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REPORT OF GEOTECHNICAL EXPLORATION AND REVIEW

EDA North Business Development
Duluth International Airport
Duluth, Minnesota

AET #07-03140

Date:

March 16, 2009

Prepared for:

Mr. Darren Christopher, PE
Reynolds, Smith & Hills
4525 Airport Approach Road, Suite A
Duluth, Minnesota 55811

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March 16, 2009

Mr. Darren Christopher, PE
Reynolds, Smith & Hills
4525 Airport Approach Road
Duluth, Minnesota 55811

RE: Geotechnical Exploration and Review
EDA North Business Development
Duluth International Airport
Duluth, Minnesota
AET #07-03140

Dear Mr. Christopher:

American Engineering Testing, Inc. (AET) has completed a subsurface exploration and geotechnical engineering review for the above referenced project. We are sending you two copies of our report. The report documents the exploration/review results and provides our opinions and recommendations to aid you and your design team in planning and construction of the project.

AET appreciates this opportunity to serve you. As your project proceeds, we remain interested in providing additional consulting or testing services. If you have questions about the report, or if we can provide additional services for you, I can be reached at (218) 628-1518 or sleow@amengtest.com.

Sincerely,
American Engineering Testing, Inc.

Sara L. Leow, PE
Geotechnical Engineer

4431 West Michigan St. Suite 4 | Duluth, MN 55807
Phone (218) 628-1518 | Toll Free 800-972-6364 | Fax (218) 628-1580 | www.amengtest.com
Offices throughout Florida, Minnesota, South Dakota & Wisconsin

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GEOTECHNICAL EXPLORATION AND REVIEW
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INTRODUCTION

This report presents the results of a subsurface exploration and geotechnical engineering review for the proposed EDA North Business Development pavement areas at the Duluth International Airport, in Duluth, Minnesota.

To protect you, American Engineering Testing, Inc. (AET), and the public, we authorize use of opinions and recommendations in this report only by you and your project team for this specific project. Contact us if other uses are intended. Even though this report is not intended to provide sufficient information to accurately determine quantities and location of particular materials, we recommend that your potential contractors be advised of the report availability.

Scope of Services

AET's work on this project was performed in accordance with our proposal #07-03140 Revised-A dated November 24, 2008 which was authorized by you. Our scope of services for this project consists of:

- Arranging for existing utility locations through the Gopher State One-Call Service and the Duluth International Airport.
- Performing twelve standard penetration test (SPT) borings to depths of 8 to 18 feet below the existing surface, or refusal, in general accordance with ASTM D1586. AET extended five of the test borings to a depth of 25 feet, as directed by RS&H.
- Performing laboratory testing on selected samples to aid in soil classification and estimation of engineering properties.
- Preparing a geotechnical report, which includes our recommendations for pavement subgrade, pavement sections, and site grading for an aircraft apron, access road, and vehicle parking lots.

The scope of our work is intended for geotechnical purposes only. This scope is not intended to explore for the presence or extent of environmental contamination at the site or provide opinions regarding the status of the site relative to "wetland" definitions.

PROJECT INFORMATION

Reynolds, Smith & Hills (RS&H) is providing design services for pavement areas for the proposed EDA North Business Development at the Duluth International Airport in Duluth, Minnesota. The development is planned to be constructed west of the existing Northwest Airlines Maintenance Hangar, north of Taxiway B and Runway 9/27.

We understand the development will consist of two hangars, a new aircraft parking apron, access roads, vehicle parking areas, and associated utilities. We also understand the present project phase consists of design of the aircraft and vehicle pavement areas. RS&H informed AET that stormwater ponds are also planned at the site, although the pond locations have not yet been selected.

According to the information provided to AET, the new aircraft apron pavement section is planned to consist of concrete or bituminous pavement, crushed aggregate base, and well-draining subbase. AET's recommendations for the pavement section are based on current Federal Aviation Administration (FAA) design guidelines presented in FAA Advisory Circular Number 150/5320-6D, "Airport Pavement Design and Evaluation," as well as local knowledge and past design experience. The access road and vehicle parking pavement areas are planned to consist of bituminous pavement, crushed aggregate base, and a well-draining subbase designed per specifications in the Mn/DOT Geotechnical Pavement Manual Part II.

RS&H informed AET that material excavated from previous construction areas at the airport was placed across the proposed apron and vehicle pavement areas, making these areas approximately 10 feet higher than the airfield perimeter road and Taxiway B. We understand the site will be cut approximately 10 feet in apron and vehicle parking areas to match the airfield perimeter road and Taxiway B grades.

Pavement Design Assumptions

RS&H informed AET that two design aircraft are being considered separately for the apron pavement design. Both of the considered aircraft have a dual-gear configuration. One design aircraft has a gross weight of 50,000 pounds, and the other aircraft has a gross weight 100,000 pounds. RS&H informed AET that the design is planned to include aircraft operating at a frequency of approximately 1,200 departures per year, which is the design minimum departure frequency. AET assumes that loaded fuel vehicles and freight trucks will also utilize the access roads and the apron areas to access the design aircraft.

Based on FAA Circular 150/5320-6D, the design air freezing index for Duluth, Minnesota, is approximately 2,750 degree-days. AET estimates the dry soil density of the subgrade soils are on the order of 115 pounds per cubic foot. Frost has been observed as deep as 100 inches in areas cleared of snow, such as taxi lanes, in past geotechnical investigations. Frost tolerant pavement sections have been successful at Duluth International Airport when a 60-inch apron pavement section is used that includes well drained, non-frost susceptible engineered fill as the pavement subbase.

> The presented project information represents our understanding of the proposed construction. This information is an integral part of our engineering review. It is important that you contact us if there are changes from that described so that we can evaluate whether changes in our recommendations are appropriate.

SITE CONDITIONS

Surface Observations

On the date of drilling, the proposed new apron, access road, and parking areas were covered by snow. Test borings 09-03 and 09-04 were advanced in existing bituminous pavement areas. An existing gravel access road follows along the majority of the proposed access road alignment, with the exception of the southern and western portions of the proposed road. A shotrock waste pile was observed to exist northeast of test boring 09-07. The ground surface in the area of the proposed apron and vehicle parking lot east of the apron was observed to be approximately 10 feet higher than the existing airfield perimeter road south of the proposed apron.

Subsurface Soils/Geology

Logs of the test borings are included in the Appendix. Please refer to the logs for more detailed information concerning soil layering, soil classification, geologic description and moisture. Relative density or consistency is also noted, which is based on the standard penetration resistance (N-value).

Apron Pavement Areas

Test borings 09-01, 09-02, 09-05, and 09-12 were performed in the proposed apron areas. Due to the planned 10 foot cut, hand samples were acquired from the flights of the hollow-stem auger to a depth of 10 feet, then split spoon samples were acquired below this depth for test borings 09-02, 09-05, and 09-12.

The soil conditions indicated by the test borings generally consist of topsoil or existing fill overlying till. Fine and coarse alluvium were encountered beneath the existing fill in test boring 09-05. The existing fill depths encountered in test borings 09-02, 09-05, and 09-12 range from 12½ to 20½ feet below the existing ground surface. Silty sand with gravel, slightly organic sandy silt, silty clayey sand with gravel, and mixtures of silty sand with gravel, sand gravel, slightly organic clay, and organic silt comprise the existing fill. Apparent cobbles were encountered in the fill in test borings 09-05 and 09-12. Approximately 2 inches of topsoil comprised of organic sandy clay was encountered in test boring 09-01, advanced near the existing airfield perimeter road.

The till is composed of silty sand with gravel, gravelly silty sand, sandy silt, and sandy silty clay. Apparent cobbles were encountered at varying depths within the till soils. The recorded N-values indicate the non-cohesive (sand) till is medium dense to dense.

The coarse alluvium encountered in test boring 09-05 is comprised of sand with silt, and the fine alluvium consists of silt. Based on the recorded N-values, the sand with silt is dense and the silt is medium dense.

Vehicle Pavement Areas

Test borings 09-03 and 09-04 were advanced in the proposed parking lot area east of the apron, test boring 09-06 was performed near the proposed parking lot area northwest of the apron, test borings 09-07 and 09-08 were performed by the access road north of the apron, and test borings 09-09, 09-10, and 09-11 were performed along the access road portion northeast of the proposed apron. Similar to the test borings advanced in the apron area, the first 10 feet of test borings 09-03 and 09-04 were advanced with hollow stem auger, and split spoon samples were collected below the 10 foot depth due to the planned 10 foot cut. The test borings performed in the access road and parking lot pavement areas indicate a general soil profile of existing fill overlying till. Coarse and fine alluvium were also encountered in two test borings.

Existing fill depths range between approximately 5 to 19 feet. Gravelly silty sand, silty sand with gravel, silty clayey sand, organic sandy silt, slightly organic sandy clay, slightly organic silty sand with gravel, and mixtures of silty sand with gravel and slightly organic to organic soils constitute the existing fill. Apparent cobbles were encountered in the existing fill in test borings 09-06, 09-08, and 09-11.

The till is composed of silty sand with gravel, gravelly silty sand, and silty clayey sand with gravel. The recorded N-values indicate the till is loose to medium dense. Apparent cobbles were encountered in the till in test boring 09-03. Fine alluvium was encountered beneath the existing fill in test boring 09-06, and consists of firm lean clay with sand. Coarse alluvium encountered in test boring 09-10 is composed of loose sand with silt, and may be fill.

The boring logs only indicate the subsurface conditions at the sampled locations. Variations often occur between and beyond borings.

Water Level Measurements

Groundwater was encountered at depths between 5.5 and 25.8 feet in test borings 09-01, 09-02, and 09-12, but was not encountered in the other test borings. The soils encountered in the test borings are considered slow draining to relatively impermeable, and any groundwater present in these soils may not have had enough time to collect and/or stabilize in the boreholes before they were abandoned. For this reason, water level measurements from the test borings may not be reliable for assessing the static groundwater level in the area. A discussion of the water level measurement methods is presented in the SUBSURFACE EXPLORATION section of this report.

> Ground water levels usually fluctuate. Fluctuations occur due to varying seasonal and yearly rainfall and snow melt, as well as other factors.

GEOTECHNICAL CONSIDERATIONS

The following geotechnical considerations are the basis for the recommendations presented later in this report.

Review of Soil Properties

Strength/Stability

The existing fill is considered to have low strength and stability due to the undocumented nature in which it was placed and/or organic content. The native till and alluvium soils are considered to have high strength and stability; however, if the native soils become disturbed or are subjected to excess moisture, the strength and stability may greatly decrease.

Compressibility

The existing fill soils are considered to have a high compressibility potential if subjected to heavy loads, such as parked aircraft. The till and alluvium soils are considered to have low compressibility potential under the anticipated aircraft loads, unless softened by disturbance or excess moisture.

Frost Susceptibility

The existing fill is considered to have high frost susceptibility due to the organic and/or silt content. The till soils and silt fine alluvium are considered to be FAA Frost Group 4 (FG-4) soils, which are highly frost susceptible. The sand with silt and lean clay are considered moderately frost susceptible.

Drainage Properties

The existing fill, till, and fine alluvium soils encountered at the site are considered slow draining to relatively impermeable. The sand with silt coarse alluvium is considered permeable and relatively fast draining.

Vehicle Pavement Area Subgrade Definitions

Critical Subgrade Zone

The subgrade is directly below the subbase or aggregate base layer. In this report, the critical subgrade zone is considered the subgrade portion within three vertical feet of the final pavement surface.

Poor Stability Soils

Poor stability soils typically have a water content that exceeds the optimum water content defined by the Standard Proctor (ASTM D698). These soils excessively rut or deflect under a test roll procedure, as described on the attached sheet entitled "Bituminous Pavement Subgrade Preparation and Design."

Modified Select Granular Borrow

Modified Select Granular Borrow is a soil meeting Mn/DOT Specification 3149.2B2, but modified such that the soil contains less than 7% (rather than 12%) by weight passing the #200 sieve. This material also meets the requirement for non-frost susceptible sand.

Geotextile Fabric

For this report, a geotextile has the minimum requirements for a Type V fabric (for separation/stabilization) defined in Mn/DOT Specification 3733, and includes filtering properties. The geotextile also meets the requirements of Type I, II, III and IV fabrics.

