FOUNDATION ANALYSIS AND DESIGN REPORT

TO: Mark Bishop, PE, Kimley-Horn and Associates, Inc.

FROM: Jeffery K. Voyen, PE, American Engineering Testing, Inc.

DATE: June 25, 2014

SUBJECT: North Cedar Lake Trail Pedestrian Bridge (Southwest of Penn Station)
Southwest Light Rail Transit Project
Minneapolis, Minnesota
AET No. 01-05697.12

1.0 PROJECT INFORMATION

This report provides preliminary foundation recommendations for the pedestrian bridge which is intended to carry the North Cedar Lake Trail over the LRT and freight rail tracks to the southwest of the Penn Station in Minneapolis. The location of the bridge has not been firmly established, although the current layout addressed in this report is presented on attached Figure 1. For the purpose of this report, bottom of foundation elevation is assumed to be about 5 feet below the current grade at the site.

The plan and profile sheets from the preliminary bridge plans are attached to this report.

The intent of this report is not to serve as a final design report, but a preliminary report to assist advanced design and preliminary pricing. Additional testing and analysis is intended to be performed for final design. The borings performed as of this report which is specific to this bridge were limited to the north side of the existing freight tracks (Minneapolis Park and Recreation Board property). The HCCRA property to the south of the tracks, which represents the east half of the bridge, is wooded; and access to the desired boring locations would have required some tree removal. Therefore, exploration in that area was deferred until advanced design, once the bridge location is firmly established.

2.0 SUBSURFACE EXPLORATION SUMMARY

2.1 Field Scope

Four standard penetration test (SPT) borings were drilled and sampled on the north side of the freight tracks in the currently proposed west half of the bridge. The borings are numbered 1241 SW, 1242 SB, 1243 SB, and 1244 SB. The locations of the borings appear on attached Figure 1.

2.2 Laboratory Scope

During laboratory classification logging, water content tests were conducted on cohesive soil samples. The test results appear on the individual boring logs, opposite the samples upon which they were performed.

2.3 Methods

2.3.1 Standard Penetration Test Borings

Logs of the noted borings are attached. The SPT borings were drilled with 3.25 inch diameter hollow stem augers and mud rotary drilling methods. Standard penetration test samples were taken with split-barrel samplers per ASTM: D1586, with the exception that the hammers were calibrated to near N_{60} values, consistent with MnDOT requirements. Additional details of the methods used appear on the attached sheet entitled *Exploration/Classification Methods*.

The soils were classified per the Unified Soil Classification System. The Soil Group category per the AASHTO Soil Classification System is also noted. The attached boring logs contain information concerning soil layering, soil classification, geologic description, and moisture condition. Relative density or consistency is also noted for the natural soils, which is based on the standard penetration resistance (N-value).

2.4 Geology/Soils Review

About 4 feet to 9 feet of fill is present at the surface; the thickness decreasing to the west. The fill is mostly sand with silt and silty sand, with a lesser amount of clayey sand. Some of the soil includes organic content and roots. Boring 1243 SB included pieces of brick. The N-values suggest relatively good compaction, but the presence of organics indicates that it was not controlled, engineered fill.

The underlying natural soils are mostly alluvial (water-deposited). The alluvium is mainly sand and sand with silt, often having significant gravel content. Boring 1244 SB does include some layers of clayey sand and silt at or near the top of the alluvial profile.

Glacially-deposited till appears at depth, deeper than elevation 800 feet, except for a thinner interbedded layer at Boring 1244 SB from 19 feet to 24 feet. The till consists of clayey sand, silty sand, sandy lean clay, and lean clay with sand.

2.5 Ground Water

Water levels appeared in the boreholes at depths ranging from about 7½ feet to 10½ feet, corresponding to approximate elevation 848½ feet to 849 feet. As the levels were measured in granular soils, they should reasonably represent the hydrostatic ground-water level for that time and location. Ground-water levels should be expected to fluctuate both seasonally and annually.

3.0 FOUNDATION REVIEW

3.1 Foundation Type

In the explored west half of the bridge and retained wall approach area, alluvial sands are present at anticipated foundation grade or are at a reasonable depth below foundation grade such that a local excavate/refill correction operation could be performed to allow spread foundation support. We recommend the footings not be supported on the existing fill due to the intermixed organics and debris, and due to the potential variation in soil type and compaction level.

It is possible that poorer soil conditions will be present on the east side of the bridge. Boring 1025 ST placed in the planned track area to the northeast of the track crossing span did show the presence of buried swamp deposits. Additional soil borings should be performed at final foundation locations during advanced design to explore this condition further.

