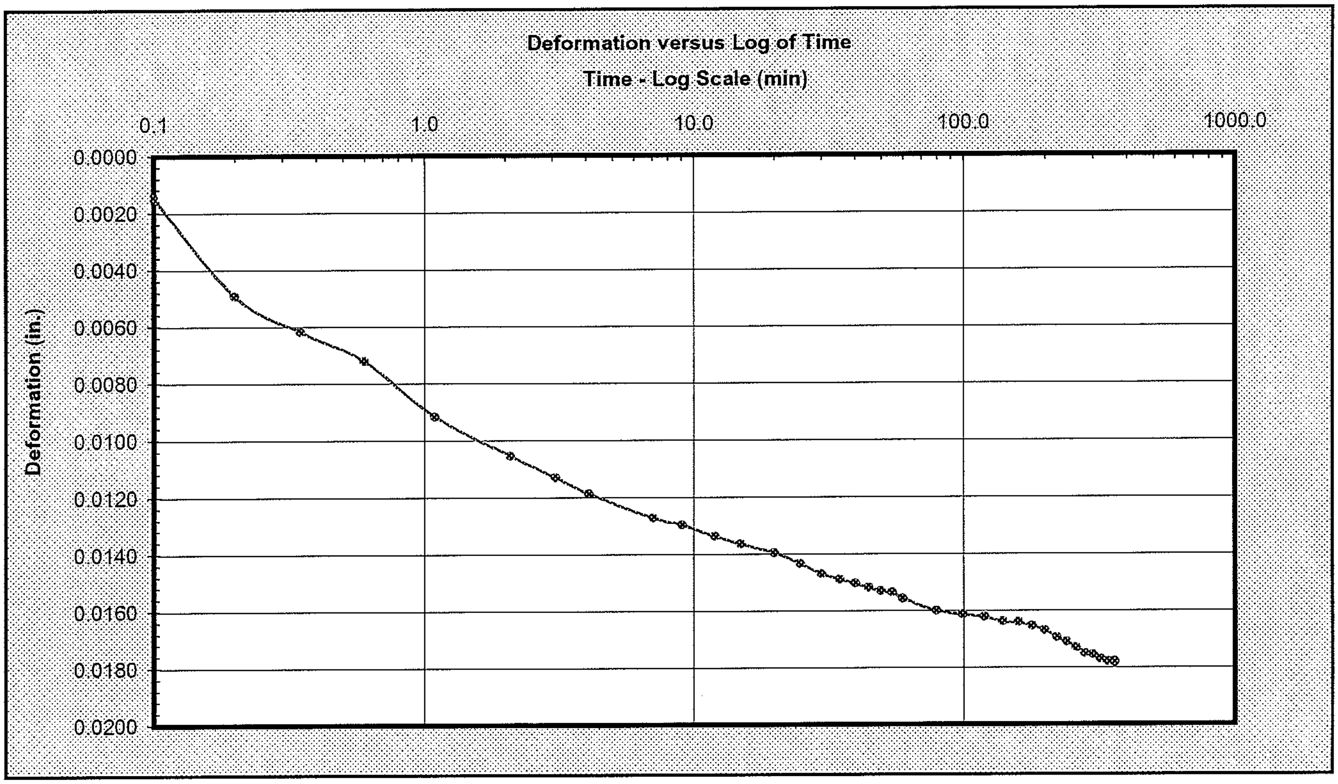
Fisher Slough
B-2 @ 12.5-14.5
500 psf Load

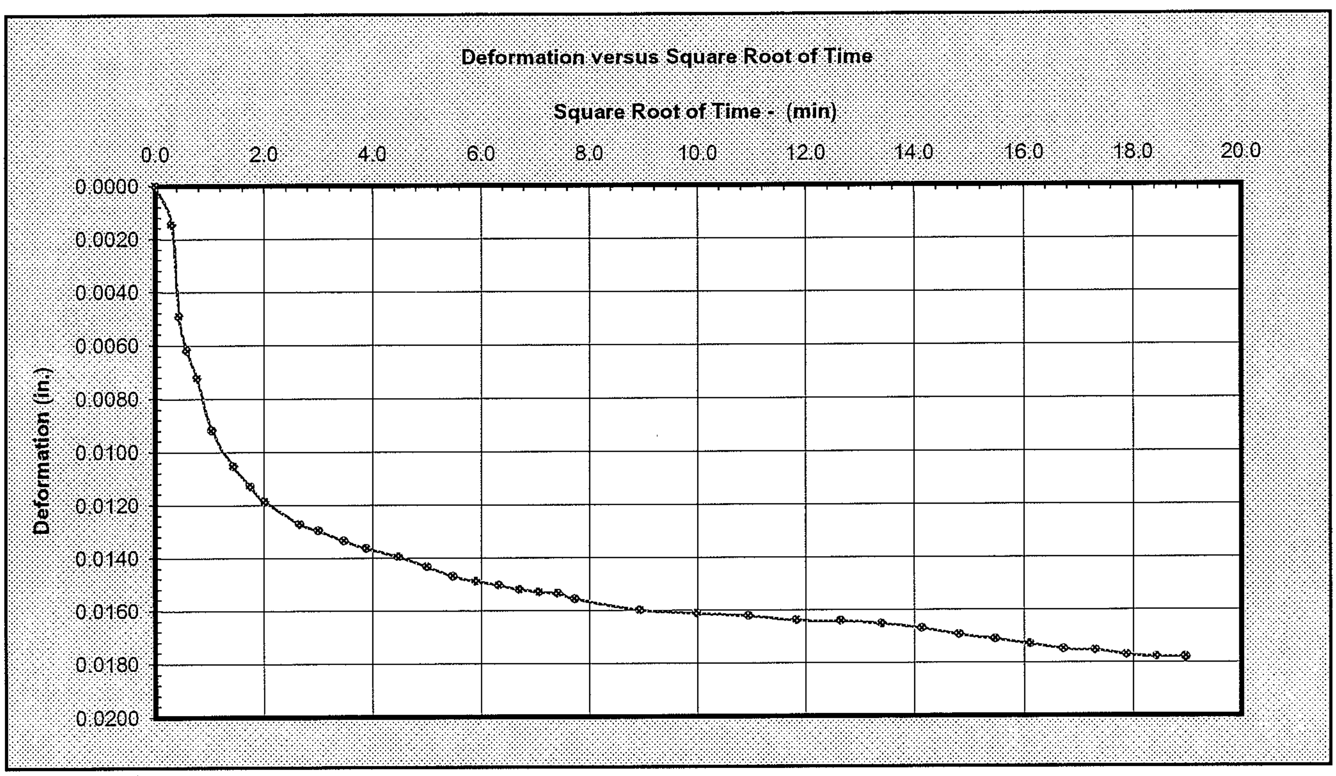




URS Corporation

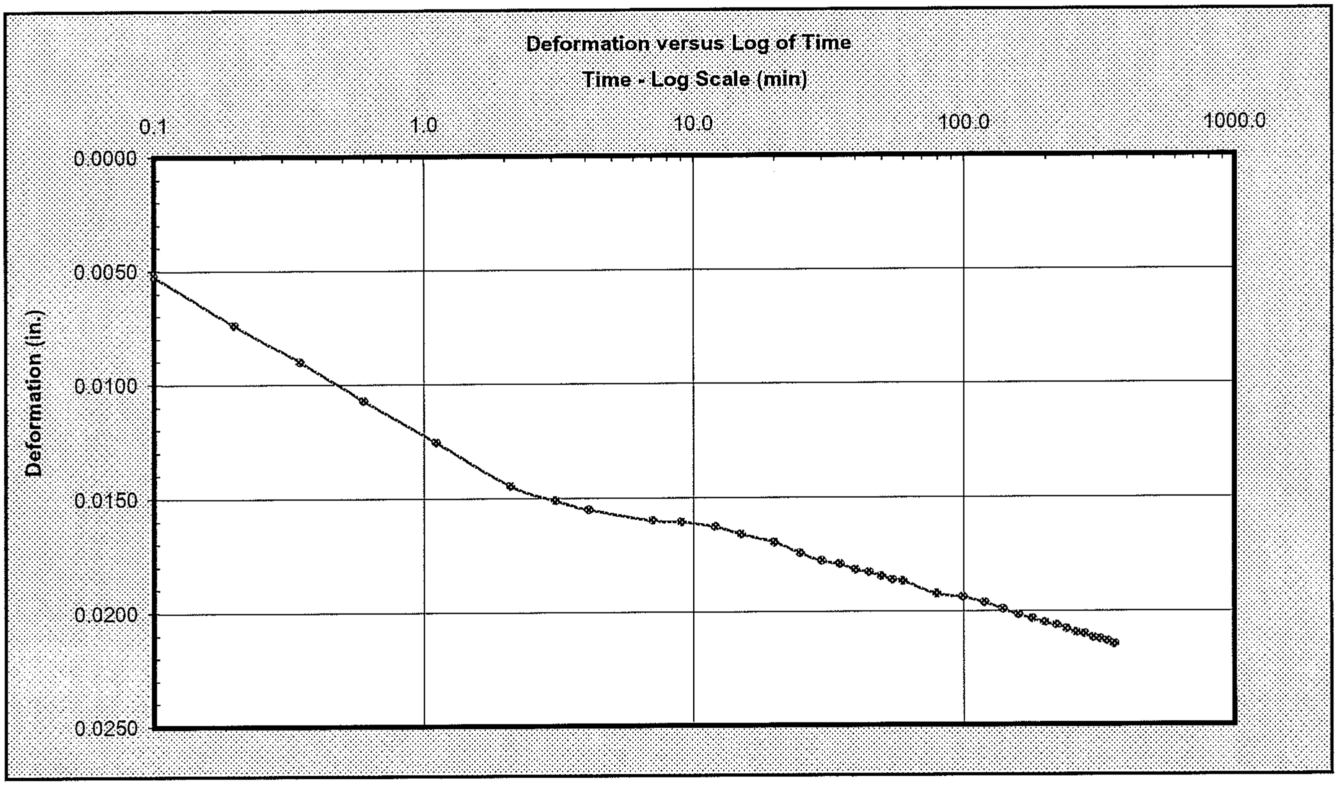
Fisher Slough
B-2 @ 12.5-14.5
1,000 psf Load