APRON PAVEMENT RECOMMENDATIONS

Soil Frost Considerations

Frost depth has been observed at the Duluth International Airport in excess of 8 feet in snow cleared areas such as aprons, taxi lanes, and runways. To develop a pavement section totally tolerant of frost, a 100 inch thick section would need to be constructed, which is a costly pavement section. Frost tolerant pavement sections, only 60 inches in thickness, have been used successfully at the Duluth International Airport. While this reduced pavement section does not eliminate the potential for frost action, this section significantly reduces differential movement at the surface of the pavement.

Site Grading for Pavement Areas

Preparation of the area for the new concrete and/or bituminous apron area should include removing existing fill, native soils, and any existing pavement sections within 60 inches of the final new pavement surface elevation. The base of the excavations should be evaluated for deviations from this depth. If unsuitable soils (i.e., disturbed native soils, wet soils, soft soils, or other compressible soils) are exposed at the base of the excavation, these soils should be removed.

Concrete Pavement

Concrete Thickness Design

FAA design methods were used to develop pavement recommendations for the proposed concrete apron. Laboratory testing results, shown in the Appendix, indicate a field CBR value of 12 for the existing fill and native till soils when undisturbed. Since the controlling factor for design is frost, stabilization of the subgrade is not primary. The use of a P-154 subbase to minimize frost action will also significantly reduce stresses at the subgrade.

A frost tolerant design consisting of a 60 inch pavement section of non-frost susceptible soils is recommended. The potential for frost action can be additionally reduced if all frost susceptible soils are excavated to additional depths. We estimate the modulus of subgrade reaction, *k*, of the undisturbed subgrade soil at the base of the pavement section to be at least 150 pounds per cubic inch. We also estimate the proposed thickness of granular subbase, P-154, will provide a *k* of at least 350 pounds per cubic inch. The use of the recommended crushed aggregate subbase, P-209, will provide a *k* at the concrete pavement interface of at least 400 pounds per cubic inch. AET recommends at least one plate load test be performed on the compacted P-154 subbase prior to base and concrete placement to document the modulus of subgrade reaction.

We recommend concrete with a minimum flexural strength of 650 pounds per square inch be used for the concrete pavement. Recent airport pavements have been developed and constructed from concrete with this design flexural strength.

Critical pavement thicknesses were designed using the FAA Rigid Pavement design method outlined in Advisory Circular 150/5320-6D. The critical pavement thicknesses were based on dual-geared aircraft with a gross weight of 50,000 or 100,000 pounds, a design concrete flexural strength of 650psi, a *k* of 350 pounds per cubic foot, and 1,200 departures per year. For a dual-geared aircraft weighing 50,000 pounds, these calculations yield a required critical pavement thickness of 7 inches. The FAA Rigid Pavement design method yields a critical pavement thickness of 11 inches for a dual-geared aircraft with a gross weight of 100,000 pounds.

Concrete Joints

The concrete pavement should be jointed a maximum of 20 feet in any direction, but the geometric jointing pattern of existing concrete pavement should be used for uniformity. At the interface of the new concrete and the existing concrete pavement for Taxiway B, a ¾ inch sealed expansion joint should be constructed, and the new concrete should be doweled into the existing concrete pavement. All joints for the concrete pavement for 50,000 pound gross weight aircraft should be doweled with ¾-inch diameter epoxy coated bars with a minimum length of 18 inches, placed every 12 inches along the joint. Concrete pavement for 100,000 pound gross weight aircraft, should have joints doweled with 1” diameter epoxy coated bars 19 inches in length, and spaced every 12 inches. Joints should conform to FAA Section 3 Table A-10A Types A, D, E, and F, as suitable for location and purpose.

Crushed Aggregate Base and Subbase

Below the concrete pavement, crushed base aggregate meeting the requirements of FAA P-209 should be placed. The subbase should consist of granular soil meeting the requirements of FAA P-154 modified so no more than 5% by weight passes the #200 sieve. If the pavement section is designed for a gross aircraft weight of 50,000 pounds, 8 inches of P-209 aggregate base should be placed over 45 inches of P-154 granular subbase. For a gross aircraft weight of 100,000 pounds, 12 inches of aggregate base should be placed over 37 inches of subbase. These designs account for trucks with a maximum weight of 68,000 pounds operating on the pavement, as well.

Compaction Requirements

The compaction requirements for the concrete pavement section vary with depth. Item P-209 in FAA Advisory Circular 150/5370-10B specifies the compaction requirements for FAA P-209 crushed aggregate base course, and Section 3, Part 329 of FAA Advisory Circular 150/5320-6D outlines the requirements for compaction depths of non-cohesive soils in cut areas. Tables 1 and 2 summarize the compaction requirements for the recommended concrete pavement sections. We do not recommend compacting the exposed subgrade soils at the base of the pavement section excavations.

Table 1: Compaction Requirements for Concrete Pavement Section – 50,000 Pound Gross Weight, Dual-Gear Aircraft

Compaction Requirement (ASTM D1557)	Depth Range from Pavement Surface (inches)	Pavement Section Materials Included
100%	0-27	8" P-209, upper 24" P-154
95%	27-60	lower 33" P-154
90%	Below 60	P-154 replacing unsuitable native soils

Table 2: Compaction Requirements for Concrete Pavement Section – 100,000 Pound Gross Weight, Dual-Gear Aircraft

Compaction Requirement (ASTM D1557)	Depth Range from Pavement Surface (inches)	Pavement Section Materials Included
100%	0-35	12" P-209, upper 12" P-154
95%	35-60	lower 25" P-154
90%	Below 60	P-154 replacing unsuitable native soils

Bituminous Pavement

Pavement Thickness Design

FAA Flexible Pavement design methods outlined in Advisory Circular 150/5320-6D were used to develop pavement recommendations for the bituminous apron. The aircraft design parameters used for the concrete pavement section were also used for design of the bituminous pavement. These parameters include dual-geared aircraft with gross weights of 50,000 or 100,000 pounds and 1,200 departures per year. A CBR of 12, as indicated from laboratory testing, was used for subgrade field conditions.

Bituminous and Crushed Aggregate Base Design

The bituminous pavement for the apron should consist of FAA P-401 placed in lifts. Each lift should be 2 inches in thickness. The bituminous pavement should utilize a PG64-28 binder, which is considered a rut resistant binder. The maximum aggregate size in the P-401 mixture should be 1 inch, and the minimum aggregate size ¾ inch, with parameters suitable for aircraft greater than 60,000 pounds.

For a 50,000 pound gross weight aircraft, we calculate the pavement section should consist of 4 inches of FAA P-401 and 8 inches of crushed aggregate base meeting the requirements for FAA P-209. For aircraft with a gross weight of 100,000 pounds, the FAA Flexible Pavement design method indicates an FAA P-401 thickness of 6 inches, and an FAA P-209 thickness of 10 inches. These thicknesses also consider trucks with a maximum weight of 68,000 pounds operating on the pavement.

Subbase

For frost tolerant design, AET recommends a total pavement section of 60 inches be placed in bituminous apron areas. If the combination of 4 inches of bituminous and 8 inches of P-209 is utilized for 50,000 pound gross weight aircraft, the subbase should be 48 inches thick. If the combination of 6 inches of P-401 and 10 inches of P-209 is utilized for 100,000 pound gross weight aircraft, the subbase should be 44 inches thick. The subbase should consist of granular soil meeting the requirements of FAA P-154 modified so no more than 5% by weight passes the #200 sieve.

Compaction Requirements

Similar to a concrete pavement section, the compaction requirements for the bituminous pavement sections differ with depth. Item P-209 in FAA Advisory Circular 150/5370-10B specifies the compaction requirements for FAA P-209 crushed aggregate base course, and Table 3-2 in FAA Advisory Circular 150/5320-6D outlines the requirements for subgrade compaction for flexible pavement sections. Tables 3 and 4 summarize the compaction requirements for the bituminous pavement sections. Compaction of FAA P-401 should follow the specifications for Item P-401 in FAA AC150/5370-10B. We do not recommend compacting the exposed subgrade soils at the base of the pavement section excavations.

Table 3: Compaction Requirements for Bituminous Pavement Section for 50,000 Pound Gross Weight, Dual-Gear Aircraft

Compaction Requirement (ASTM D1557)	Depth Range from Pavement Surface (inches)	Pavement Section Materials Included
100%	0-24	8" P-209, 12" P-154
95%	24-40	16" P-154
90%	40-50	10" P-154
85%	Below 50	P-154 replacing unsuitable native soils

Table 4: Compaction Requirements for Bituminous Pavement Section for 100,000 Pound Gross Weight, Dual-Gear Aircraft

Compaction Requirement (ASTM D1557)	Depth Range from Pavement Surface (inches)	Pavement Section Materials Included
100%	0-33	10" P-209, 17" P-154
95%	33-46	13" P-154
90%	46-58	12" P-154
85%	Below 58	P-154 replacing unsuitable native soils

Drainage, Geotextile, and Transitions

Subbase Drainage

The subgrade should be shaped to promote drainage and prevent ponding of water within the subbase. Water within the subbase will reduce soil strength.

Geotextile Fabric for Separation

If gravel is used as fill, a geotextile fabric should be used to separate the gravel from native soils, granular subbase, or coarse aggregate base. A geotextile fabric should meet the requirements of Mn/DOT 3733 Type V fabric.

Section Transitions

The thickness of the subbase should be tapered where it needs to transition between the existing pavement structure, or a pavement section with a differing thickness of subbase. The taper of the subbase thickness should be no steeper than 10 horizontal to 1 vertical (10H:1V). If possible, transitions should be limited to 20 horizontal to 1 vertical (20H:1V) to reduce the potential for abrupt differential movement from frost action.

VEHICLE PAVEMENT AREA RECOMMENDATIONS

Our recommendations for a pavement design for the access roads and parking lots are based on the Minnesota Department of Transportation (Mn/DOT) Geotechnical and Pavement Manual Part II. We understand the access road pavement may be subjected to passenger vehicles and relatively heavy truck traffic stopping, turning, and operating at low speeds. The parking lots may be subjected to passenger vehicles and light trucks. Maintenance equipment may also access these areas. This type of traffic loading for the access road is considered Mn/DOT Traffic Level C, and traffic loading for the parking lots is considered Mn/DOT Traffic Level A.

Subgrade Preparation

As discussed for the apron pavement sections, frost can penetrate to depths of 100 inches at the Duluth International Airport. The soils encountered in the test borings advanced in access road and parking lot pavement areas mainly consist of silty soils. These subgrade soils are highly frost susceptible. These soils will heave upon freezing, and then soften with each spring thaw, which can contribute to premature pavement failure. Removing all frost susceptible soils from the pavement areas, and replacing these soils with engineered fill, would result in the best pavement performance. Removing all frost susceptible soils is usually costly, however, and we assume the owner can tolerate some frost movement to make the pavement section more economically feasible.

To help reduce frost heave and provide greater support for the pavement section, frost susceptible soils are typically removed from the critical subgrade zone and replaced with a pavement section that includes a granular subbase. In the new pavement area, we recommend subcutting to a depth which allows placing a new pavement section with a granular subbase throughout the critical subgrade zone. We recommend a geotechnical engineer observe and review all pavement area excavations prior to placing the pavement section.

Pavement Section Design

Similar to the apron pavement areas, a CBR value of 12 was considered for the subgrade soils in the access road and parking lot areas. For the access road, we recommend placing the following pavement section directly on existing soils observed by a geotechnical engineer. This pavement section is based on Traffic Level C.

- 2 inches of Bituminous Wear (Mn/DOT SPWEB440E)
- 2 inches of Bituminous Binder Course (Mn/DOT SPWEB440E)
- 2 inches of Bituminous Base Course (Mn/DOT SPNWB430B)
- 6 inches of Class 6 Aggregate Base (Mn/DOT 3138)
- 24 inches Modified Select Granular Borrow

For parking lot areas that will mainly be subjected to passenger vehicle/ light truck traffic, and will be trafficked infrequently by heavy trucks, the traffic level is considered Mn/DOT Traffic Level A. The following pavement section may be constructed in parking lot areas:

- 1.5 inches of Bituminous Wear (Mn/DOT SPWEB240B)
- 2 inches of Bituminous Base Course (Mn/DOT SPWEB240B)
- 6 inches of Class 6 Aggregate Base (Mn/DOT 3138)
- 26 inches Modified Select Granular Borrow

These pavement sections do not totally eliminate frost heave. They will, however, reduce the amount of frost heave and settlement, and will significantly decrease the abruptness or differential nature of heave and settlement, to provide relatively good performance.