3.2 Spread Foundation for Bridge and Retained Wall Approaches

The alluvial sands are judged competent to support spread foundations. However, we recommend the existing fill not be relied upon for foundation support. Excavation to assumed foundation grade is expected to expose either the fill or the alluvial sandy soils. Where fill is encountered, we recommend excavation of the fill to expose the alluvium. Excavation depth needed at each boring location included in the report is shown on Table 3.2.

Table 3.2 –Required Excavation Depth

Boring No.	Boring Surface Elevation, ft	Excavation Depth, ft	Excavation Elevation, ft	Ground Water Anticipated
1241 SW	857.7	4	853½	no
1242 SB	859.1	6½	852½	no
1243 SB	857.4	6½	851	no
1244 SB	856.0	9	847	yes

As shown, the excavation in the area of Boring 1244 SB may extend 1½ feet to 2 feet below the water level. This boring was completed this June (2014) during a time when ground-water levels are above normal. If standing water is present during construction, we recommend local dewatering be performed as needed to allow observation and verification of a competent excavation bottom.

Excavations and subsequent engineered fill placement should maintain minimum lateral oversizing of the excavation bottom. This lateral excavation oversizing should be a minimum of 1:1(H:V). The exception would be if organic soils are encountered during the excavation (which is not expected in the area of the four borings). If excavation sides expose organic soils, the lateral excavation bottom oversize requirement should be increased to at least 1.5:1 (H:V).

Engineered fill placed below foundations should meet the requirements of MnDOT Specification 3149.2B1 for Granular Borrow. On-site soils could be used, provided they are evaluated at the time of construction to uniformly meet material specifications and to be free of organic soils and debris. If wet or sensitive excavation bottom conditions exist, it may then be necessary to use Select Granular Borrow (Specification 3149.2B2) or cleaner sand as the lower lifts of fill.

The fill should be compacted in thin lifts, such that the entire lift achieves a minimum compaction level of 98% of the *standard maximum dry unit weight* per ASTM:D698 (Standard Proctor test). The fill lift thicknesses should be no greater than 12 inches for granular soils and no greater than 8 inches for more clayey/silty soils. The lifts should be thinner than the above if needed to achieve the minimum specified compaction level with the type of compaction equipment being used.

3.3 Spread Foundation Design

Considering the preliminary nature of the bridge and approach design, specific foundation load information is not yet available. Advanced design should consider strength resistance and settlement control under axial loads; and for imbalanced/retained loads, resistance to sliding and global stability. For preliminary purposes, the foundations can be sized for an allowable bearing pressure of 4,000 psf (per Allowable Stress Design methods).

3.4 Approach Considerations

Fill will be placed between the retained walls leading up to the structured bridge. The fill will impose loads upon underlying soils. However, it is our opinion that trail support over the existing fill would be acceptable with low risk, provided conditions are consistent with that portrayed by the borings. The wall footing excavations will expose the fill along the trench sidewalls and these conditions can be further evaluated during construction.

3.5 Retaining Wall Backfilling

Imbalanced retaining walls and abutment/wing walls should be designed to properly resist the lateral pressures exerted. The backfill material should consist of Select Granular Borrow (MnDOT 3149.2B2), which is modified to containing less than 10% by weight passing the #200 sieve. The "Select Granular Borrow 10% Modified" geometry should be maintained per the requirements shown on attached MnDOT *Diagram F-1*. However, all excavation backsloping must also meet OSHA requirements and the need for frost zone tapering below the approach pavement. For trail approach performance, frost tapering of the Select Granular Borrow below the trail of 1V:10H is recommended within the frost zone (assume a frost zone of 4.5 feet). The backfill should be compacted per the Specified Density Method (MnDOT 2105.3F1). The wall design can be based on lateral pressures presented in MnDOT design charts.