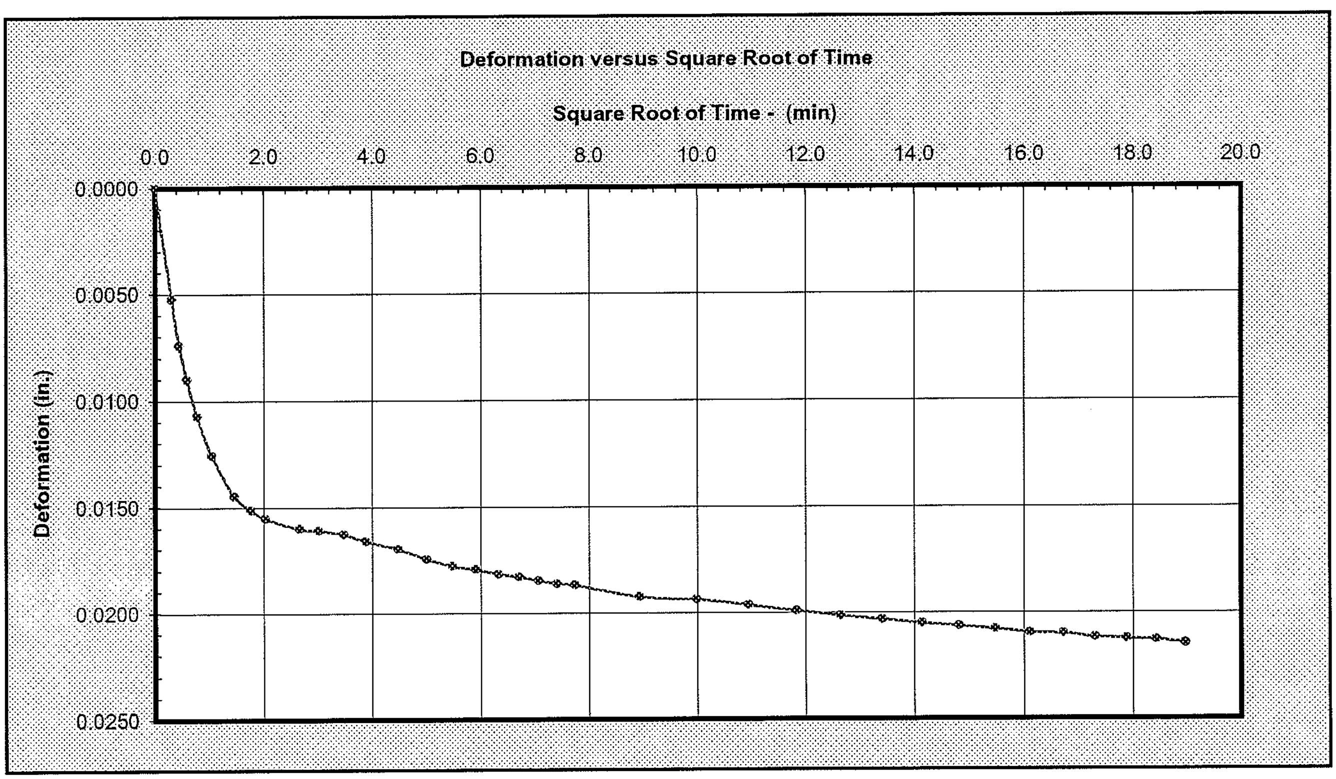




URS Corporation

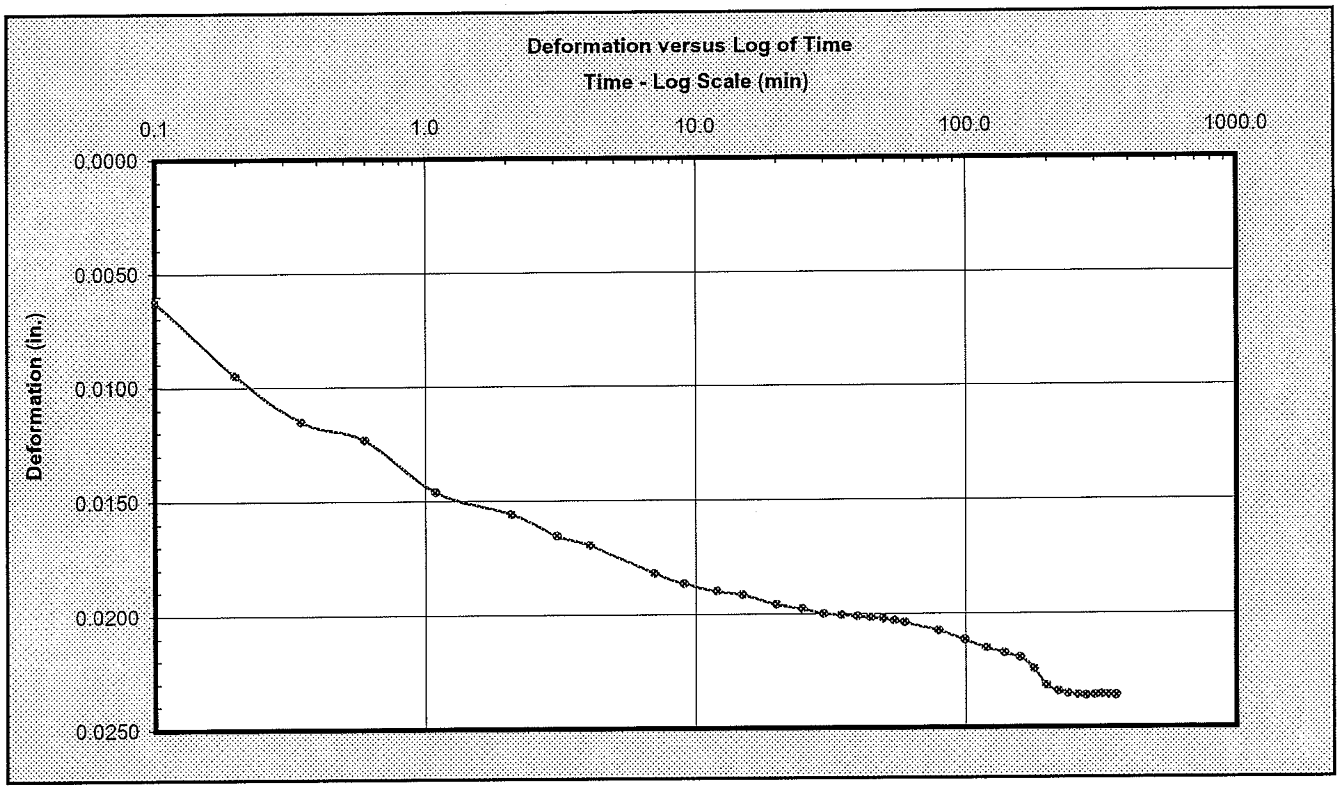
Fisher Slough
B-2 @ 12.5-14.5
2,000 psf Load