Engineered fill should be used to attain grade in areas where the subgrade elevation is to be raised. Non-organic select granular soils are the preferred type of engineered fill for drainage and strength. AET recommends a granular subbase consisting of Modified Select Granular Borrow. All topsoil and soils containing organics should be removed prior to placing engineered fill. Also, any areas that become soft or disturbed as a result of construction activity, or vehicle traffic, should be subcut to undisturbed firm soil and replaced with engineered fill. For additional information, please refer to the attached standard sheet entitled “Bituminous Pavement Subgrade Preparation and Design."

Pavement Section Placement

The subbase and Class 6 aggregate base course should be placed in thin loose lifts and compacted to at least 100% of the maximum Standard Proctor dry density (ASTM D698). A uniform thickness of the sand subbase and Class 6 aggregate base layers should be maintained. If there is a need to change the thickness of the subbase, the subbase should include thickness transition tapers no steeper than 10 horizontal to 1 vertical (10H:1V).

After the aggregate base course has been placed, compacted, and tested, the contractor should maintain the base course in a suitable condition for paving. If the base course becomes saturated after testing, it may be rendered unsuitable for paving due to softness and pumping. This condition would require remedial action before the pavement can be placed.

The bituminous pavement should be placed according to the provisions of Mn/DOT specification 2360 Plant Mixed Asphalt Pavement. The Mn/DOT 2360 bituminous pavement should be compacted to at least 91.0 % of the maximum theoretical density (Gmm) for placement over Class 5 aggregate base coarse, and 92.0% for placement over a bituminous pavement layer.

Before placing a binder course, the base course should be cleaned of all dust and debris, and before placing a wear course, the binder course should be cleaned of all dust and debris. A tack coat should be applied in accordance with Mn/DOT 2357.

AET recommends that the pavement smoothness requirements of Mn/DOT specification 2360.7C be waived for this project. If the owner wishes to eliminate the incentive for bituminous density on the project, then the target pavement density requirements of Mn/DOT specification 2360.6B2 should be reduced by 1% as shown in table 2360.6-B2, and the acceptance payment schedule for bituminous density should follow table 2360.6-B4A where maximum payment is 100% of unit bid price.

STORMWATER PONDS AND UTILITY CONSTRUCTION

Stormwater Ponds

Since the locations of stormwater ponds have not yet been selected, no test borings were performed in stormwater pond areas. Based on the test borings performed in pavement areas, existing fill overlying till soils and/or fine alluvium will likely be encountered in stormwater pond areas. The permeability of the native silty and clayey soils is estimated to be between approximately $1x10^{-7}$ to $1x10^{-4}$ cm/s. We recommend either field permeability tests and/or laboratory permeability testing be performed if hydraulic conductivity values are needed for design of pond areas. The field permeability testing, such double ring infiltrometer testing, should be performed within the stormwater pond areas at the planned depth of the base of each pond.

The slopes of pond embankments should be no steeper than 3 horizontal to 1 vertical (3H:1V). Slope faces should be protected from erosion with seed, mulch, or a permanent erosion control mat. Further testing and geotechnical review should be performed where slopes are designed to be steeper than 3H:1V.

Utility Construction

Care should be taken to ensure that utility lines are designed with sufficient flexibility to accommodate potential differential movements than can occur between frost susceptible soils and soils not susceptible to freezing. As utilities enter the pavement areas, they cross a transition from non-frost protected to frost protected soils, which can result in local differential movement within the transition zone. We recommend that buried utility lines be provided with a minimum of 7 feet of soil cover for protection from frost. If utility lines are placed at shallower depths, they should be protected from frost with insulation.

As mentioned previously, apparent cobbles and/or boulders were encountered in two test borings. Construction considerations should be made for encountering cobbles and/or boulders during utility installation.

Standard data sheets entitled "Standard Recommendations for Utility Trench Backfilling" and "Standard Recommendations for Utility Bedding/Support Fill" are also included. These standard sheets provide recommendations for backfill materials and placement.

CONSTRUCTION CONSIDERATIONS

Potential Difficulties

Runoff Water in Excavation

The soils encountered in the borings are likely to perch water during periods of wet weather. To allow observation of the excavation bottom, reduce the potential for soil disturbance, and to facilitate filling operations, we recommend that all free-standing water within the excavations be removed prior to proceeding with construction. Based on the soils encountered, we anticipate that the groundwater which enters the excavations can be handled with conventional sump pumping.

Soil Disturbance

The native soils encountered in our borings are very susceptible to disturbance when exposed to traffic, especially when saturated or exposed to free ground water. If soils do become disturbed, they should be carefully excavated and be replaced with compacted, engineered fill as described above.

Cobbles and/or Boulders

Apparent cobbles and/or boulders were encountered in some of the test borings, and may be present within planned excavation areas. Boulders and cobbles may present difficult excavation conditions for the construction of the pavement areas and associated utilities

Excavation Side-Sloping/Retention

If unretained, excavations should maintain sideslopes in accordance with OSHA Regulations (Standards 29 CFR), Part 1926, Subpart P, "Excavations" (can be found on www.osha.gov). Even with the required OSHA sloping, water can potentially induce side slope erosion which could require slope maintenance.

Observation and Testing

On-site observation by a geotechnical engineer/technician is recommended during construction to evaluate potential changes in soil conditions. The recommendations in this report are based on the subsurface conditions found at our test boring locations. Soil density testing should also be performed on new fill placed in order to document that project specifications for compaction have been satisfied. Where fill material type is important, sieve analysis tests should be performed to document the actual fill meets the recommended gradation criteria.

SUBSURFACE EXPLORATION

General

Our subsurface exploration program included advancing twelve standard penetration test borings at the site on February 11^{th} and 12^{th}, 2009. Test boring locations and elevations provided to AET by Reynolds, Smith, & Hills are shown on Figure 1 in the Appendix.

Drilling Methods

The standard penetration test borings were drilled using 2.25 inch inner-diameter hollow-stem augers. The boreholes were backfilled in compliance with the Minnesota Department of Health regulations.

Sampling Methods

Split Spoon Sample (SS)

Standard penetration (split-spoon) samples were collected in accordance with ASTM D1586 with one primary modification. The ASTM test method consists of driving a 2” O.D. split-barrel sampler into the in-situ soil with a 140-pound hammer dropped from a height of 30”. The sampler is driven a total of 18” into the soil. After an initial set of 6”, the number of hammer blows to drive the sampler the final 12” is known as the standard penetration resistance or N-value.

Sampling Limitations

Unless actually observed in a sample, contacts between soil layers are estimated based on the spacing of samples and the action of drilling tools. Cobbles, boulders, and other large objects generally cannot be recovered from test borings. They may still be present in the ground even if they are not noted on the boring logs.

Classification Methods

Soil classifications shown on the boring logs are generally based on the Unified Soil Classification System (USCS). The USCS is described in ASTM D2487 and D2488. Where laboratory classification tests (sieve analysis or Atterberg Limits) have been performed, classifications per ASTM D2487 are possible. Otherwise, soil classifications shown on the boring logs are visual-manual judgments. We have attached charts in the Appendix illustrating the USCS, the descriptive terminology, and the symbols used on the boring logs.

The boring logs include judgments of the geologic depositional origin. This judgment is primarily based on observation of the soil samples, which can be limited. Observations of the surrounding topography, vegetation and development can sometimes aid this judgment.

Water Level Measurements

The ground water measurements are shown at the bottom of the boring logs. The following information appears under "Water Level Measurements" on the logs:

- Date and Time of measurement
- Sampled Depth: lowest depth of soil sampling at the time of measurement
- Casing Depth: depth to bottom of casing or hollow-stem auger at time of measurement
- Cave-in Depth: depth at which measuring tape stops in the borehole
- Water Level: depth in the borehole where free water is encountered
- Drilling Fluid Level: same as Water Level, except that the liquid in the borehole is drilling fluid

The true location of the water table at the boring locations may be different than the water levels measured in the boreholes. This is possible because there are several factors that can affect the water level measurements in the borehole. Some of these factors include: permeability of each soil layer in profile, presence of perched water, amount of time between water level readings, presence of drilling fluid, weather conditions and use of borehole casing.

Sample Storage

We will retain representative samples of the soils recovered from the borings for a period of 30 days. The samples will then be discarded unless you notify us otherwise.

LIMITATIONS

The data derived through the exploration program have been used to develop our opinions about the subsurface conditions at your site. However, because no exploration program can totally reveal what is in the subsurface, conditions between borings and between samples and at other times, may differ from conditions described in this report. The exploration we conducted identified subsurface conditions only at those points where we took samples or observed ground water conditions. Depending on the sampling methods and sampling frequency, every soil layer may not be observed, and some materials or layers which are present in the ground may not be noted on the boring logs.

If conditions encountered during construction differ from those indicated by our borings, it may be necessary to alter our conclusions and recommendations, or to modify construction procedures, and the cost of construction may be affected.

The extent and detail of information about the subsurface condition are directly related to the scope of the exploration. It should be understood, therefore, that information can be obtained by means of additional exploration.

STANDARD OF CARE

Our services for your project have been conducted to those standards considered normal for services of this type at this time and location. Other than this, no warranty, either expressed or implied, is intended. When we refer to an ASTM Standard in this report, we mean that our services were performed in general accordance with that standard. Compliance with any other standards referenced within the specified standard is neither inferred nor implied.

SIGNATURES

Report Prepared by:
American Engineering Testing, Inc.

Sara L. Leow, PE
Geotechnical Engineer
MN License No. 47103

Report Reviewed by:
American Engineering Testing, Inc.

Robert J. Wahlstrom, PE, PG
Senior Geotechnical Engineer

Report Prepared by:
American Engineering Testing, Inc.

Andrew E. Edlund, EIT
Project Engineer

BITUMINOUS PAVEMENT SUBGRADE PREPARATION AND DESIGN

GENERAL

Bituminous pavements are considered layered Aflexible" systems. Dynamic wheel loads transmit high local stresses through the bituminous/base onto the subgrade. Because of this, the upper portion of the subgrade requires high strength/stability to reduce deflection and fatigue of the bituminous/base system. The wheel load intensity dissipates through the subgrade such that the high level of soil stability is usually not needed below about 2' to 4' (depending on the anticipated traffic and underlying soil conditions). This is the primary reason for specifying a higher level of compaction within the upper subgrade zone versus the lower portion. Moderate compaction is usually desired below the upper critical zone, primarily to avoid settlements/sags of the roadway. However, if the soils present below the upper 3' subgrade zone are unstable, attempts to properly compact the upper 3' zone to the 100% level may be difficult or not possible. Therefore, control of moisture just below the 3' level may be needed to provide a non-yielding base upon which to compact the upper subgrade soils.

Long-term pavement performance is dependent on the soil subgrade drainage and frost characteristics. Poor to moderate draining soils tend to be susceptible to frost heave and subsequent weakening upon thaw. This condition can result in irregular frost movements and Apopouts,@ as well as an accelerated softening of the subgrade. Frost problems become more pronounced when the subgrade is layered with soils of varying permeability. In this situation, the free-draining soils provide a pathway and reservoir for water infiltration which exaggerates the movements. The placement of a well drained sand subbase layer as the top of subgrade can minimize trapped water, smooth frost movements and significantly reduce subgrade softening. In wet, layered and/or poor drainage situations, the long-term performance gain should be significant. If a sand subbase is placed, we recommend it be a ASelect Granular Borrow@ which meets Mn/DOT Specification 3149.2B2.

PREPARATION

Subgrade preparation should include stripping surficial vegetation and organic soils. Where the exposed soils are within the upper Acritical@ subgrade zone (generally 2 2N deep for "auto only" areas and 3' deep for Aheavy duty@ areas), they should be evaluated for stability. Excavation equipment may make such areas obvious due to deflection and rutting patterns. Final evaluation of soils within the critical subgrade zone should be done by test rolling with heavy rubber-tired construction equipment, such as a loaded dump truck. Soils which rut or deflect 1" or more under the test roll should be corrected by either subcutting and replacement; or by scarification, drying, and recompaction. Reworked soils and new fill should be compacted per the ASpecified Density Method@ outlined in Mn/DOT Specification 2105.3F1 (a minimum of 100% of Standard Proctor density in the upper 3' subgrade zone, and a minimum of 95% below this).