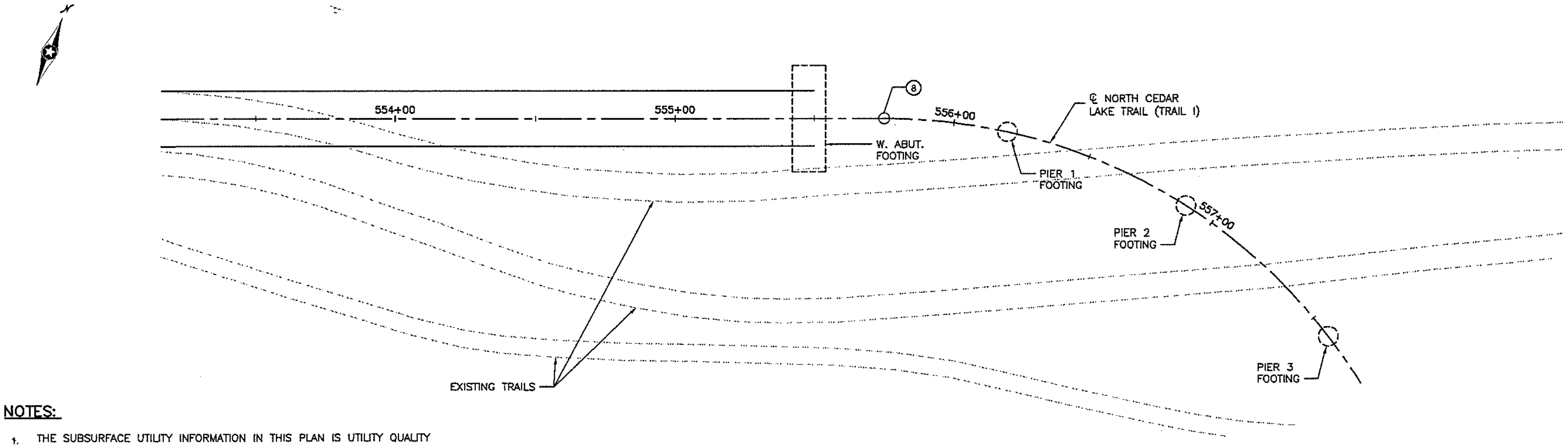
I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under Minnesota Statute Section 326.02 to 326.15

Name: Jeffery K. Voyen
Jeffery K. Voyen

Date: 6/25/14 **License #: 15928**

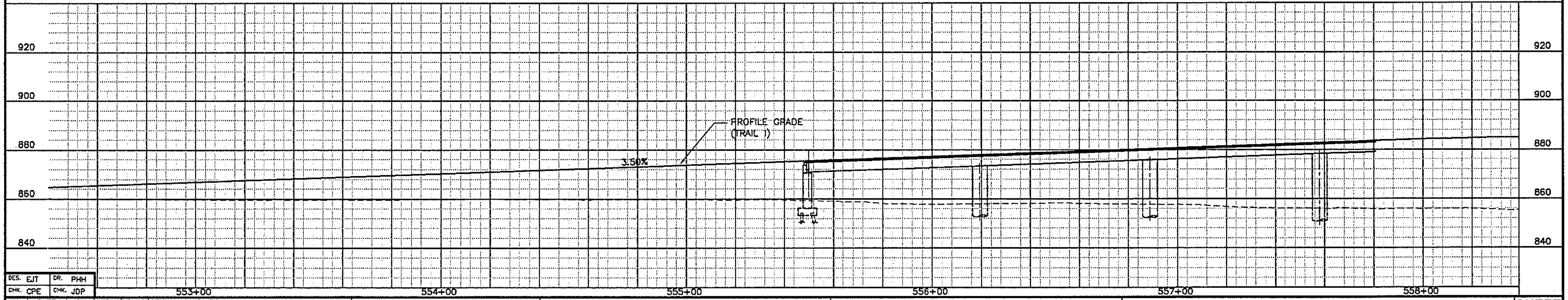
Report Reviewed By: Joseph G. Bentler
Joseph G. Bentler, PE

Attachments:
- Preliminary Bridge Plan-Profile Sheets
- Figure 1 – Boring Locations
- Subsurface Boring Logs
- Exploration/Classification Methods
- Boring Log Notes
- Unified Soil Classification System
- AASHTO Soil Classification System
- MnDOT Diagram F-1



NOTES:

1. THE SUBSURFACE UTILITY INFORMATION IN THIS PLAN IS UTILITY QUALITY LEVEL D. THIS UTILITY QUALITY LEVEL WAS DETERMINED ACCORDING TO GUIDELINES OF CI/ASCE 38-02, ENTITLED "STANDARD GUIDELINES FOR THE COLLECTION AND DEPICTION OF EXISTING SUBSURFACE UTILITY DATA".
2. BORINGS WILL BE OBTAINED AFTER MUNICIPAL CONSENT AND DURING ADVANCED DESIGN.
3. FOR P.C., P.T., AND P.R.C. COORDINATES SEE GENERAL PLAN, SHEET 138.