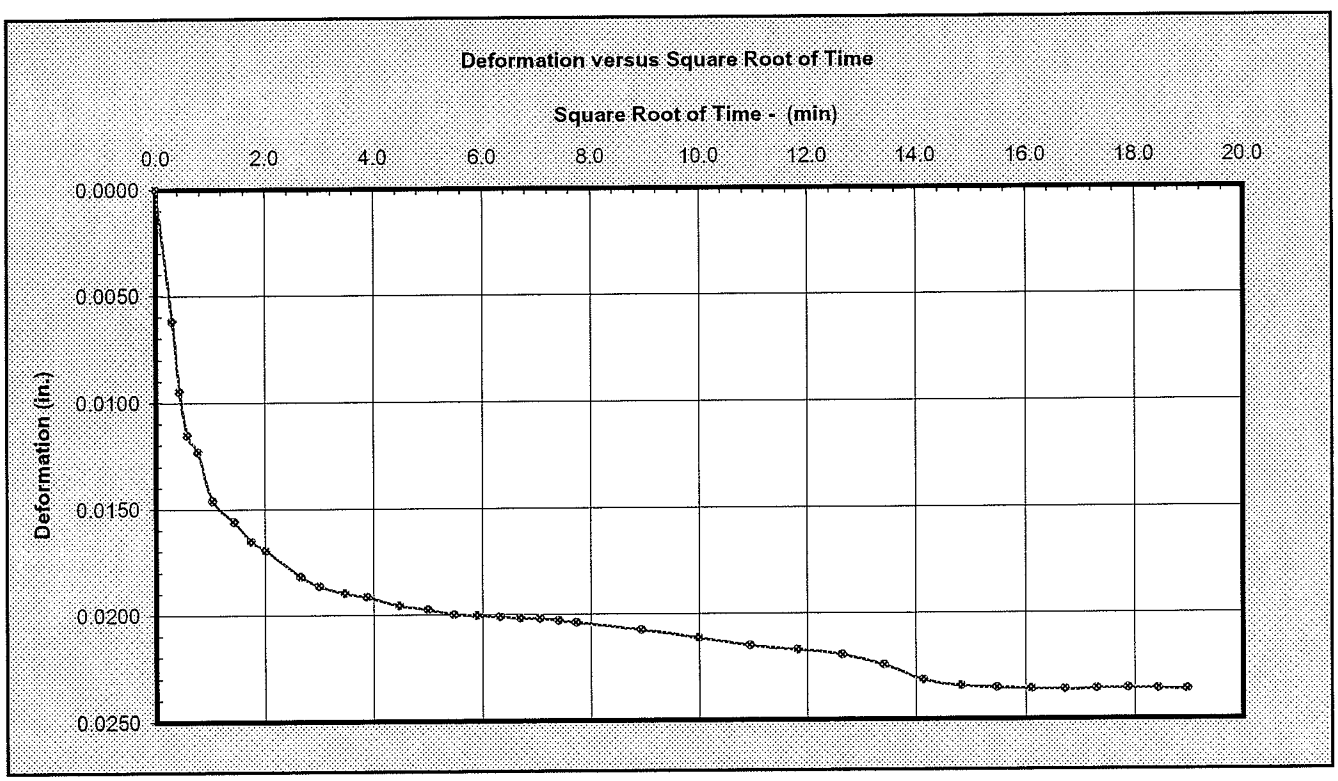




URS Corporation

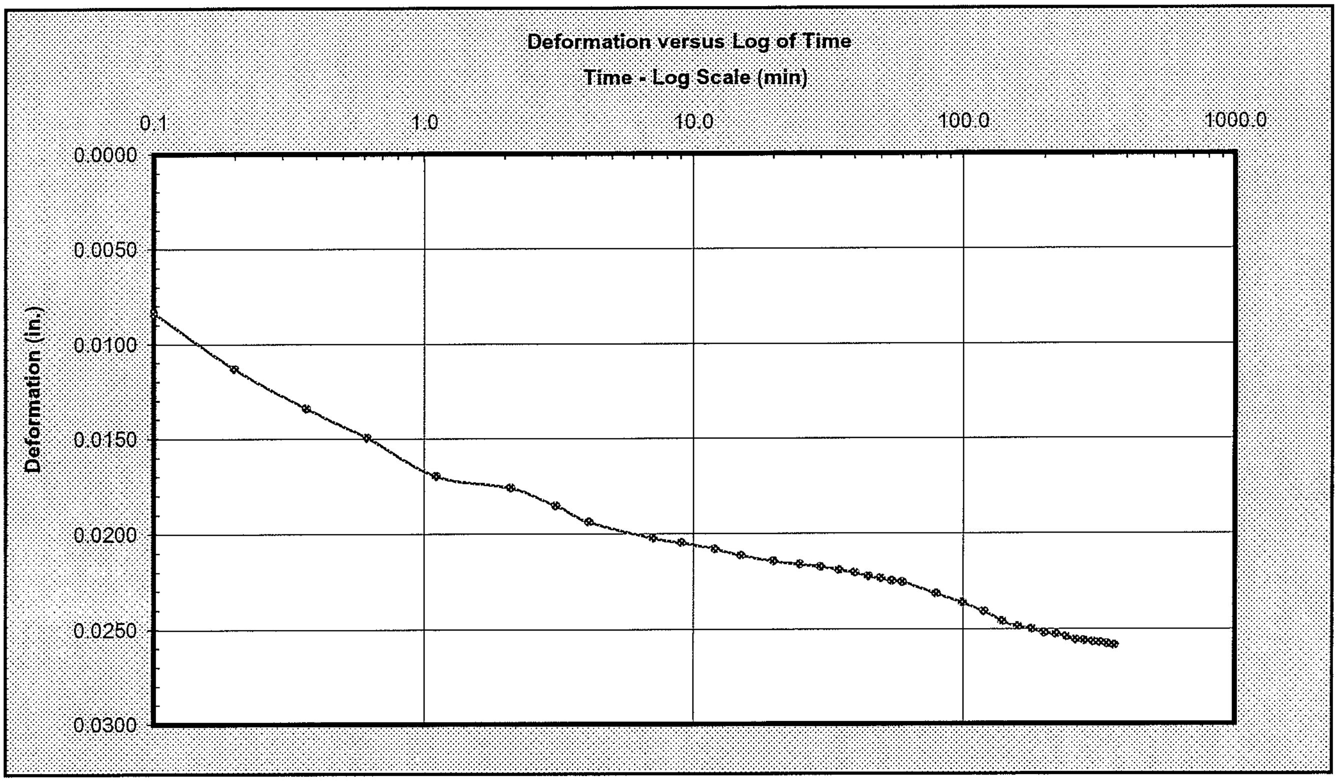
Fisher Slough
B-2 @ 12.5-14.5
4,000 psf Load