Subgrade preparation scheduling can be an important consideration. Fall and Spring seasons usually have unfavorable weather for soil drying. Stabilizing non-sand subgrades during these seasons may be difficult, and attempts often result in compromising the pavement quality. Where construction scheduling requires subgrade preparation during these times, the use of a sand subbase becomes even more beneficial for constructability reasons.

SUBGRADE DRAINAGE

If a sand subbase layer is used, it should be provided with a means of subsurface drainage to prevent water build-up. This can be in the form of draintile lines which dispose into storm sewer systems, or outlets into ditches. Where sand subbase layers include sufficient sloping, and water can migrate to lower areas, draintile lines can be limited to finger drains at the catch basins. Even if a sand layer is not placed, strategically placed draintile lines can aid in improving pavement performance. This would be most important in areas where adjacent non-paved areas slope towards the pavement. Perimeter edge drains can aid in intercepting water which may infiltrate below the pavement.

BEDDING/FOUNDATION SUPPORT OF BURIED PIPE

GENERAL

This page addresses soil bedding and foundation support of rigid pipe, such as reinforced concrete, and flexible pipe, such as steel and plastic. This does not address selection of pipe based on loads and allowable deflections, but rather addresses the geotechnical/soil aspects of uniform pipe support. Bedding/foundation support needs relate to local conditions directly beneath and to the sides of the pipe zone, which may be influenced by soft in-situ ground conditions or by soil disturbance due to soil sensitivity or ground water. Bedding relates to granular materials placed directly beneath the bottom of the pipe (usually 4" to 6" thick), which is intended to provide increased support uniformity. We refer to foundation soils as thicker layers of sands and/or gravels (beneath the bedding zone) intended to provide increased foundation strength support, usually needed due to soft, unstable and/or waterbearing conditions.

GRANULAR BEDDING

With circular pipes, high local loads (approaching point loads) develop if pipes are placed on hard surfaces. Load distribution is improved by placing granular bedding materials beneath the pipe, which are either shaped to match the pipe bottom or are placed without compaction to allow “settling in.” The bedding should be placed in such a manner that the pipe will be at the proper elevation and slope when the pipe is laid on the bedding. Common bedding material is defined in Mn/DOT Specification 3149.2F, Granular Bedding. Published documents recommend rigid pipes having a diameter of 12" to 54" be placed on a bedding thickness of 4", which increases to 6" of bedding for pipe diameters ranging from 54" to 72". Beyond a 72" diameter, the bedding thickness can be equal to the pipe outside diameter divided by 12. Typically, the need for bedding under small diameter pipes (less than 12") depends on the pipe designer’s specific needs, although in obvious point loads situations (bedrock, cobbles, significant coarse gravel content), bedding is recommended. Note that bedding should also account for larger diameter bells at joints.

FOUNDATION FILL

Positive uniform strength is usually compromised in soft or unstable trench bottom conditions. In this case, deeper subcuts and foundation fill placement is needed beneath the pipe. In moderate instability conditions, improvement can likely be accomplished with a thicker bedding layer. However, in more significant instability situations, particularly where ground water is present, coarser materials may be needed to provide a stronger foundation. Thicker gravel layers can also be a favorable media from which to dewater. The following materials would be appropriate for stability improvement, with the coarser materials being appropriate for higher instability/ground water cases.

- Fine Filter Aggregate – Mn/DOT Specification 3149.2J
- Coarse Filter Aggregate –Mn/DOT Specification 3149.2H

When using a coarser material which includes significant void space, we highly recommend enveloping the entire gravel layer within a geotextile fabric. The gravel material includes open void space, and the fabric acts as a separator which minimizes the intrusion of fines into the open void space. If an additional granular bedding sand is used above foundation gravel, the fabric would also prevent downward infiltration of bedding sand into the rock void space.

Although it is preferred to not highly compact thin granular bedding zones directly beneath the pipe center, it is desirable to compact the foundation materials to prevent more significant pipe settlement. We recommend foundation fill be compacted to a minimum of 95% of the Standard Proctor density (ASTM:D698). It is not possible to test coarse rock fill, although this material should still be well compacted/ tamped.

Often, pipes entering structures such as catch basins, lift stations, etc., enter the structure at a higher elevation than the structure bottom, and are therefore placed on the structure backfill. Fill beneath these pipes should be considered foundation fill. Depending on the flexibility of the connection design, it may be necessary to increase the minimum compaction level to reduce differential settlements, particularly with thicker fills.

SIDE FILL SUPPORT

If the pipe designer requires support from the side fill, granular bedding should also be placed along the sides of the pipe. In poor soil conditions, the sand fill may need to be placed laterally up to two pipe diameters on both sides of the pipe. With rigid pipe, compacted sand placement up to the spring line (within the haunch area) is usually sufficient. With flexible pipe, side fill should be placed and compacted at least to the top of the pipe. For positive support, it is very important to properly compact the sands within the haunch area.

STANDARD RECOMMENDATIONS FOR UTILITY TRENCH BACKFILLING

GENERAL

Clayey and silty soils are often difficult to compact, as they may be naturally wet or may become wet due to ground water or surface/rain water during construction. Soils will need to be placed within a certain range of water (moisture) content to attain desired compaction levels. Moisture conditioning to within this range can be time consuming, labor intensive, and requires favorable weather.

The degree of compaction and the soil type used for backfill within open cut utility trenches depends on the function of the overlying land surface. Details are as follows:

ROADWAYS

Where trenches are located below roadways, we recommend using inorganic fill and compacting these soils per Mn/DOT Specification 2105.3F1 (Specified Density Method). This specification requires 100% of the Standard Proctor density in the upper one meter subgrade zone, and 95% below this. Note that this specification includes moisture content range requirements which are important for proper subgrade stability.

Where available soils are wet or of poor quality, it may be possible to use the “Quality Compaction Method” (Mn/DOT Specification 2105.3F2) for soils below the upper one meter subgrade zone if you can tolerate some subsidence. However, a high level of stability is still important within the upper subgrade zone and recommend that the “Specified Density Method" be used in this upper subgrade area. We caution that if backfill soils in the lower trench area are significantly unstable, it may be difficult or even impossible to properly compact soils within the upper one meter subgrade zone. In this case, placing a geotextile fabric directly over the unstable soils can aid in offsetting the instability.

STRUCTURAL AREAS

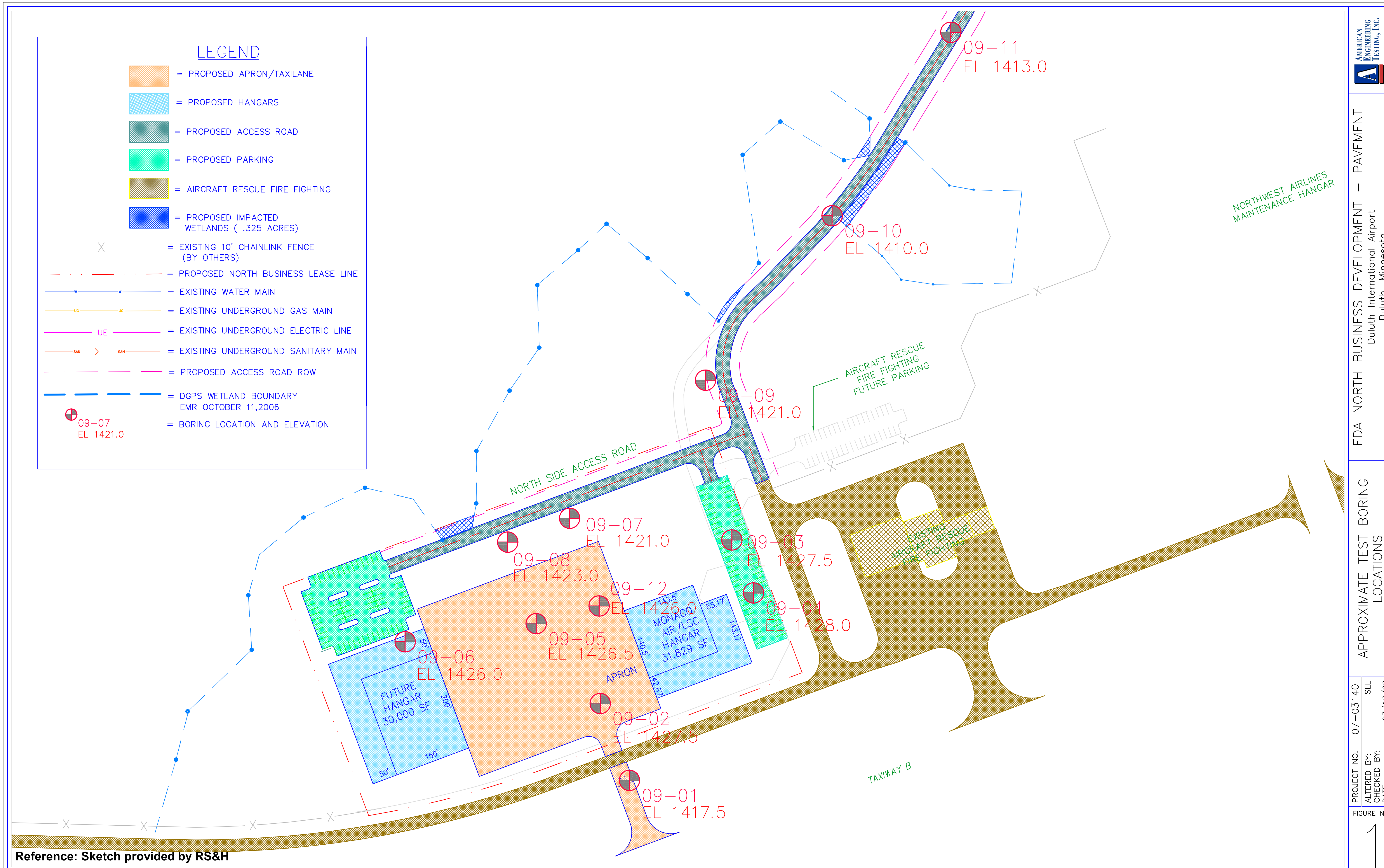
If fill is placed beneath or within the significant zone of influence of a structure (typically a 1:1 lateral oversize zone), the soil type and minimum compaction level will need to be evaluated on an individual basis. Because trenches result in variable fill depths over a short lateral distance, higher than normal compaction levels and/or more favorable (sandy) soil fill types may be needed. If this situation exists, it is important that special geotechnical engineering review be performed.

NON-STRUCTURAL AREAS

In grass/ditch areas, backfill soils should be placed in reasonable lift thicknesses and compacted to a minimum of 90% of the Standard Proctor density (ASTM:D698) and/or per the Mn/DOT “Quality Compaction Method.” If lower compaction levels are attained, more noticeable subsidence at the surface can occur. Steep or high slopes require special consideration.