DES. EJT	DR. PHH
CHK. CPE	CHK. JDP

NO.	DATE	BY	CHECK	DESIGN	REVISION / SUBMITTAL

Kimley»Horn

PRELIMINARY ENGINEERING

METROPOLITAN COUNCIL

SOUTHWEST Green Line LRT Extension

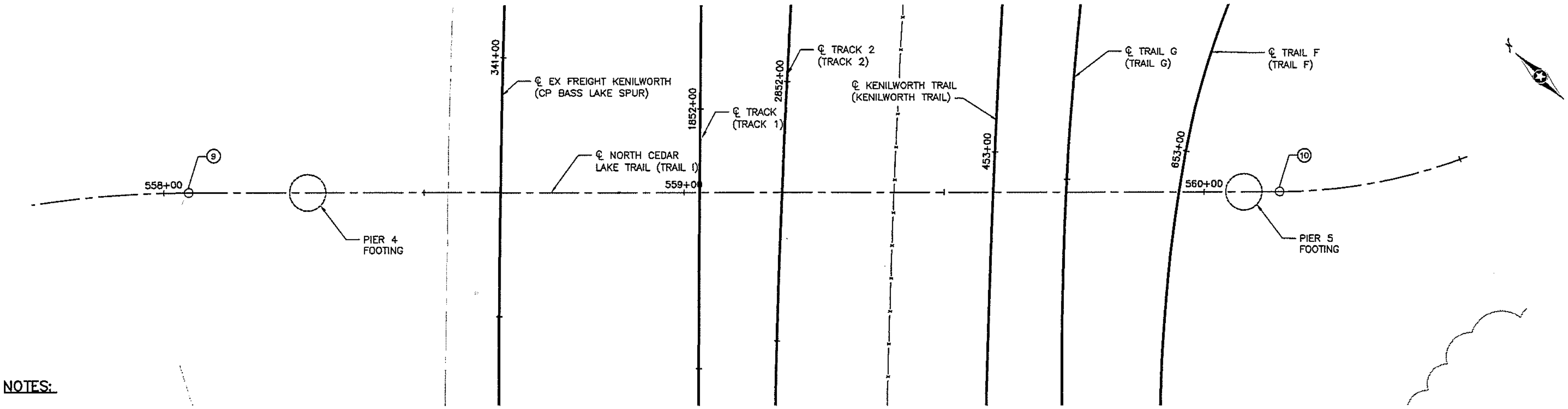
EAST - VOLUME 2 (STRUCTURES)
NORTH CEDAR LAKE TRAIL
BRIDGE XXXXX (TRL)
BORINGS (1 OF 7)

DISCIPLINE: STRUCTURES

SHEET NAME: E4-STU-BRG-NCDL-TRL-BOR-001

SHEET 147 OF 277

Jun, 20 2014 10:15 am V:\3300_PEC-E\CAD\SEGMENT E4\PLAN SHEETS\STRUCTURES\E4-STU-BRG-NCDL-TRL-SUR-002.dwg By: phil.horton



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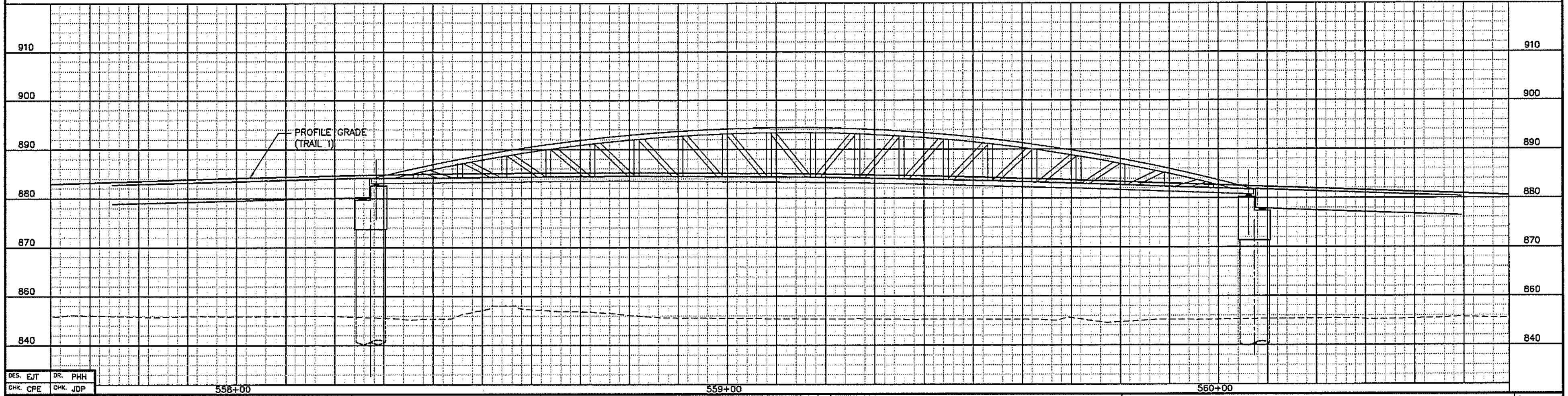