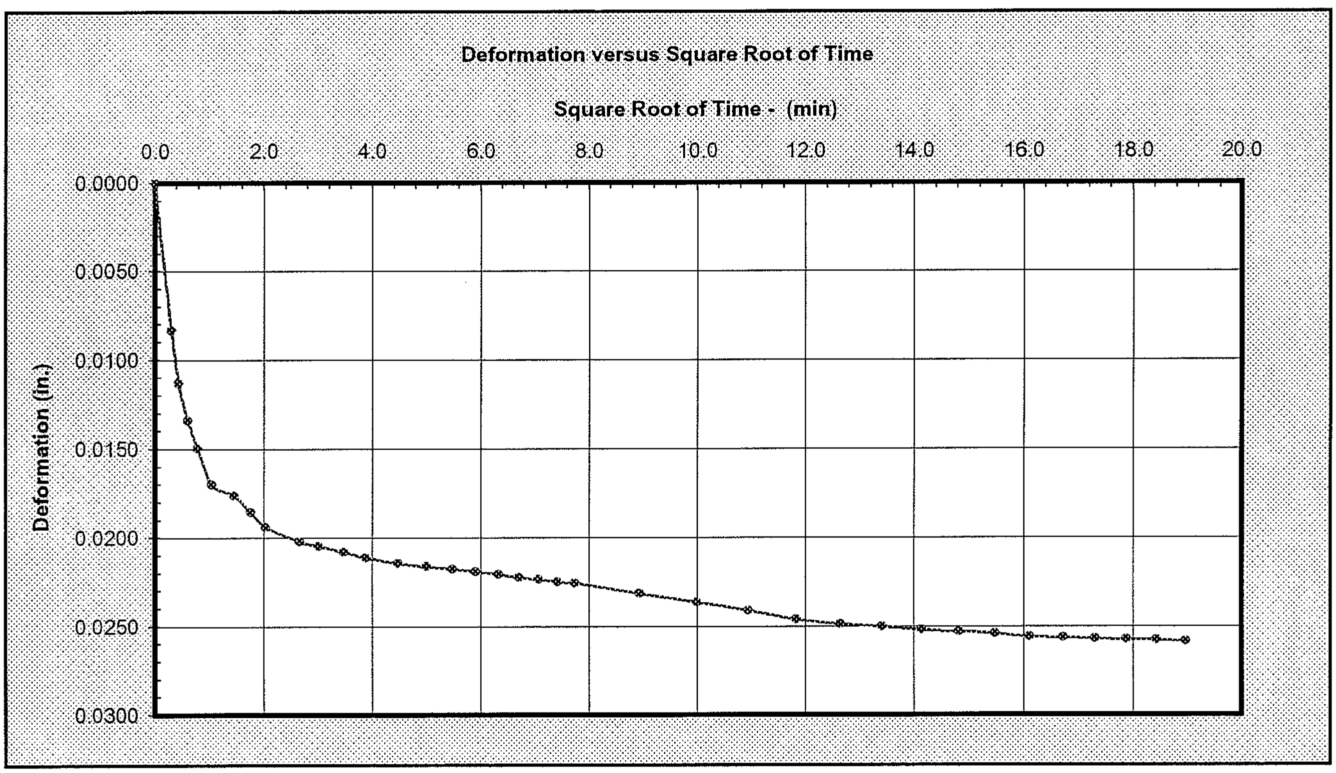




URS Corporation

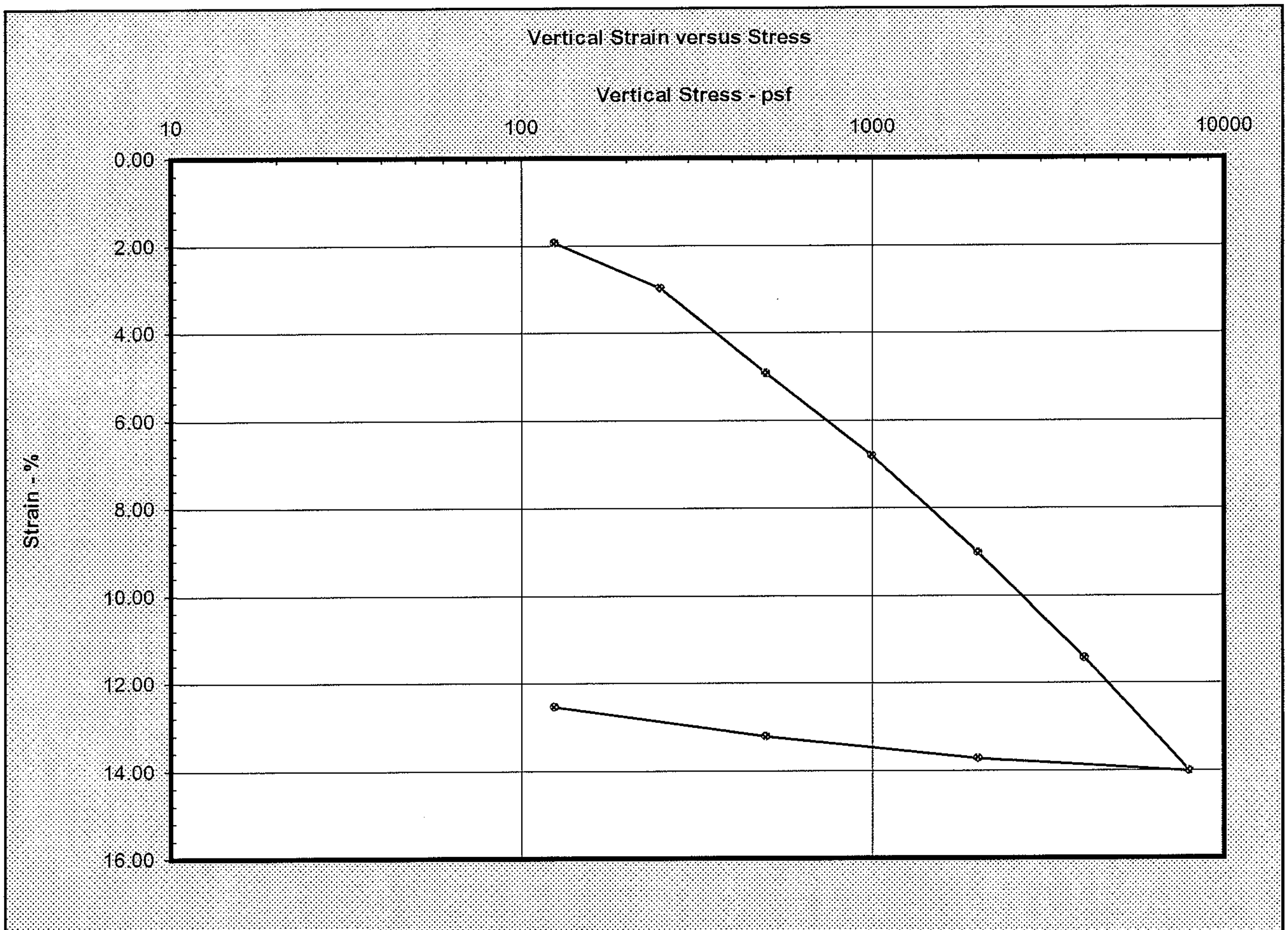
Fisher Slough
B-2 @ 12.5-14.5
8,000 psf Load

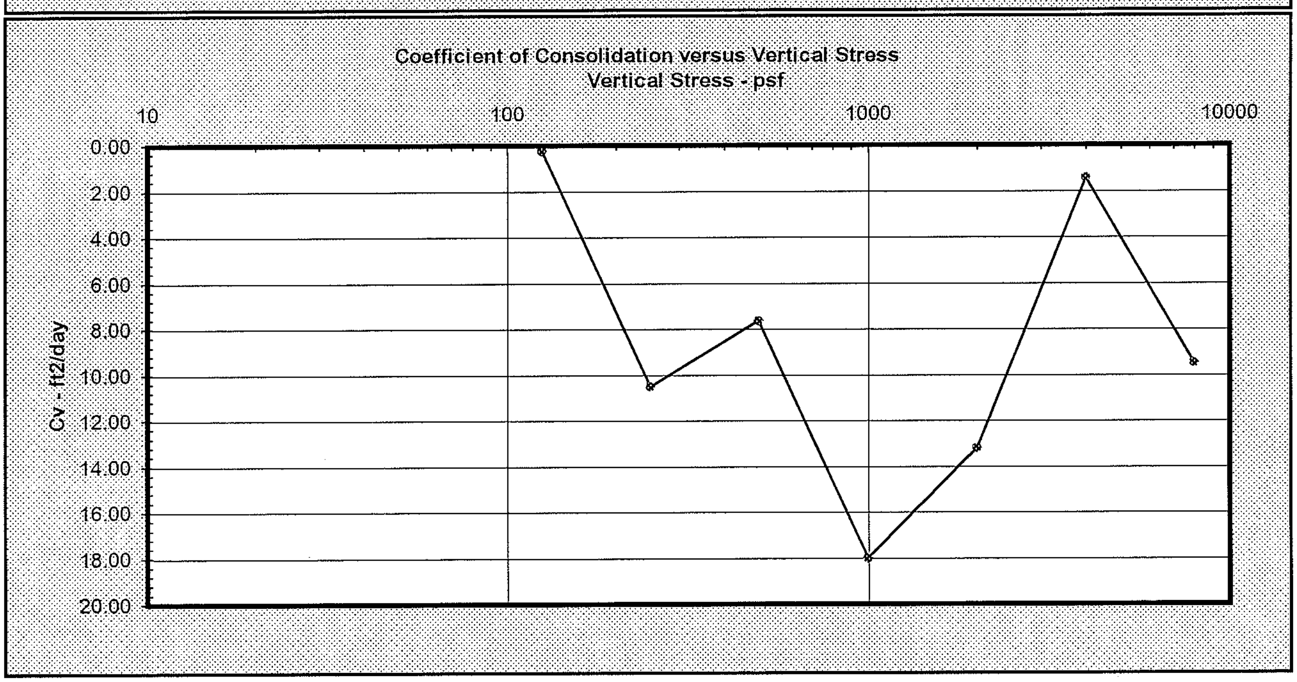




URS Corporation

Fisher Slough
B-2 @ 12.5-14.5





Analytical Resources, Incorporated
Analytical Chemists and Consultants

November 2, 2008

Mr. Suren Balendra, P.E.
URS Corporation
Century Square
1501 – 4th Avenue, Suite 1400
Seattle, WA 98101-1616

RE: Client Project: Fisher Slough
ARI Project: NU48

Dear Mr. Balendra;

The following pages provide the information you requested. Please call me to discuss any questions or comments you may have on the data or its presentation.