Appendix

Figure 1 – Approximate Test Boring Locations
Logs of Test Borings
Boring Log Notes
Gradation Results
California Bearing Ratio Test Results
Unified Soil Classification System
Geologic Terminology



LEGEND
= PROPOSED APRON/TAXILANE
= PROPOSED HANGARS
= PROPOSED ACCESS ROAD
= PROPOSED PARKING
= AIRCRAFT RESCUE FIRE FIGHTING
= PROPOSED IMPACTED WETLANDS (.325 ACRES)
= EXISTING 10' CHAINLINK FENCE (BY OTHERS)
= PROPOSED NORTH BUSINESS LEASE LINE
= EXISTING WATER MAIN
= EXISTING UNDERGROUND GAS MAIN
UE
= EXISTING UNDERGROUND ELECTRIC LINE
= EXISTING UNDERGROUND SANITARY MAIN
= PROPOSED ACCESS ROAD ROW
= DGPS WETLAND BOUNDARY EMR OCTOBER 11,2006
09–07 EL 1421.0
= BORING LOCATION AND ELEVATION
09–11 EL 1413.0
09–10 EL 1410.0
09–09 EL 1421.0
09–07 EL 1421.0
09–08 EL 1423.0
09–03 EL 1427.5
09–12 EL 1426.0
09–04 EL 1428.0
09–05 EL 1426.5
09–06 EL 1426.0
09–02 EL 1427.5
09–01 EL 1417.5
NORTHWEST AIRLINES MAINTENANCE HANGAR
AIRCRAFT RESCUE FIRE FIGHTING FUTURE PARKING
NORTH SIDE ACCESS ROAD
EXISTING AIRCRAFT RESCUE FIRE FIGHTING
MONACO AIR/LSC HANGAR 31,829 SF
143.5'
55.17'
140.5'
143.17'
42.67'
FUTURE HANGAR 30,000 SF
50'
200'
150'
50'
APRON
TAXIWAY B
Reference: Sketch provided by RS&H
AMERICAN ENGINEERING TESTING, INC.
EDA NORTH BUSINESS DEVELOPMENT – PAVEMENT
Duluth International Airport
Duluth, Minnesota
APPROXIMATE TEST BORING LOCATIONS
PROJECT NO. 07–03140
ALTERED BY: SLL
CHECKED BY:
DATE: 03/16/09
FIGURE NO. 1

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

AET JOB NO: **07-03140**

LOG OF BORING NO. **09-01 (p. 1 of 1)**

PROJECT: **EDA North Business Development; Duluth, MN**

SURFACE ELEVATION: **1417.5**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% #4	LL	PL	%-#200
0–1	ORGANIC SANDY CLAY WITH ROOTS, dark brown, frozen (OL)	TOPSOIL									
1–2	SANDY SILTY CLAY, a little gravel, brown, moist, frozen above about 1' (CL)	TILL		F/M	SU						
2–6.5	SILTY SAND WITH GRAVEL, dark brown, moist, dense (SM)		31	M	SS	11					
			38	M	SS	14					
6.5–12	GRAVELLY SILTY SAND, dark brown, moist, dense (SM)		35	M	SS	6					
			32	M	SS	9	6				26
12–14	SILTY SAND WITH GRAVEL, dark brown, wet, medium dense (SM)		29	W	SS	11					
14–16	SILTY SAND WITH GRAVEL, dark brown, wet, dense, lenses of dark reddish brown sandy silt (SM)		47	M/W	SS	8					
16	**END OF BORING AT 16.0 FEET** Borehole backfilled with auger cuttings										

DEPTH:	DRILLING METHOD
0-14½'	**2.25" HSA**

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
2/12/09	**9:15**	**13.5**	**12.0**	**13.5**	**---**	**12.0**

BORING COMPLETED: **2/12/09**

DR: **MH** LG: **JU** Rig: **84R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

AET JOB NO: **07-03140**   LOG OF BORING NO. **09-02 (p. 1 of 1)**

PROJECT: **EDA North Business Development; Duluth, MN**

DEPTH IN FEET	SURFACE ELEVATION: 1427.5 MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% #4	LL	PL	%-#200
0–9	FILL, silty sand with gravel, trace roots, frozen above about 2'	FILL		F/M	SU						
9–12	FILL, slightly organic sandy silt with roots and gravel, dark grayish brown		39	M	SS	11					
12–18	SANDY SILT, a little gravel, dark brown to brown, moist, medium dense (ML)		12	M	SS	6	16				
			11	M	SS	12	13				52
18–26	GRAVELLY SILTY SAND, apparent cobbles, dark brown, wet, dense (SM)	TILL		▼							
			46	W	SS	11					
			43	W	SS	10					
26	**END OF BORING AT 26.0 FEET** Borehole backfilled with auger cuttings										

DEPTH:	DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-24½'	**2.25" HSA**	**2/12/09**	**11:15**	**21.0**	**19.5**	**19.5**	**---**	**18.5**

WATER LEVEL MEASUREMENTS

BORING COMPLETED: **2/12/09**

DR: **MH** LG: **JU** Rig: **84R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

06/06

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

AET JOB NO: **07-03140** LOG OF BORING NO. **09-03 (p. 1 of 1)**

PROJECT: **EDA North Business Development; Duluth, MN**

SURFACE ELEVATION: **1427.5**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% #4	LL	PL	%-#200
0	Bituminous Pavement - 2½" thickness	PAVEMENT									
1–5	FILL, gravelly silty sand, dark brown, frozen above about 3'	FILL		F/M	SU						
5–10	SILT WITH SAND, a little gravel, dark brown, moist, lenses of slightly organic silt (ML)	TILL		M	SU						
10–12	GRAVELLY SILTY SAND, apparent cobbles, dark brown, moist (SM)		38	M	SS	6					
12–24.5	SILTY SAND WITH GRAVEL, dark brown, moist to wet, medium dense (SM)		16	M	SS	10					
			23	M	SS	11					
			29	M/W	SS	11					
			50/0'		SS	0					

END OF BORING AT 24.5 FEET
Borehole backfilled with auger cuttings

DEPTH:	DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-24½'	**2.25" HSA**	**2/11/09**		**24.5**	**24.5**	**24.5**	**---**	**None**

WATER LEVEL MEASUREMENTS

BORING COMPLETED: **2/11/09**

DR: **MH** LG: **JU** Rig: **84R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

AET JOB NO: **07-03140** LOG OF BORING NO. **09-04 (p. 1 of 1)**

PROJECT: **EDA North Business Development; Duluth, MN**

DEPTH IN FEET	SURFACE ELEVATION: **1428.0** MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% #4	LL	PL	%-#200
	Bituminous Pavement - 2½" thickness	PAVEMENT									
1	FILL, gravelly silty sand, dark brown, frozen above about 3' (undetermined fill depth)										
2											
3											
4		FILL TO TILL									
5				F/M	SU						
6											
7											
8											
9	SILTY SAND WITH GRAVEL, dark brown, moist with wet lenses below about 20', medium dense (SM)										
10			28	M	SS	11					
11											
12											
13			22	M	SS	10	10				37
14											
15			30	M	SS	13					
16											
17		TILL									
18											
19											
20			27	M/W	SS	12					
21											
22											
23											
24											
25			18/0.5' 50/0.3'	M/W	SS	6					
	END OF BORING AT 25.3 FEET Borehole backfilled with auger cuttings										

DEPTH:	DRILLING METHOD	WATER LEVEL MEASUREMENTS							NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG
0-24½'	**2.25" HSA**	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL	
		2/11/09	**14:05**	**21.0**	**19.5**	**21.0**	**---**	**None**	
BORING COMPLETED: **2/11/09**									
DR: **MH** LG: **JU** Rig: **84R**									

06/06

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

AET JOB NO: **07-03140** LOG OF BORING NO. **09-05 (p. 1 of 1)**

PROJECT: **EDA North Business Development; Duluth, MN**

SURFACE ELEVATION: **1426.5**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% #4	LL	PL	%-#200
0–10	FILL, silty sand with gravel, apparent cobbles, dark brown, frozen above about 2'	FILL		F/M	SU						
			53	M	SS	10					
10.5–12	FILL, silty sand with gravel, trace roots, dark grayish brown										
12–19.5	FILL, a mixture of silty sand with gravel, slightly organic sandy clay, and organic silt, trace roots, dark brown and dark grayish brown		7	M	SS	11	19				
			7	M/W	SS	11					
19.5–23	SAND WITH SILT, a little gravel, brown, moist, dense, lenses of silty sand with gravel (SP-SM)	COARSE ALLUVIUM	37	M	SS	15	8				12
23–26	SILT, dark brown, wet, medium dense (ML)	FINE ALLUVIUM	23	W	SS	10					
26	**END OF BORING AT 26.0 FEET** Borehole backfilled with auger cuttings										

DEPTH:	DRILLING METHOD
0-24½'	**2.25" HSA**

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
2/12/09	**12:20**	**26.0**	**24.5**	**24.5**	**---**	**None**

BORING COMPLETED: **2/12/09**

DR: **MH** LG: **JU** Rig: **84R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

AET JOB NO: **07-03140** LOG OF BORING NO. **09-06 (p. 1 of 1)**

PROJECT: **EDA North Business Development; Duluth, MN**

SURFACE ELEVATION: **1426.0**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% #4	LL	PL	%-#200
0–2	FILL, gravelly silty sand, grayish brown, frozen	FILL		F	SU						
2–12	FILL, silty sand with gravel, apparent cobbles, dark brown	FILL	34	M	SS	15					
			34	M	SS	11					
			25	M	SS	10					
			28	M	SS	12					
12–14.5	FILL, organic sandy silt with roots and gravel, dark brown	FILL	11	M	SS	12					
14.5–19	FILL, slightly organic sandy clay with roots, a little gravel, dark brown	FILL	5	M	SS	5					
19–21	LEAN CLAY WITH SAND, trace roots, brown and gray mottled, firm (CL)	FINE ALLUVIUM	6	M	SS	11					

END OF BORING AT 21.0 FEET
Borehole backfilled with auger cuttings

DEPTH:	DRILLING METHOD
0-19½'	**2.25" HSA**

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
2/12/09		**21.0**	**19.5**	**19.5**	**---**	**None**

BORING COMPLETED: **2/12/09**

DR: **MH** LG: **JU** Rig: **84R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

06/06

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

AET JOB NO: **07-03140** LOG OF BORING NO. **09-07 (p. 1 of 1)**

PROJECT: **EDA North Business Development; Duluth, MN**

DEPTH IN FEET	SURFACE ELEVATION: **1421.0** MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% #4	LL	PL	%-#200
0–2	FILL, silty sand with gravel, trace roots, dark brown, frozen	FILL		M	SU						
2–7	FILL, silty sand with gravel, dark brown		30	M	SS	14					
			21	M	SS	15					
7–10	FILL, a mixture of silty sand with gravel, lean clay, and organic silt, trace roots, brown, gray, grayish brown, and black		21	M	SS	13					
10–14	FILL, silty sand with gravel		21	M	SS	9					
			26	M	SS	13					
14–16	FILL, a mixture of silty sand with gravel and slightly organic sandy silt, trace roots, dark brown and dark grayish brown		17	M	SS	15					
16	**END OF BORING AT 16.0 FEET** Borehole backfilled with auger cuttings										

DEPTH:	DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-14½'	**2.25" HSA**	**2/12/09**		**16.0**	**14.5**	**14.5**	**---**	**None**

WATER LEVEL MEASUREMENTS

BORING COMPLETED: **2/12/09**

DR: **MH** LG: **JU** Rig: **84R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

AET JOB NO: **07-03140** LOG OF BORING NO. **09-08 (p. 1 of 1)**

PROJECT: **EDA North Business Development; Duluth, MN**

DEPTH IN FEET	SURFACE ELEVATION: **1423.0** MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% #4	LL	PL	%-#200
0–2	FILL, slightly organic silty sand with gravel, trace roots, dark brown, frozen	FILL		F/M	SU						
2–5.5	FILL, silty sand with gravel, apparent cobbles, dark brown, wire debris at about 2½'		23	M	SS	9					
			8		SS	0					
5.5–9	FILL, silty sand, a little gravel, trace roots, dark brown		6	M	SS	12					
9–13.5	FILL, silty clayey sand, a little gravel, trace roots, dark brown		5	W	SS	13					
			3	M/W	SS	4					
13.5–16	SILTY SAND, a little gravel, dark brown, moist, loose (SM)	TILL	6	M	SS	8					

END OF BORING AT 16.0 FEET
Borehole backfilled with auger cuttings

Refusal at 3.8' on first attempt
Boring offset 5' south

DEPTH:	DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-14½'	**2.25" HSA**	**2/12/09**		**16.0**	**14.5**	**14.5**	**---**	**None**

WATER LEVEL MEASUREMENTS

BORING COMPLETED: **2/12/09**

DR: **MH** LG: **JU** Rig: **84R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

AET JOB NO: **07-03140** LOG OF BORING NO. **09-09 (p. 1 of 1)**

PROJECT: **EDA North Business Development; Duluth, MN**

DEPTH IN FEET	SURFACE ELEVATION: 1421.0 MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% #4	LL	PL	%-#200
0–1	FILL, organic sandy silt with roots, a little gravel, dark brown, frozen	FILL		F/M	SU						
1–8.5	FILL, silty sand with gravel, trace roots, dark brown		3/0.5' 50/0.3'	M	SS	2					
			4	M	SS	7					
			10	M	SS	13					
8.5–12	SILTY SAND WITH GRAVEL, dark brown, moist, medium dense (SM)	TILL	23	M	SS	11					
12–14	SILTY CLAYEY SAND WITH GRAVEL, dark brown, moist, medium dense, a little sandy dark gray weathered gravel (SC-SM)		26	M	SS	14					
14–16	SILTY SAND WITH GRAVEL, dark brown, moist, medium dense (SM)		28	M	SS	5					
16	**END OF BORING AT 16.0 FEET** Borehole backfilled with auger cuttings										

DEPTH:	DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-14½'	**2.25" HSA**	**2/11/09**		**16.0**	**14.5**	**14.5**	**---**	**None**

WATER LEVEL MEASUREMENTS

BORING COMPLETED: **2/11/09**

DR: **MH** LG: **JU** Rig: **84R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

AET JOB NO: **07-03140** LOG OF BORING NO. **09-10 (p. 1 of 1)**

PROJECT: **EDA North Business Development; Duluth, MN**

SURFACE ELEVATION: **1410.0**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% #4	LL	PL	%-#200
	FILL, silty sand with gravel, gray, frozen	FILL									
1	FILL, silty sand with gravel, dark brown, frozen above about 4' (fabric observed during drilling)			F	SU						
2											
3				F	SU						
4											
5			50/0.5'	M	SS	5					
6	SAND WITH SILT, a little gravel, fine to medium grained, dark brown, wet, loose (SP-SM) (may be fill)	COARSE ALLUVIUM OR FILL									
7			10	W	SS	7					
8	**END OF BORING AT 8.0 FEET** Borehole backfilled with auger cuttings *Refusal at 3.5' on first attempt* *Boring offset 4' south*										

DEPTH:	DRILLING METHOD
0-6½'	**2.25" HSA**

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
2/11/09	**11:25**	**8.0**	**6.5**	**8.0**	**---**	**5.5**

BORING COMPLETED: **2/11/09**

DR: **MH** LG: **JU** Rig: **84R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN
ENGINEERING
TESTING, INC.