DES.	EJT	DR.	PHH
CHK.	CPE	CHK.	JDP

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METROPOLITAN COUNCIL

SOUTHWEST Green Line LRT Extension

EAST - VOLUME 2 (STRUCTURES)
NORTH CEDAR LAKE TRAIL
BRIDGE XXXXX (TRL)
BORINGS (2 OF 7)

DISCIPLINE: STRUCTURES

SHEET NAME: E4-STU-BRG-NCDL-TRL-BOR-002

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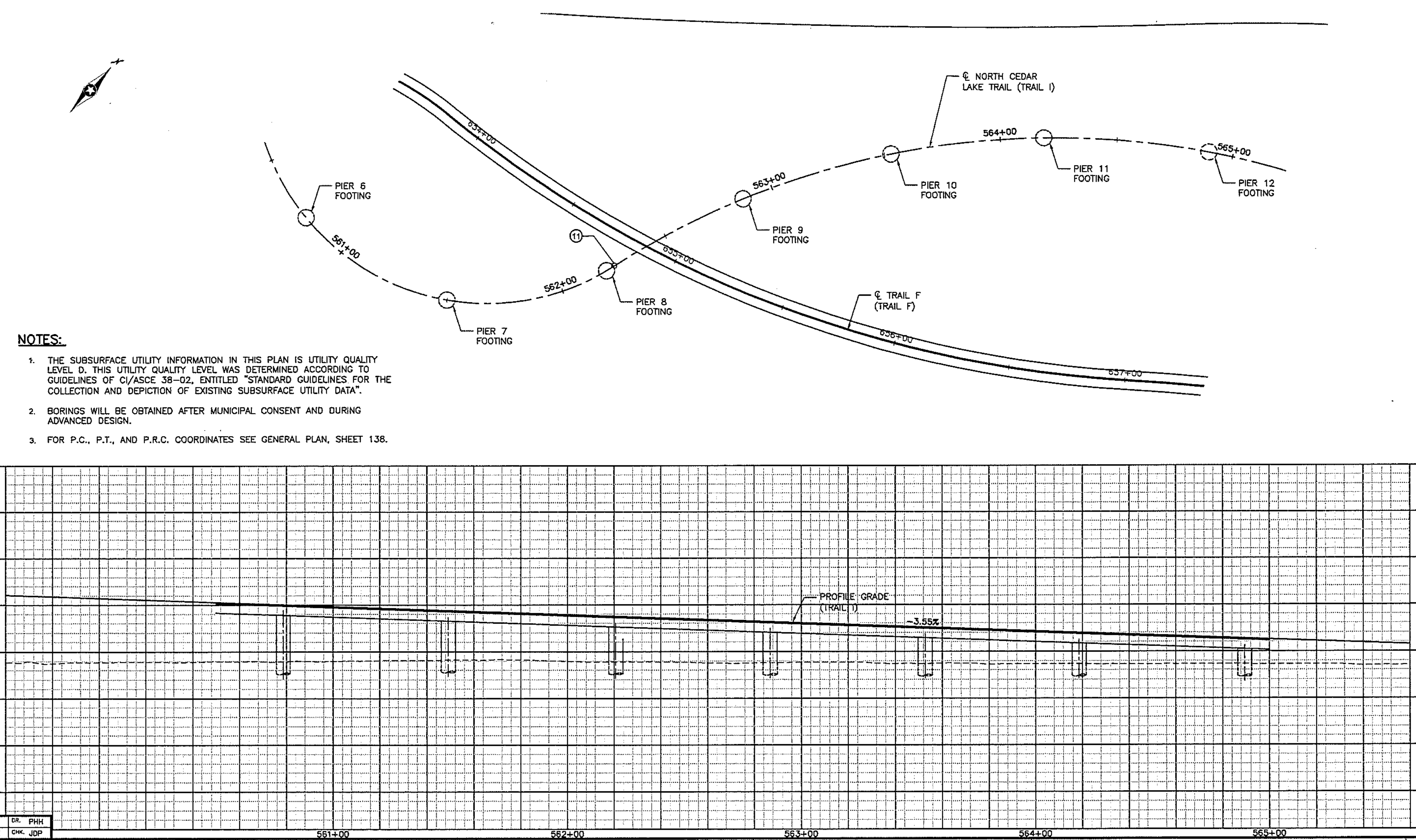

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CHK. CPE	CHK. JDP

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SOUTHWEST Green Line LRT Extension

EAST - VOLUME 2 (STRUCTURES)
NORTH CEDAR LAKE TRAIL
BRIDGE XXXXX (TRL)
BORINGS (3 OF 7)