Best Regards,

Analytical Resources, Inc.

Harold Benny
Geotechnical Laboratory Manager
206-695-6246
haroldb@arilabs.com

Enclosures

cc: Files NU48

Analytical Resources, Incorporated
Analytical Chemists and Consultants

Client: URS Corporation	Project No.: NU48
Client Project: Fisher Slough	

Case Narrative

1. Five samples were submitted for Modified Proctor testing. They were received on October 15, 2008, in good condition.
2. The Modified Proctor testing was run according to ASTM D1557, method C. Material greater than the ¾ inch sieve was removed.
3. The grain size analysis was run according to ASTM D422. Only the sieve portion of the analysis was run.
4. The percent fines were measured according to ASTM D1140.
5. The data is provided in summary tables and plots.
6. There were no other noted anomalies in the samples or methods on this project.

Approved by: [signature] Date: 11/2/08
Title: Geotechnical Division Manager

fax 866 495 5288

Chain of Custody Record & Laboratory Analysis Request

Analytical Resources, Incorporated
Analytical Chemists and Consultants
4611 South 134th Place, Suite 100
Tukwila WA 98168
206-695-6200 206-695-6201 (fax)

ARI Assigned Number: NU48	Turn-around Requested:
ARI Client Company: URS, Seattle	Phone: 206 438 2333
Client Contact: Suren Balendra	
Client Project Name: Fisher Slough	
Client Project #: 33760911	Samplers:
Date: 10/13/08	Page: 1 of 1
No. of Coolers:	Cooler Temps:

Sample ID	Date	Time	Matrix	No. Containers	Compaction ASTM D1557/D698	Sieve							Notes/Comments
TP-1 @ 0-4'	10/6/08				X	X							
TP-1 @ 7.5'	10/6/08				X	X							
ATP-2 @ 0-4'	10/6/08				X	X							
TP-4 @ 2-4	10/6/08				X	X							
TP-6 @ 0-2	10/6/08				X	X							

Comments/Special Instructions	Relinquished by:	Received by:	Relinquished by:	Received by:
5 gal bucket sample	(Signature) B. Sivendra	(Signature) [signature]	(Signature)	(Signature)
	Printed Name: Suren Balendra	Printed Name: Erik Kacarda	Printed Name:	Printed Name:
	Company: URS, Seattle	Company: ARI	Company:	Company:
	Date & Time: 10/13/08	Date & Time: 10/14/08 12:02	Date & Time:	Date & Time:

Limits of Liability: ARI will perform all requested services in accordance with appropriate methodology following ARI Standard Operating Procedures and the ARI Quality Assurance Program. This program meets standards for the industry. The total liability of ARI, its officers, agents, employees, or successors, arising out of or in connection with the requested services, shall not exceed the invoiced amount for said services. The acceptance by the client of a proposal for services by ARI release ARI from any liability in excess thereof, not withstanding any provision to the contrary in any contract, purchase order or co-signed agreement between ARI and the Client.

Sample Retention Policy: All samples submitted to ARI will be appropriately discarded no sooner than 90 days after receipt or 60 days after submission of hardcopy data, whichever is longer, unless alernate retention schedules have been established by work-order or contract.

URS Corporation

Fisher Slough

Sample Identification	Moisture Content (%)	Percent Fines (-#200 Sieve)
TP-A @ 0-4	4.45	32.4
TP-1 @ 7.5	5.66	73.5
TP-4 @ 2-4	20.18	81.5
TP-6 @0-2	3.61	77.2

URS Corporation
Fisher Slough

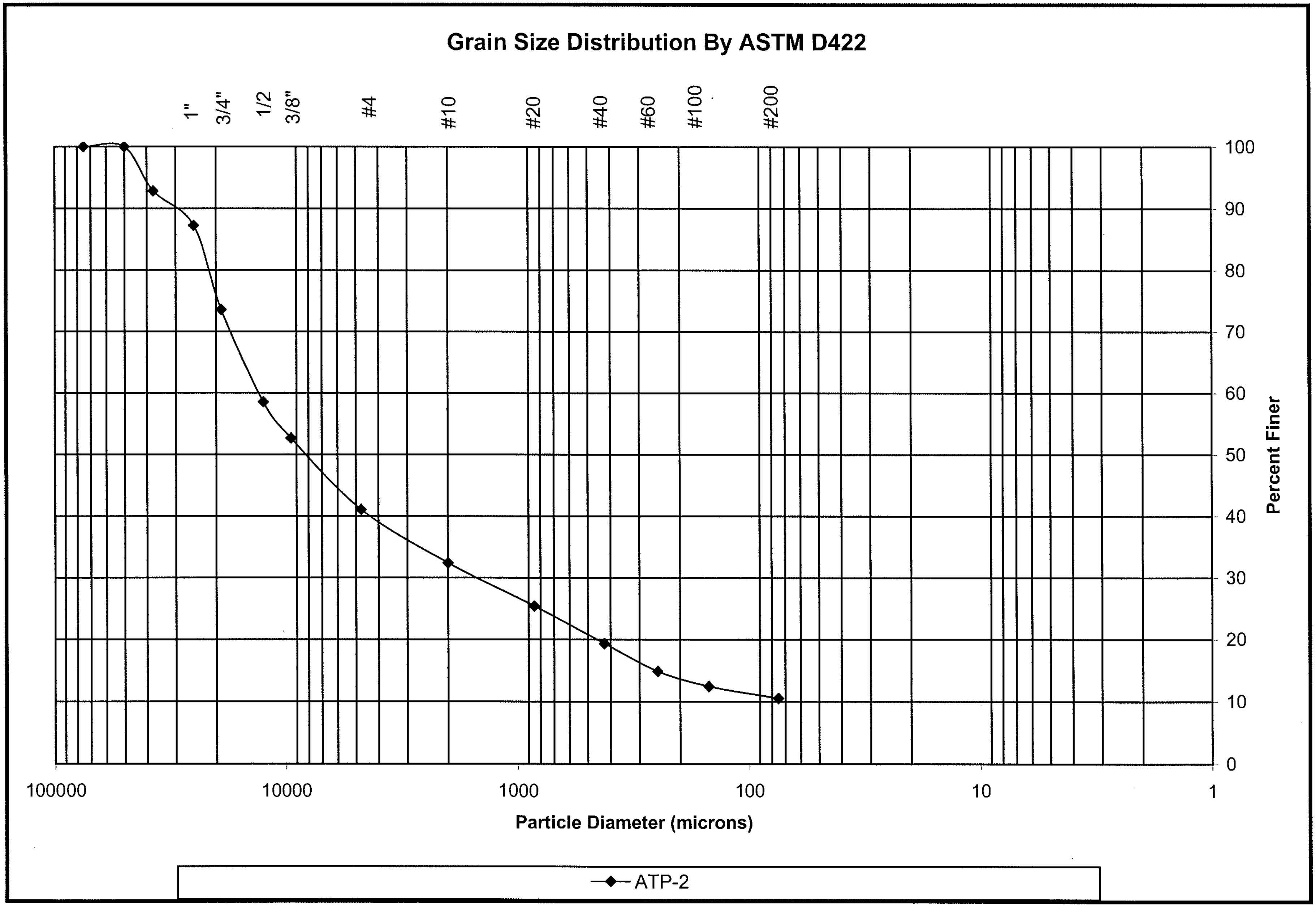
Percent Finer Than Indicated Size, By ASTM D422

Sample ID	Depth (ft)	Moisture Content (%)	3"	2"	1.5"	1"	3/4"	1/2"	3/8"	#4	#10	#20	#40	#60	#100	#200
ATP-2	0-4'	2.92	100.0	100.0	92.8	87.2	73.6	58.5	52.7	41.1	32.4	25.4	19.3	14.9	12.5	10.5