SUBSURFACE TEST BORING LOG

AET JOB NO: **07-03140** LOG OF BORING NO. **09-11 (p. 1 of 1)**

PROJECT: **EDA North Business Development; Duluth, MN**

DEPTH IN FEET	SURFACE ELEVATION: 1413.0 MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% #4	LL	PL	%-#200
	FILL, silty sand with gravel, gray, frozen	FILL									
1	FILL, silty sand with gravel, dark brown, frozen			F	SU						
2	FILL, gravelly silty sand, apparent cobbles, brown, frozen										
3				F	SU						
4	SILTY CLAYEY SAND WITH GRAVEL, dark brown, moist, medium dense (SC-SM)	TILL									
5			30	M	SS	14	15				
6											
7	GRAVELLY SILTY SAND, dark brown, moist, medium dense (SM)		25	M	SS	10					
8	**END OF BORING AT 8.0 FEET** Borehole backfilled with auger cuttings										

DEPTH:	DRILLING METHOD	DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
0-6½'	**2.25" HSA**	**2/11/09**		**8.0**	**6.5**	**6.5**	**---**	**None**

WATER LEVEL MEASUREMENTS

BORING COMPLETED: **2/11/09**

DR: **MH** LG: **JU** Rig: **84R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AMERICAN ENGINEERING TESTING, INC.

SUBSURFACE TEST BORING LOG

AET JOB NO: **07-03140**   LOG OF BORING NO. **09-12 (p. 1 of 1)**

PROJECT: **EDA North Business Development; Duluth, MN**

SURFACE ELEVATION: **1426.0**

DEPTH IN FEET	MATERIAL DESCRIPTION	GEOLOGY	N	MC	SAMPLE TYPE	REC IN.	WC	% #4	LL	PL	%-#200
0–1	FILL, organic sandy silt with roots, dark brown, frozen	FILL									
1–3	FILL, silty sand with gravel, trace roots, dark brown, frozen			F	SU						
3–8.5	FILL, silty sand with gravel, dark brown, frozen above about 4'			F	SU						
				F/M	SU						
8.5–14	FILL, silty clayey sand with gravel, trace roots, dark brown and dark grayish brown		13	M	SS	8	12				
			15	M	SS	15					
14–20	FILL, a mixture of silty clayey sand with gravel and sand with silt, apparent cobbles, trace roots, dark brown and grayish brown		12	M	SS	12					
20–20.5	FILL, organic sandy silt, trace roots, black		20	M	SS	10					
20.5–26	SILTY SAND WITH GRAVEL, dark brown, moist to wet, dense (SM)	TILL									
			43	M/W	SS	15					
26	**END OF BORING AT 26.0 FEET** Borehole backfilled with auger cuttings										

DEPTH:	DRILLING METHOD
0-24½'	2.25" HSA

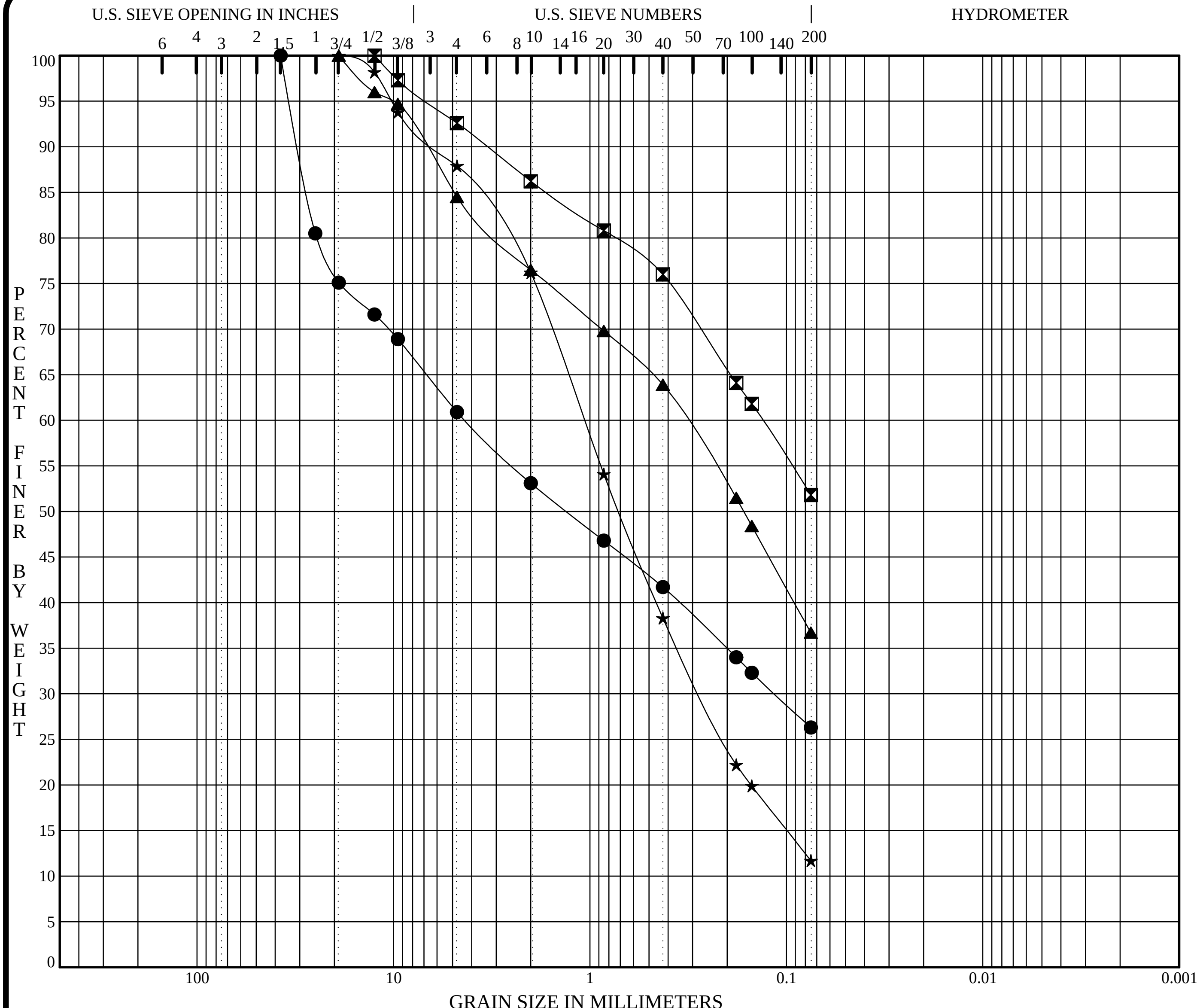
WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	DRILLING FLUID LEVEL	WATER LEVEL
2/11/09		26.0	24.5	26.0	---	25.8

BORING COMPLETED: **2/11/09**

DR: **MH** LG: **JU** Rig: **84R**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification			Classification	MC%	LL	PL	PI	Cc	Cu
●	**09-01**	**9.5**	**GRAVELLY SILTY SAND (SM)**	**6**					
⧗	**09-02**	**14.5**	**SANDY SILT, a little gravel (ML)**	**13**					
▲	**09-04**	**12.0**	**SILTY SAND WITH GRAVEL (SM)**	**10**					
★	**09-05**	**19.5**	**SAND WITH SILT, a little gravel (SP-SM)**	**8**				**1.07**	**16.4**

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**09-01**	**9.5**	**37.50**	**4.30**	**0.115**		**39.1**	**34.6**	**26.3**	
⧗	**09-02**	**14.5**	**12.50**	**0.13**			**7.4**	**40.8**	**51.8**	
▲	**09-04**	**12.0**	**19.00**	**0.32**			**15.5**	**47.8**	**36.7**	
★	**09-05**	**19.5**	**19.00**	**1.07**	**0.273**		**12.1**	**76.2**	**11.7**	

PROJECT **EDA North Business Development; Duluth, MN**

JOB NO. **07-03140**
DATE **2/12/09**

AMERICAN ENGINEERING TESTING, INC.

GRADATION CURVES

CALIFORNIA BEARING RATIO TESTS

PROJECT: EDA NORTH BUSINESS DEVELOPMENT
DULUTH INTERNATIONAL AIRPORT
DULUTH, MINNESOTA

REPORTED TO: REYNOLDS, SMITH & HILLS

AET JOB NO: 07-03140

DATE: MARCH 3, 2009

SAMPLE IDENTIFICATION: Composite boring samples.

LABORATORY MOISTURE-DENSITY RELATIONS OF SOIL:

Method:	ASTM: D-1557, Method C
Maximum Dry Density (pcf):	132.4
Optimum Moisture (%):	10.1
Classification:	Silty Sand (SM)

CALIFORNIA BEARING RATIO TEST: (See attached curve)

Method:	ASTM: D-1883		
Molding Data:			
Compaction Hammer	10 lb 18" Drop Segment Face	10 lb 18" Drop Segment Face	10 lb 18" Drop Segment Face
Number of Layers	5	5	5
Blows Per Layer	77	26	12
Molding Moisture (%)	10.8	11.1	10.8
Molding Dry Density (pcf)	136.0	126.3	117.8
Relative Compaction (%)	102.7	95.4	89.0
Penetration Test: (3 sq in piston)			
Surcharge (psf)	50	50	50
Corrected CBR (Soaked)			
At 0.1 in. penetration (%)	23.5	22.6	6.3
At 0.2 in. penetration (%)	24.0	21.8	5.3
At 0.3 in. penetration (%)	27.8	21.2	4.5
Moisture Content After Penetration:			
Top 1 in. of Specimen (%)	11.0	12.6	13.7
Full Height of Specimen (%)	10.1	11.1	15.5
Swell Test: (4 day soak)			
Surcharge (psf)	50	50	50
Swell after 4 days (%)	0.00	+ 0.19	+ 0.22