DISCIPLINE: STRUCTURES

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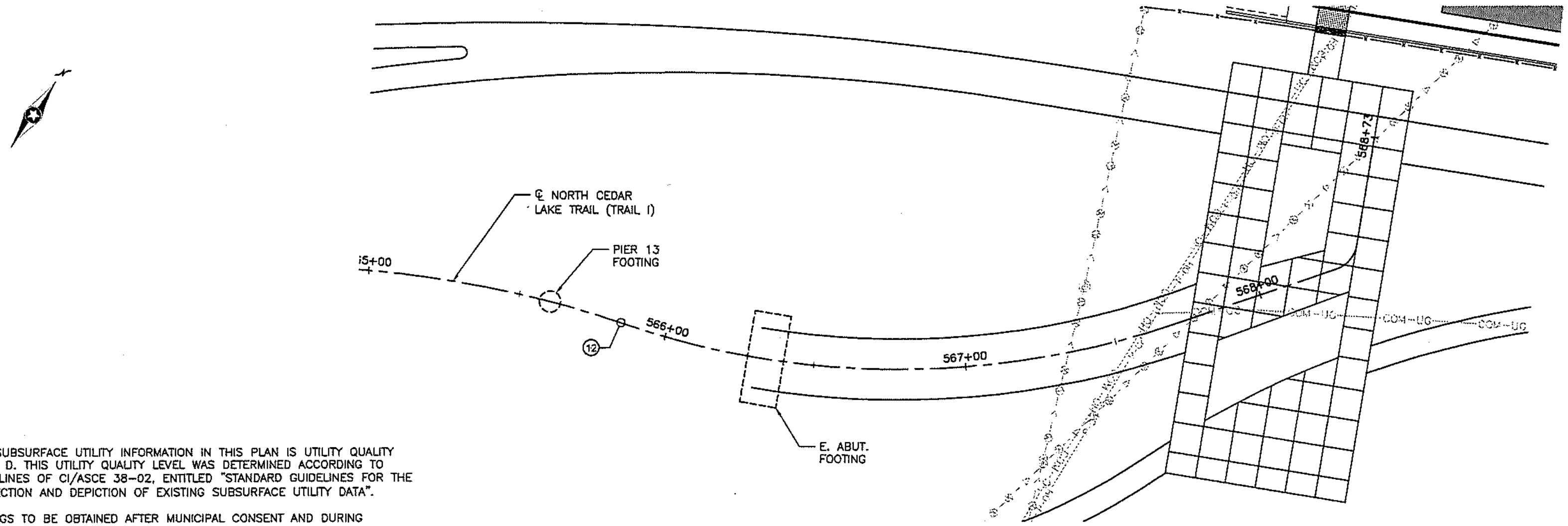

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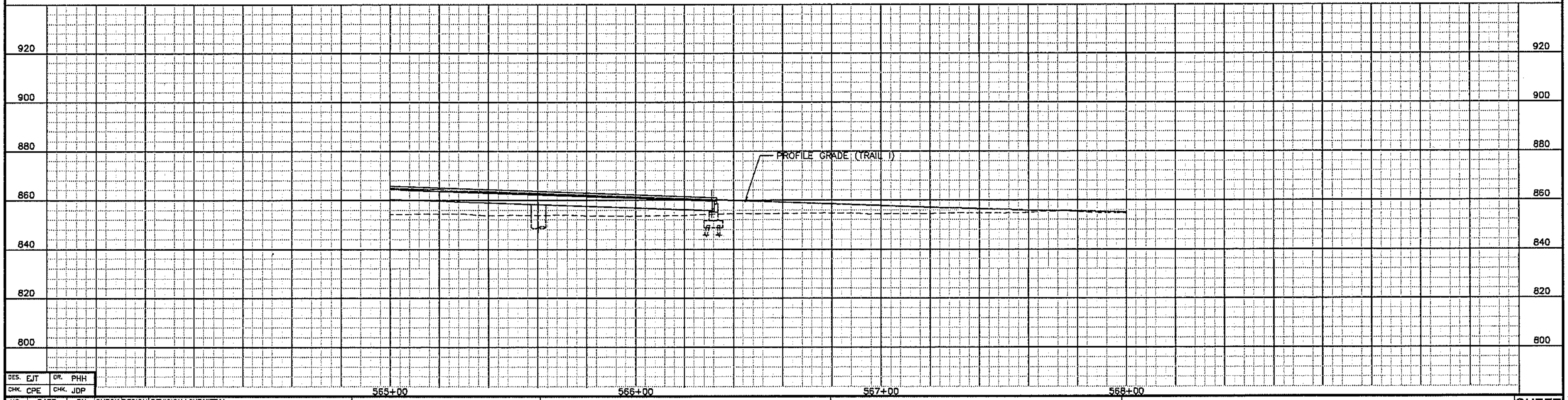