URS Corporation
Fisher Slough

Percent Retained in Each Size Fraction, By ASTM D422

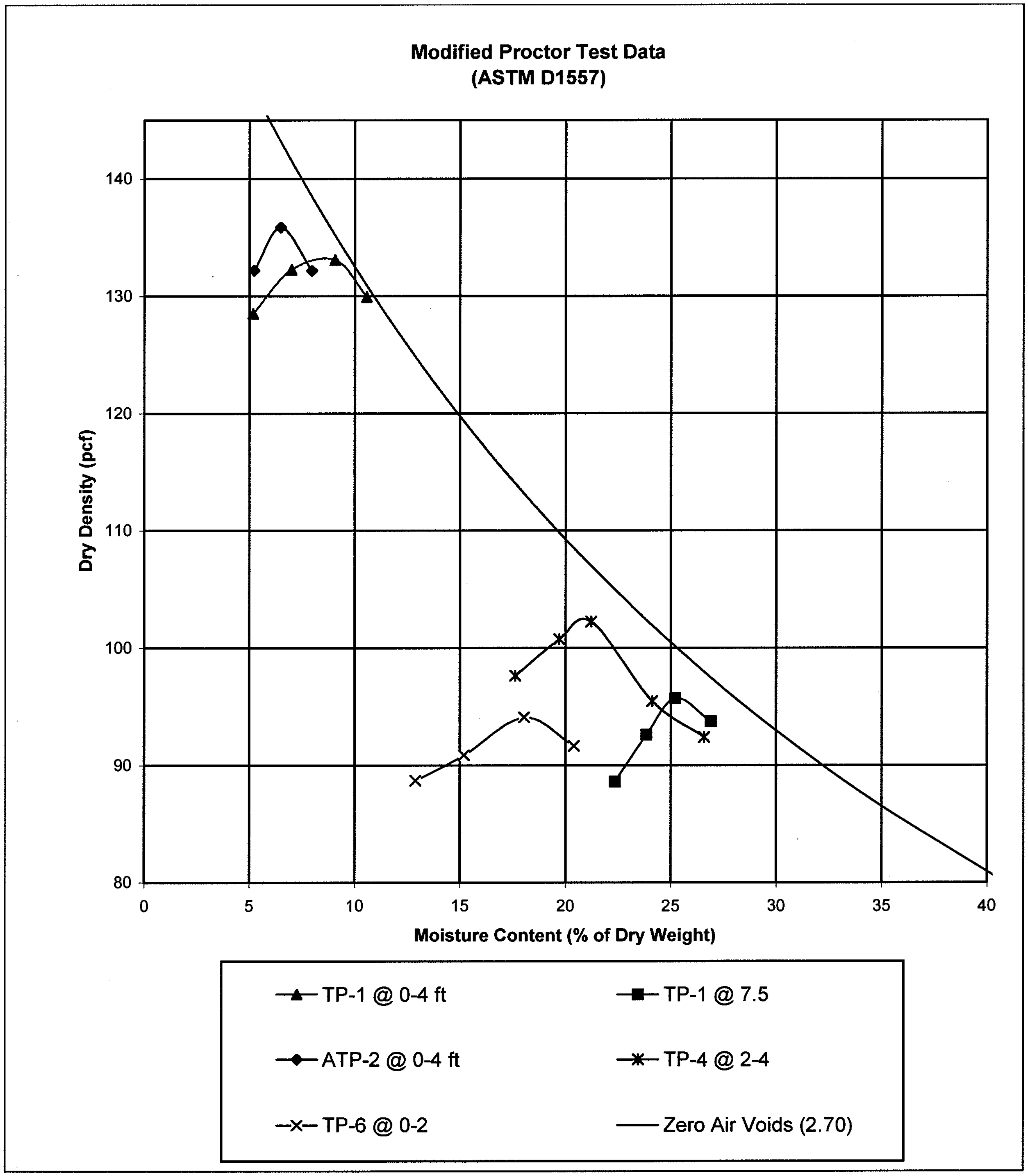
Sieve Size (microns)	3-2"	2-1.5"	1.5-1"	1-3/4"	3/4-1/2"	1/2-3/8"	3/8-#4	4750-2000	2000-850	850-425	425-250	250-150	150-75	<75
ATP-2	0.0	7.2	5.6	13.7	15.1	5.9	11.6	8.7	7.0	6.1	4.5	2.4	1.9	10.5



Grain Size Distribution By ASTM D422
1"
3/4"
1/2
3/8"
#4
#10
#20
#40
#60
#100
#200
100
90
80
70
60
50
40
30
20
10
0
Percent Finer
100000
10000
1000
100
10
1
Particle Diameter (microns)
ATP-2

URS - Seattle

Fisher Slough



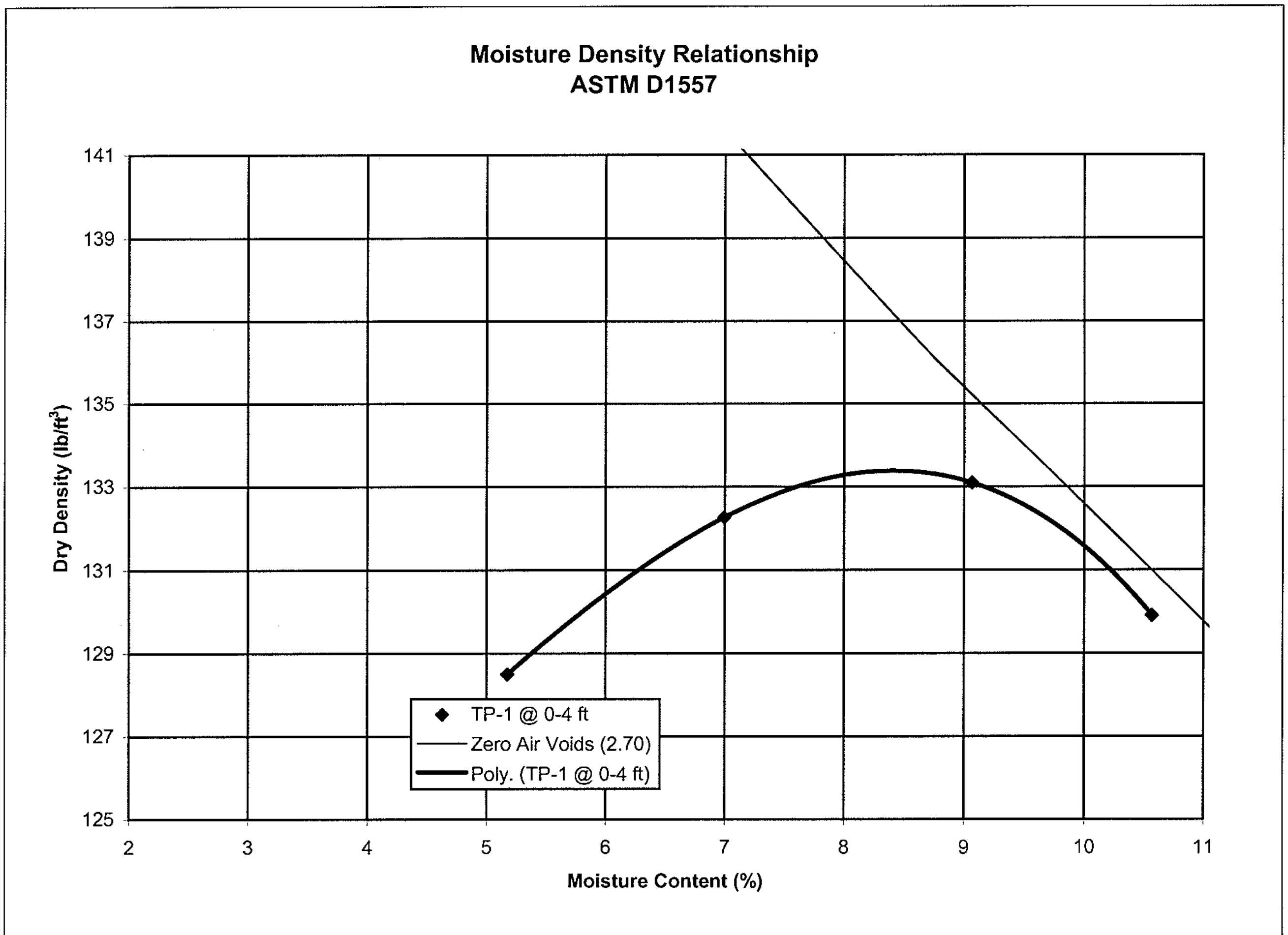
Moisture Density Relationship
ASTM D-1557, Method C

Client:	URS - Seattle	Date:	November 2, 2008
Project:	Fisher Slough		
Project No.:	33760911		
Sample ID:	TP-1 @ 0-4 ft		

	Standard		Corrected	
Optimum Moisture Content	8.4	%	NA	%
Maximum Density	133.5	lb/ft^3	NA	lb/ft^3

Percent retained on the 3/4 inch sieve	0.0	Rock correction required?	No

Note: The plot shows as-tested data (material greater than 3/4" removed).