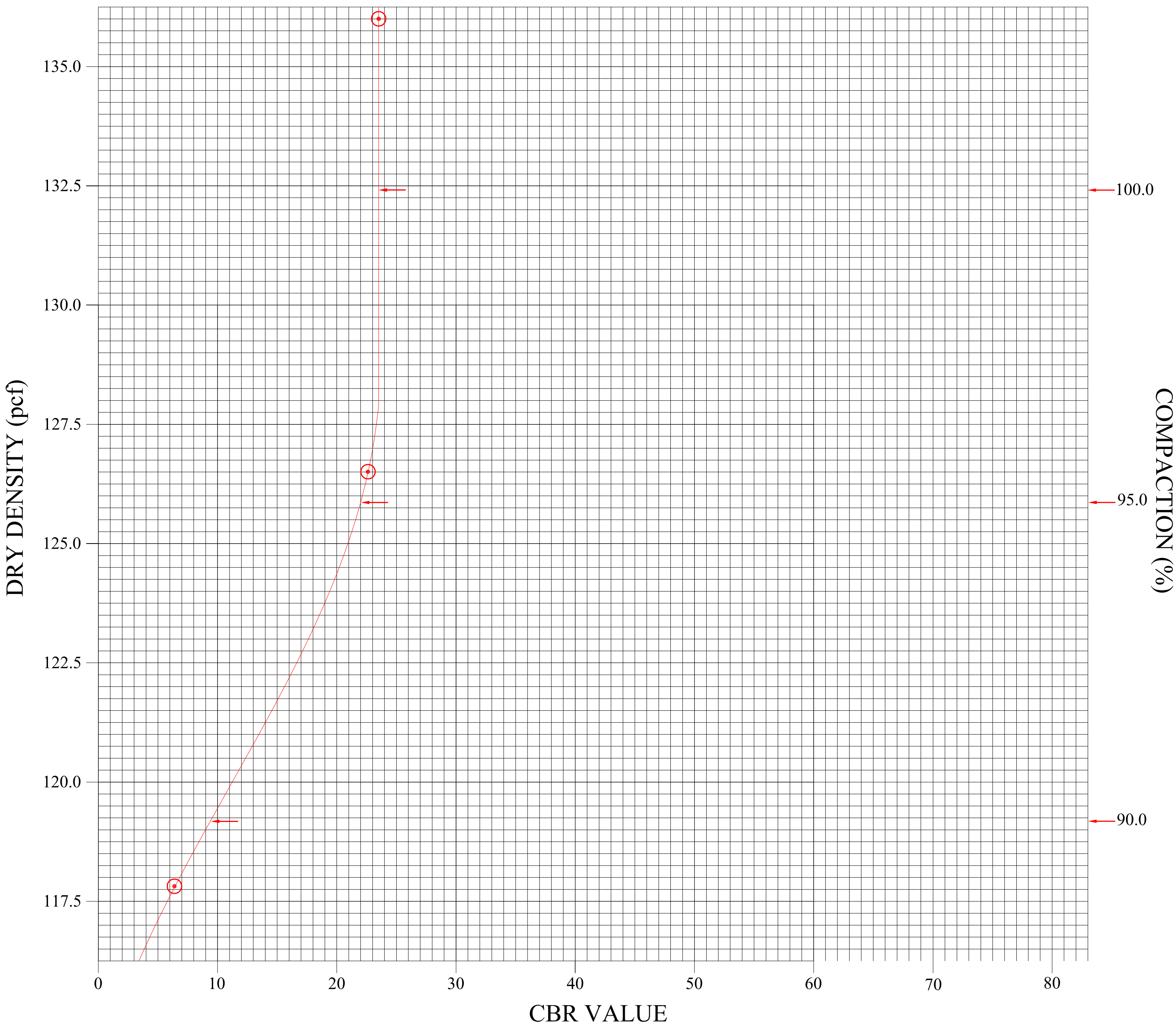
PROJECT: EDA NORTH BUSINESS DEVELOPMENT
DULUTH INTERNATIONAL AIRPORT
DULUTH, MINNESOTA

AET JOB NO: 07-03140

SAMPLE ID: COMPOSITE BORING SAMPLE

PROJECTED CBR @ 0.1" PENETRATION:

% Compaction	CBR
90	9.4
95	22.0
100	23.9



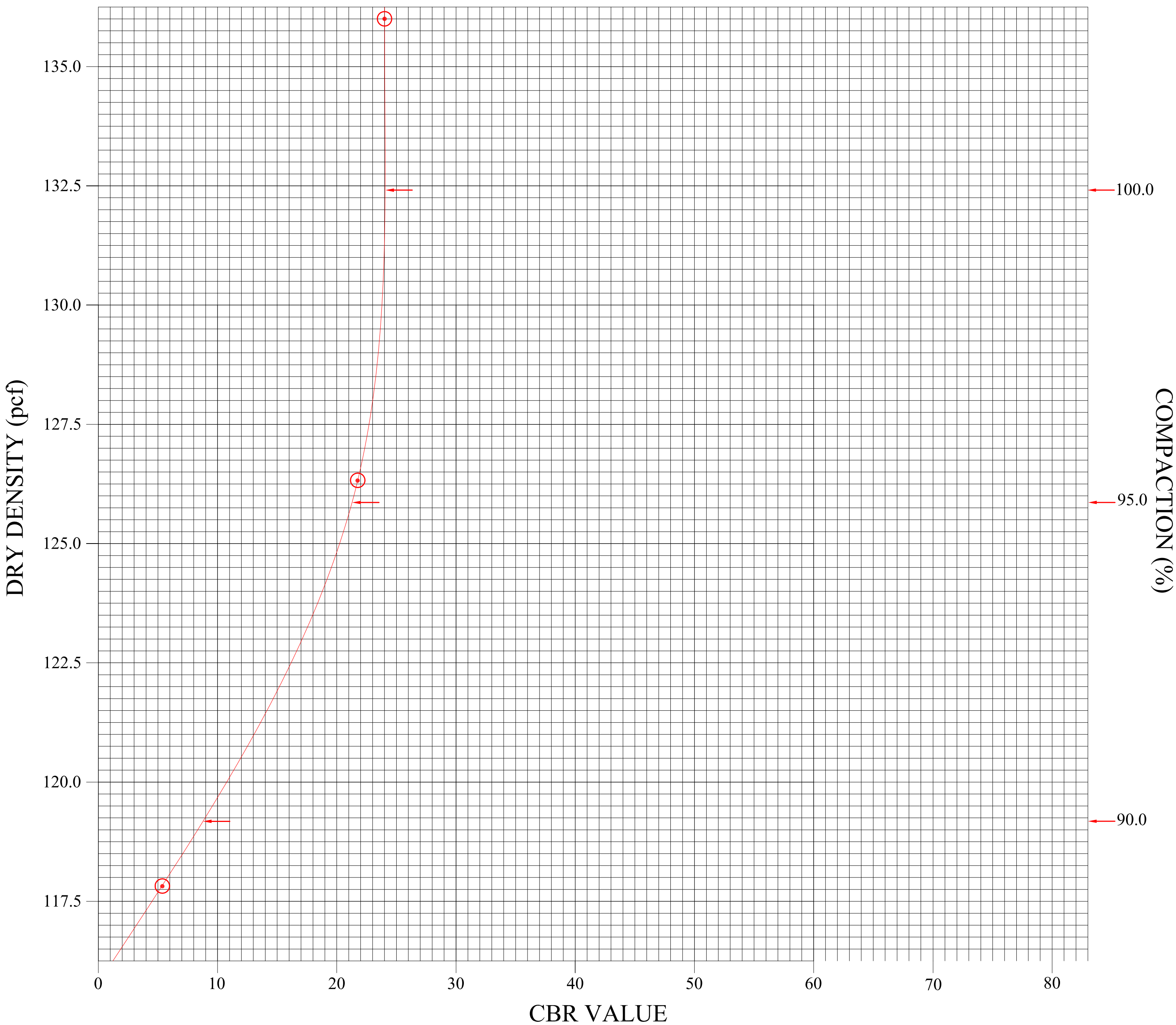
PROJECT: EDA NORTH BUSINESS DEVELOPMENT
DULUTH INTERNATIONAL AIRPORT
DULUTH, MINNESOTA

AET JOB NO: 07-03140

SAMPLE ID: COMPOSITE BORING SAMPLE

PROJECTED CBR @ 0.2" PENETRATION:

% Compaction	CBR
90	8.8
95	21.2
100	24.1



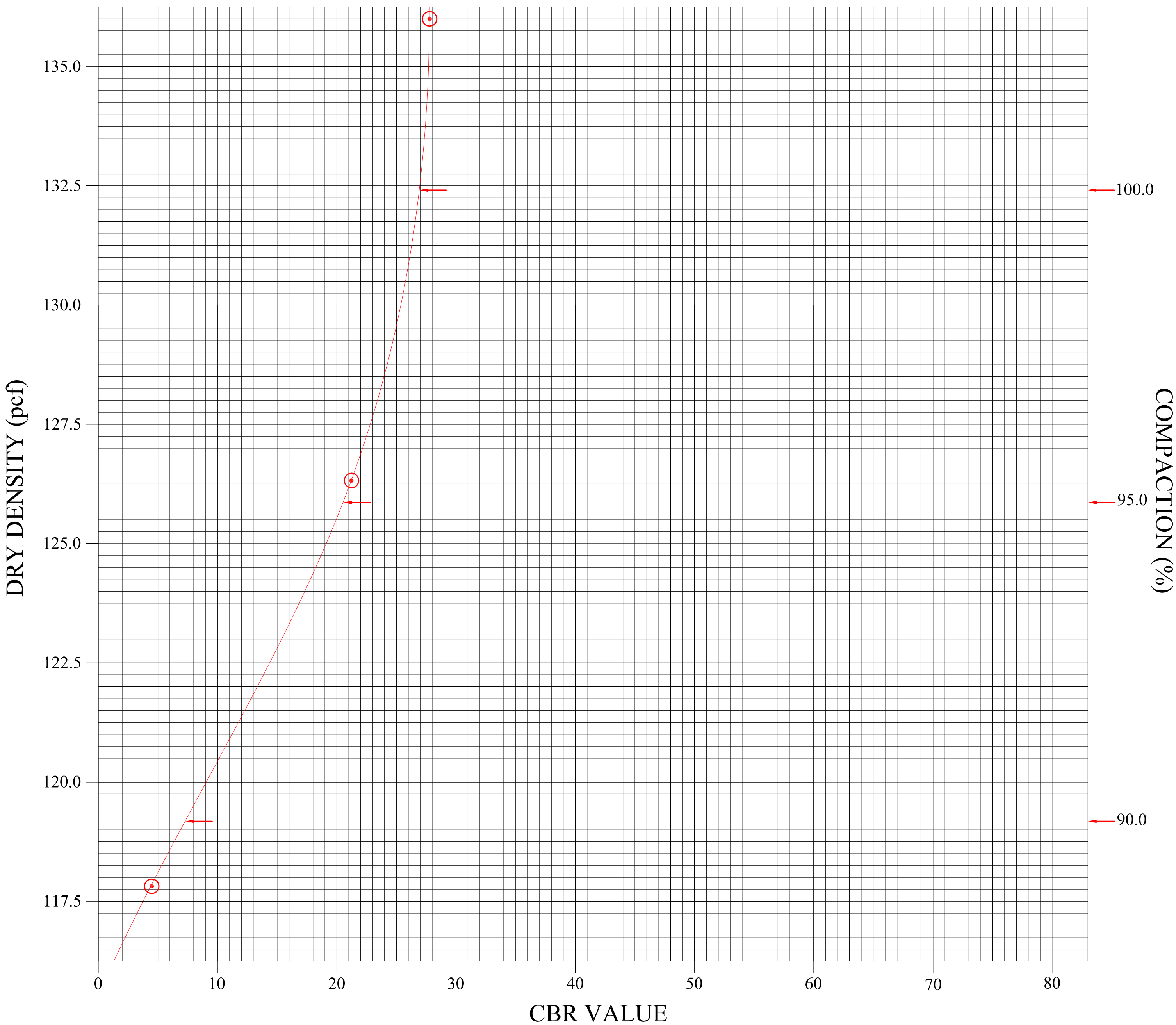
PROJECT: EDA NORTH BUSINESS DEVELOPMENT
DULUTH INTERNATIONAL AIRPORT
DULUTH, MINNESOTA

AET JOB NO: 07-03140

SAMPLE ID: COMPOSITE BORING SAMPLE

PROJECTED CBR @ 0.3" PENETRATION:

% Compaction	CBR
90	7.3
95	20.5
100	26.9



BORING LOG NOTES

DRILLING AND SAMPLING SYMBOLS

Symbol	Definition
B,H,N:	Size of flush-joint casing
CA:	Crew Assistant (initials)
CAS:	Pipe casing, number indicates nominal diameter in inches
CC:	Crew Chief (initials)
COT:	Clean-out tube
DC:	Drive casing; number indicates diameter in inches
DM:	Drilling mud or bentonite slurry
DR:	Driller (initials)
DS:	Disturbed sample from auger flights
FA:	Flight auger; number indicates outside diameter in inches
HA:	Hand auger; number indicates outside diameter
HSA:	Hollow stem auger; number indicates inside diameter in inches
LG:	Field logger (initials)
MC:	Column used to describe moisture condition of samples and for the ground water level symbols
N (BPF):	Standard penetration resistance (N-value) in blows per foot (see notes)
NQ:	NQ wireline core barrel
PQ:	PQ wireline core barrel
RD:	Rotary drilling with fluid and roller or drag bit
REC:	In split-spoon (see notes) and thin-walled tube sampling, the recovered length (in inches) of sample. In rock coring, the length of core recovered (expressed as percent of the total core run). Zero indicates no sample recovered.
REV:	Revert drilling fluid
SS:	Standard split-spoon sampler (steel; 1d" is inside diameter; 2" outside diameter); unless indicated otherwise
SU	Spin-up sample from hollow stem auger
TW:	Thin-walled tube; number indicates inside diameter in inches
WASH:	Sample of material obtained by screening returning rotary drilling fluid or by which has collected inside the borehole after Afalling@ through drilling fluid
WH:	Sampler advanced by static weight of drill rod and 140-pound hammer
WR:	Sampler advanced by static weight of drill rod
94mm:	94 millimeter wireline core barrel
?:	Water level directly measured in boring
I:	Estimated water level based solely on sample appearance