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SOUTHWEST Green Line LRT Extension

EAST - VOLUME 2 (STRUCTURES)
NORTH CEDAR LAKE TRAIL
BRIDGE XXXXX (TRL)
BORINGS (4 OF 7)

DISCIPLINE: STRUCTURES

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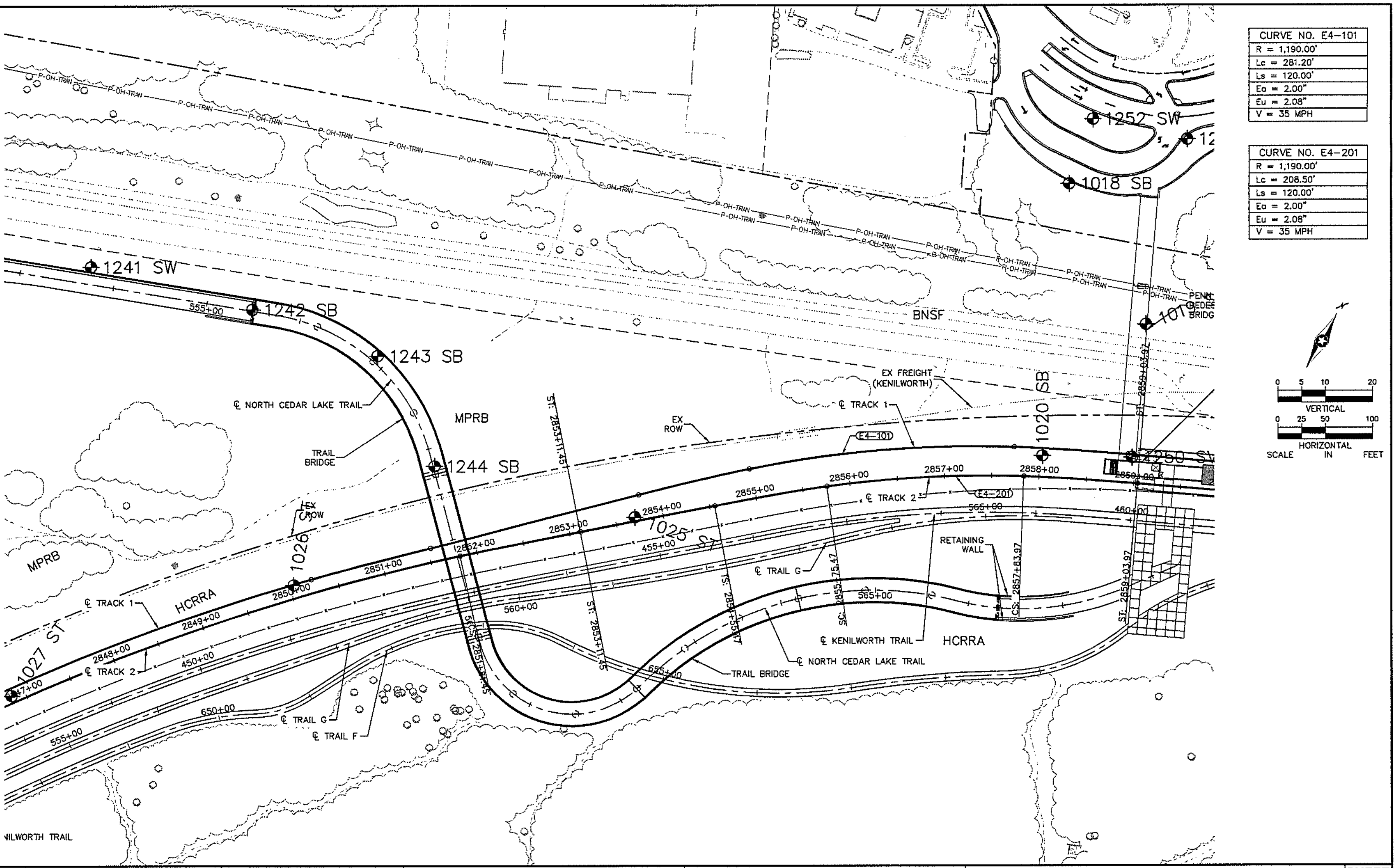