If required, the Rock Correction is performed according to ASTM D4718

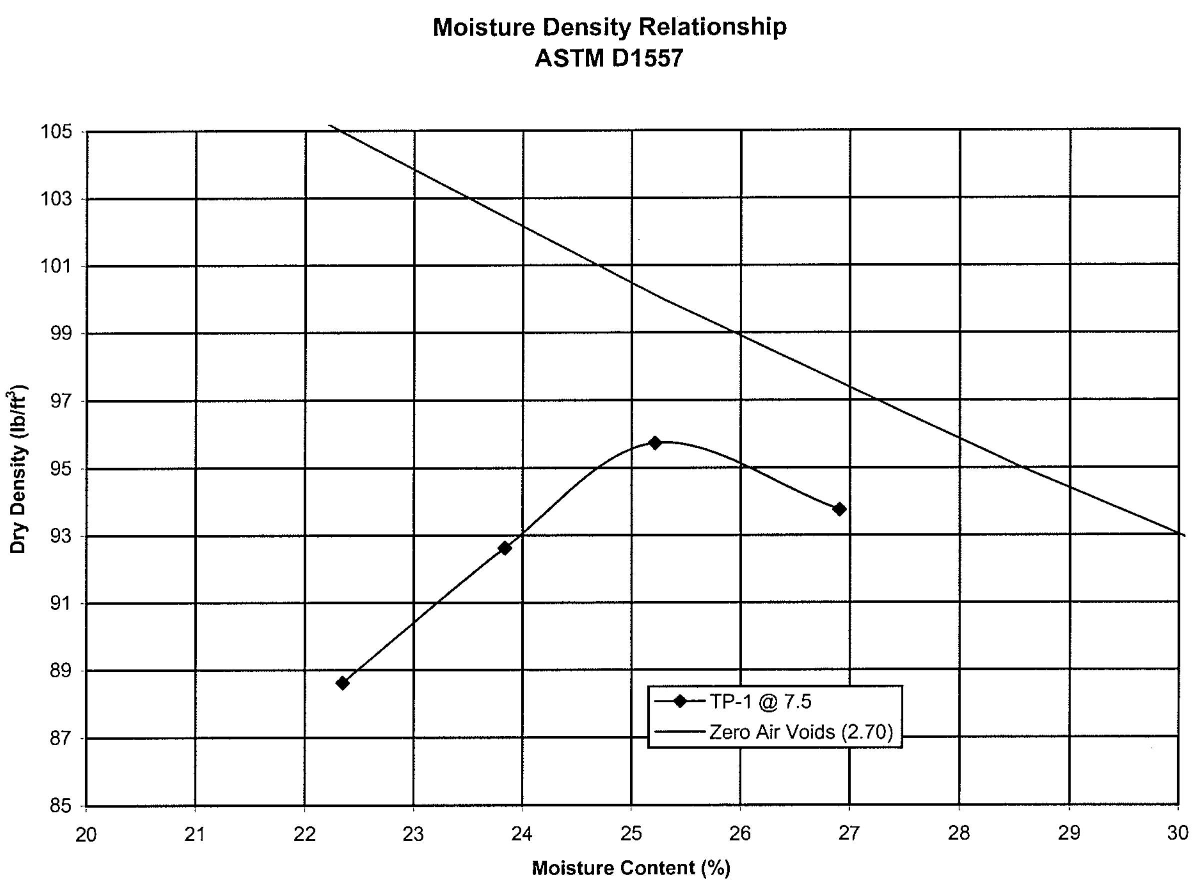
Moisture Density Relationship
ASTM D-1557, Method C

Client:	URS - Seattle	Date:	November 2, 2008
Project:	Fisher Slough		
Project No.:	33760911		
Sample ID:	TP-1 @ 7.5		

	Standard		Corrected	
Optimum Moisture Content	25.3	%	NA	%
Maximum Density	95.8	lb/ft^3	NA	lb/ft^3

Percent retained on the 3/4 inch sieve	0.0	Rock correction required?	No

Note: The plot shows as-tested data (material greater than 3/4" removed).



If required, the Rock Correction is performed according to ASTM D4718

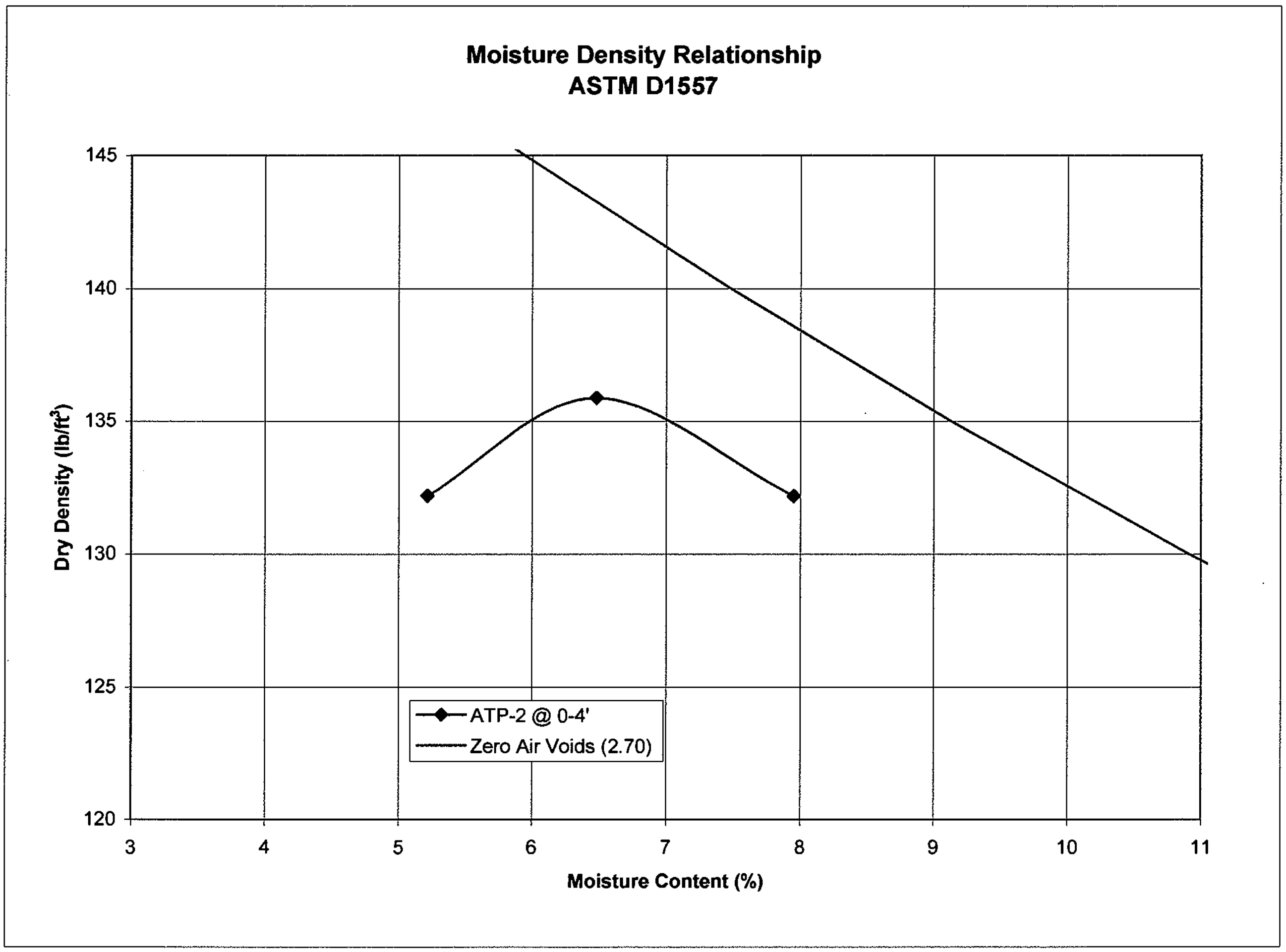
Moisture Density Relationship
ASTM D-1557, Method C

Client:	URS - Seattle	Date:	November 2, 2008
Project:	Fisher Slough		
Project No.:	33760911		
Sample ID:	ATP-2 @ 0-4'		

	Standard		Corrected	
Optimum Moisture Content	6.5	%	4.7	%
Maximum Density	138.9	lb/ft^3	147.2	lb/ft^3

Percent retained on the 3/4 inch sieve	33.9	Rock correction required?	Yes

Note: The plot shows as-tested data (material greater than 3/4" removed).