TEST SYMBOLS

Symbol	Definition
CONS:	One-dimensional consolidation test
DEN:	Dry density, pcf
DST:	Direct shear test
E:	Pressuremeter Modulus, tsf
HYD:	Hydrometer analysis
LL:	Liquid Limit, %
LP:	Pressuremeter Limit Pressure, tsf
OC:	Organic Content, %
PERM:	Coefficient of permeability (K) test; F - Field; L - Laboratory
PL:	Plastic Limit, %
q_p:	Pocket Penetrometer strength, tsf (approximate)
q_c:	Static cone bearing pressure, tsf
q_u:	Unconfined compressive strength, psf
R:	Electrical Resistivity, ohm-cms
RQD:	Rock Quality Designation of Rock Core, in percent (aggregate length of core pieces 4" or more in length as a percent of total core run)
SA:	Sieve analysis
TRX:	Triaxial compression test
VSR:	Vane shear strength, remoulded (field), psf
VSU:	Vane shear strength, undisturbed (field), psf
WC:	Water content, as percent of dry weight
%-200:	Percent of material finer than #200 sieve

STANDARD PENETRATION TEST NOTES

The standard penetration test consists of driving the sampler with a 140 pound hammer and counting the number of blows applied in each of three 6" increments of penetration. If the sampler is driven less than 18" (usually in highly resistant material), permitted in ASTM:D1586, the blows for each complete 6" increment and for each partial increment is on the boring log. For partial increments, the number of blows is shown to the nearest 0.1' below the slash.

The length of sample recovered, as shown on the AREC@ column, may be greater than the distance indicated in the N column. The disparity is because the N-value is recorded below the initial 6" set (unless partial penetration defined in ASTM:D1586 is encountered) whereas the length of sample recovered is for the entire sampler drive (which may even extend more than 18").

UNIFIED SOIL CLASSIFICATION SYSTEM
ASTM Designations: D 2487, D2488

AMERICAN ENGINEERING TESTING, INC.

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification: Group Symbol	Soil Classification: Group Name[B]
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$[E]	GW	Well graded gravel[F]
			$Cu < 4$ and/or $1 > Cc > 3$[E]	GP	Poorly graded gravel[F]
		Gravels with Fines more than 12% fines[C]	Fines classify as ML or MH	GM	Silty gravel[F.G.H]
			Fines classify as CL or CH	GC	Clayey gravel[F.G.H]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[D]	$Cu \geq 6$ and $1 \leq Cc \leq 3$[E]	SW	Well-graded sand[I]
			$Cu < 6$ and $1 > Cc > 3$[E]	SP	Poorly-graded sand[I]
		Sands with Fines more than 12% fines[D]	Fines classify as ML or MH	SM	Silty sand[G.H.I]
			Fines classify as CL or CH	SC	Clayey sand[G.H.I]
Fine-Grained Soils 50% or more passes the No. 200 sieve (see Plasticity Chart below)	Silts and Clays Liquid limit less than 50	inorganic	PI>7 and plots on or above "A" line[J]	CL	Lean clay[K.L.M]
			PI<4 or plots below "A" line[J]	ML	Silt[K.L.M]
		organic	$\frac{\text{Liquid limit–oven dried}}{\text{Liquid limit – not dried}} < 0.75$	OL	Organic clay[K.L.M.N] Organic silt[K.L.M.O]
	Silts and Clays Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat clay[K.L.M]
			PI plots below "A" line	MH	Elastic silt[K.L.M]
		organic	$\frac{\text{Liquid limit–oven dried}}{\text{Liquid limit – not dried}} < 0.75$	OH	Organic clay[K.L.M.P] Organic silt[K.L.M.Q]
Highly organic soil			Primarily organic matter, dark in color, and organic in odor	PT	Peat[R]

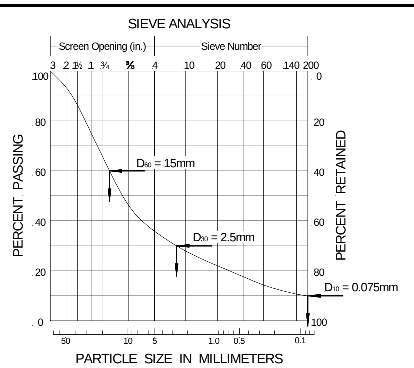
Notes

[A]Based on the material passing the 3-in (75-mm) sieve.
[B]If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.
[C]Gravels with 5 to 12% fines require dual symbols:
- GW-GM well-graded gravel with silt
- GW-GC well-graded gravel with clay
- GP-GM poorly graded gravel with silt
- GP-GC poorly graded gravel with clay

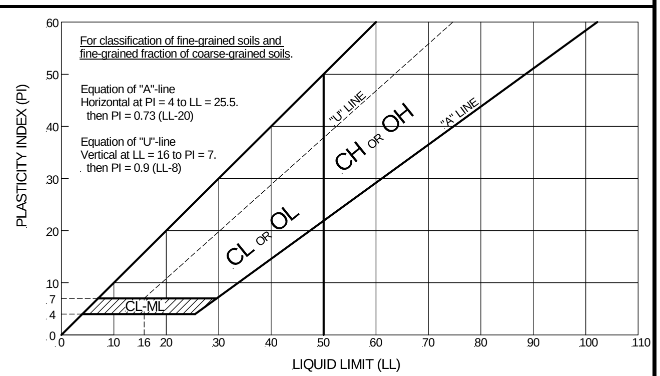
[D]Sands with 5 to 12% fines require dual symbols:
- SW-SM well-graded sand with silt
- SW-SC well-graded sand with clay
- SP-SM poorly graded sand with silt
- SP-SC poorly graded sand with clay

[E]$Cu = D_{60}/D_{10}$, $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F]If soil contains $\geq$15% sand, add "with sand" to group name.
[G]If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.
[H]If fines are organic, add "with organic fines" to group name.
[I]If soil contains $\geq$15% gravel, add "with gravel" to group name.
[J]If Atterberg limits plot is hatched area, soils is a CL-ML silty clay.
[K]If soil contains 15 to 29% plus No. 200 add "with sand" or "with gravel", whichever is predominant.
[L]If soil contains $\geq$30% plus No. 200, predominantly sand, add "sandy" to group name.
[M]If soil contains $\geq$30% plus No. 200, predominantly gravel, add "gravelly" to group name.
[N]$PI \geq 4$ and plots on or above "A" line.
[O]$PI < 4$ or plots below "A" line.
[P]PI plots on or above "A" line.
[Q]PI plots below "A" line.
[R]Fiber Content description shown below.



$C_u = \frac{D_{60}}{D_{10}} = \frac{15}{0.075} = 200$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{2.5^2}{0.075 \times 15} = 5.6$



Plasticity Chart

ADDITIONAL TERMINOLOGY NOTES USED BY AET FOR SOIL IDENTIFICATION AND DESCRIPTION

Grain Size

Term	Particle Size
Boulders	Over 12"
Cobbles	3" to 12"
Gravel	#4 sieve to 3"
Sand	#200 to #4 sieve
Fines (silt & clay)	Pass #200 sieve

Gravel Percentages

Term	Percent
A Little Gravel	3% - 14%
With Gravel	15% - 29%
Gravelly	30% - 50%

Consistency of Plastic Soils

Term	N-Value, BPF
Very Soft	less than 2
Soft	2 - 4
Firm	5 - 8
Stiff	9 - 15
Very Stiff	16 - 30
Hard	Greater than 30

Relative Density of Non-Plastic Soils

Term	N-Value, BPF
Very Loose	0 - 4
Loose	5 - 10
Medium Dense	11 - 30
Dense	31 - 50
Very Dense	Greater than 50

Moisture/Frost Condition (MC Column)

D (Dry):	Absense of moisture, dusty, dry to touch.
M (Moist):	Damp, although free water not visible. Soil may still have a high water content (over "optimum").
W (Wet/ Waterbearing):	Free water visible intended to describe non-plastic soils. Waterbearing usually relates to sands and sand with silt.
F (Frozen):	Soil frozen

Layering Notes

Laminations:	Layers less than ½" thick of differing material or color.
Lenses:	Pockets or layers greater than ½" thick of differing material or color.

Fiber Content of Peat

Term	Fiber Content (Visual Estimate)
Fibric Peat:	Greater than 67%
Hemic Peat:	33 – 67%
Sapric Peat:	Less than 33%

Organic/Roots Description (if no lab tests)

Soils are described as *organic*, if soil is not peat and is judged to have sufficient organic fines content to influence the soil properties. *Slightly organic* used for borderline cases.

With roots:	Judged to have sufficient quantity of roots to influence the soil properties.
Trace roots:	Small roots present, but not judged to be in sufficient quantity to significantly affect soil properties.

GEOLOGIC TERMINOLOGY (SOILS)

General categories of geologic deposits used, descriptive information and common soil types is as follows:

FILL (F): Soils, rock and/or waste products placed or disturbed by man rather than through geologic processes. Mixed soils are usually easy to identify. Uniform material is more difficult, and signs such as small inclusions, underlying topsoil, topography or knowledge of below grade improvements (e.g., basement backfill, utility trenches, etc.) may be needed to properly judge. When mixed condition is stratified horizontally, the soil may be a weathered natural soil rather than fill.

TOPSOIL (TS): Upper darker colored layer formed by weathering of inorganic soil and accumulation of organic material. Usually black, dark brown, dark gray or dark grayish brown. Often transitions from darker to lighter color.

SLOPEWASH (SW): Organic and/or inorganic materials (sometimes interlayered) washed from slopes and redeposited. Usually stratified. Will be located in depressed areas where they can be washed in from slopes. When topsoil layers are thick in depressed areas, there is a good chance the soil is slopewash.

SWAMP DEPOSITS (SD): Highly organic material (peats and organic clays) which are formed through accumulation of organic material under water. **Peat, Organic clay**

COARSE ALLUVIUM (CA): Sandy (and gravelly). Stratified. Deposited from fast moving waters in streams and rivers. Includes glacial outwash. **Sand, Sand with silt, Silty sand, Gravels**

FINE ALLUVIUM (FA): Clayey and/or silty. Stratified. Deposited from slow moving waters in streams, rivers, lakes and ponds. Includes glacial outwash. **Lean clay, Fat clay, Silty clay, Silt, Sandy silt**

MIXED ALLUVIUM (MA): Combination of Fine and Coarse Alluvium. **Clayey sand, Sandy lean clay,** interlayered **CA/FA**

LACUSTRINE (LAC): Fine grained lake bed deposits (lakes may or may not still be in existence). Usually in very flat topography. **Fat clay, Lean clay, Silty clay, Silt**

LOESS (LOESS): Uniform, non-stratified, silty material (or very fine sand) which is deposited by wind. Can include significant clay content, and grain contacts may be cemented by clay or calcareous (limestone/chalky) material. **Silt, Sandy silt, Silty clay, Lean clay**

TILL (T): Normally contains a wide range of grain sizes, from boulders through clay. Usually non-stratified (not sorted through water action). Deposited directly from glaciers. **Silty sand, Clayey sand, Sandy lean clay,** usually contains **gravel**

WEATHERED TILL (WT): Tills which have been altered by exposure to the action of frost, water, or chemicals. Often softer than underlying soils. May be stratified with varying colors/soil types due to filling in or other changes in frost lensed zones.

COLLUVIUM (COL): Dominantly gravel, boulders and rock slabs, sometimes intermixed or layered with soils. Deposited from gravity flow down hills or cliffs.