If required, the Rock Correction is performed according to ASTM D4718

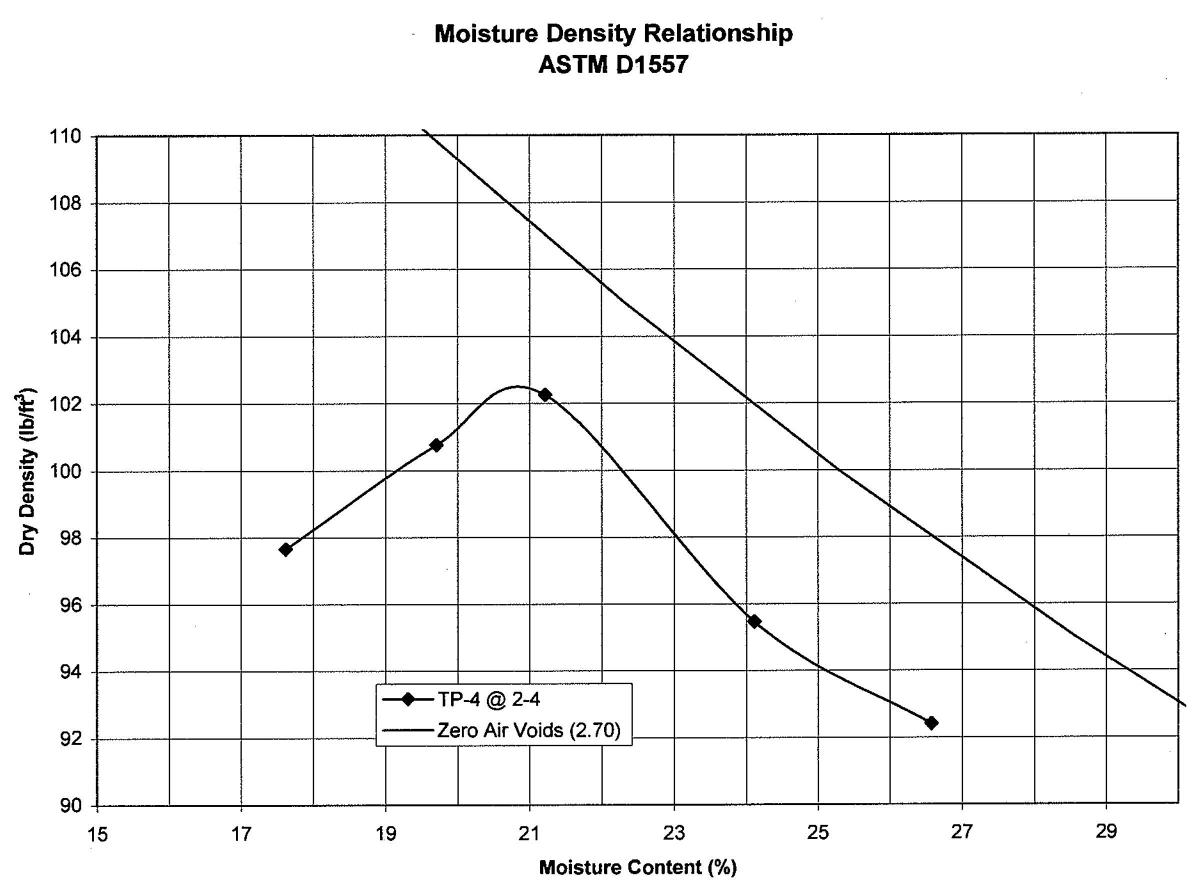
Moisture Density Relationship
ASTM D-1557, Method C

Client:	URS - Seattle	Date:	October 27, 2008
Project:	Fisher Slough		
Project No.:	33760911		
Sample ID:	TP-4 @ 2-4		

	Standard		Corrected	
Optimum Moisture Content	20.9	%	NA	%
Maximum Density	102.3	lb/ft^3	NA	lb/ft^3

Percent retained on the 3/4 inch sieve	0.0	Rock correction required?	No

Note: The plot shows as-tested data (material greater than 3/4" removed).



If required, the Rock Correction is performed according to ASTM D4718

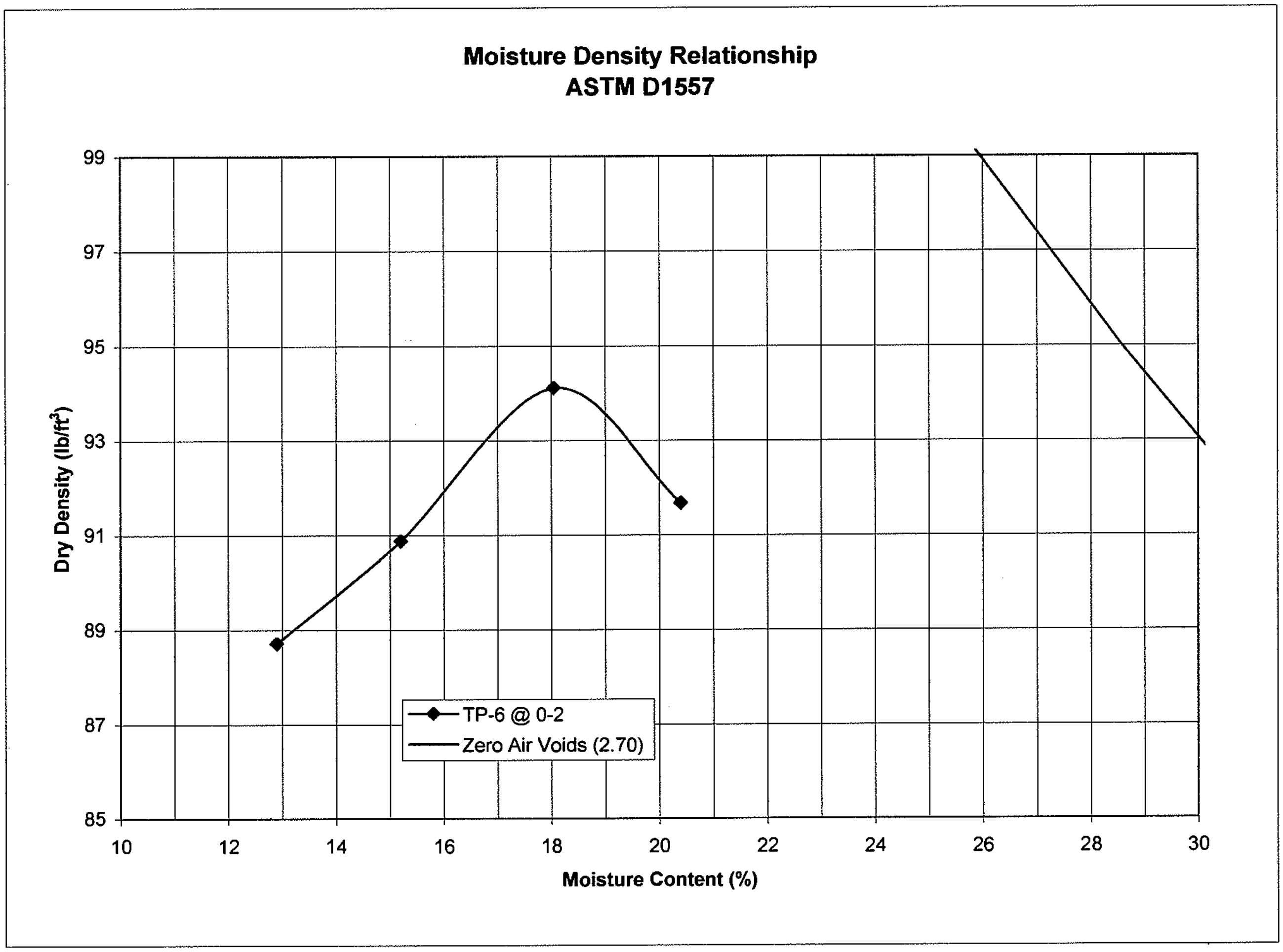
Moisture Density Relationship
ASTM D-1557, Method C

Client:	URS - Seattle	Date:	October 27, 2008
Project:	Fisher Slough		
Project No.:	33760911		
Sample ID:	TP-6 @ 0-2		

	Standard		Corrected	
Optimum Moisture Content	18.1	%	NA	%
Maximum Density	94.1	lb/ft^3	NA	lb/ft^3

Percent retained on the 3/4 inch sieve	0.0	Rock correction required?	No

Note: The plot shows as-tested data (material greater than 3/4" removed).



If required, the Rock Correction is performed according to ASTM D4718