CURVE NO. E4-101
R = 1,190.00'
Lc = 281.20'
Ls = 120.00'
Ea = 2.00"
Eu = 2.08"
V = 35 MPH

CURVE NO. E4-201
R = 1,190.00'
Lc = 208.50'
Ls = 120.00'
Ea = 2.00"
Eu = 2.08"
V = 35 MPH

NO.	DATE	BY	CHECK	DESIGN	REVISION / SUBMITTAL

Kimley»Horn
SYSTRA
PRELIMINARY ENGINEERING

METROPOLITAN COUNCIL
SOUTHWEST Green Line LRT Extension

EAST SEGMENT 4
SOIL BORINGS
PLANS
NCDL TRAIL BRIDGE

DISCIPLINE: CIVIL
SHEET NAME: E4-BRDG-SB - 003

SHEET 32 OF 42

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Figure 1 – Boring Locations
AET No. 01-05697.12

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

METROPOLITAN
COUNCIL

MINNESOTA DEPARTMENT OF TRANSPORTATION

A AMERICAN
ENGINEERING
TESTING, INC.

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UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	NCDL Bridge	**Southwest LRT, PEC East**	**1241 SW**	**857.7** *(Surveyed)*

Location **, , ft. LT**

Co. Coordinate: X=518281 Y=164250 (ft.)

Latitude (North)=44.9673033 Longitude (West)=-93.3127070

Drill Machine **68C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 1

Drilling Completed **6/13/14**

DEPTH	Depth Elev.	Lithology	Classification	Drilling Operation	SPT N60 REC (%)	MC (%) RQD (%)	COH (psf) ACL (ft)	γ (pcf) Core Breaks	Soil / Rock: Other Tests Or Remarks Formation or Member
	2.0 855.7	▨	Silty sand with organic fines, a little gravel and sandy lean clay, trace roots, dark brown, a little brown (A-2-4) fill	☒	34				Hammer Calibration: 68% efficiency with 110 lb. hammer, 6/9/14
	4.0 853.7	▨	Sand with silt and gravel, light brown (A-1-b) fill	☒	33				
5	6.5 851.2		SAND WITH SILT, fine grained, light brown, moist, medium dense, lenses of silty sand (SP-SM) (A-3, A-2-4) alluvium	☒	23				
	9.0 848.7		SAND, a little gravel, medium to fine grained, light brown, a little brown, moist, medium dense, a lens of sand with silt (SP) (A-1-b) alluvium	☒	14				
▼ 10	11.5 846.2		GRAVELLY SAND WITH SILT, medium to coarse grained, brown, waterbearing, medium dense, a lens of silt (SP-SM) (A-1-b) alluvium	☒	16				Water level measured at 9.3' deep with HSA to 14.5' deep
	14.0 843.7		GRAVELLY SAND WITH SILT, medium grained, brown, waterbearing, medium dense, lenses of clayey sand (SP-SM) (A-1-b) alluvium	☒	29				
15	19.0 838.7		SAND, a little gravel, medium to fine grained, brown, waterbearing, medium dense, a lens of sand with silt (SP) (A-1-b) alluvium	☒ PD ☒	17 14				
20	21.5 836.2		SAND WITH SILT, a little gravel, fine to medium grained, brown, waterbearing, medium dense, lenses of clayey sand (SP-SM) (A-3, A-6) alluvium	PD ☒	 23				
	24.0 833.7		SAND WITH SILT, a little gravel, medium to fine grained, brown, waterbearing, dense (SP-SM) (A-1-b) alluvium	PD ☒	 34				
25	25.5 832.2		SAND WITH GRAVEL, medium to coarse grained, brown, waterbearing, dense (SP) (A-1-b) alluvium	PD ☒	 33				
	29.5 828.2		SAND WITH SILT, a little gravel, fine to medium grained, brown, waterbearing, dense (SP-SM) (A-3) alluvium	PD ☒	 46				
30	31.0 826.7		SAND, medium to fine grained, brown, waterbearing, dense (SP) (A-1-b) alluvium	PD ☒	 38				
			END OF BORING						

Index Sheet Code

Soil Class: Rock Class: Edit: Date: 8/25/14

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LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

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UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	NCDL Bridge	**Southwest LRT, PEC East**	**1242 SB**	**859.1** (Surveyed)

Location **, , ft. LT**

Co. Coordinate: X=518453 Y=164299 (ft.)

Latitude (North)=44.9674373 Longitude (West)=-93.3120424

Drill Machine **68C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 3

Drilling Completed **6/12/14**

Depth / Elev.	Classification	Drilling Operation	SPT N60	MC (%)	COH (psf)	γ (pcf)	Other Tests Or Remarks
4.0 855.1	Silty sand, a little gravel, trace roots, black and dark brown (A-2-4) fill		18 22				Hammer Calibration: 68% efficiency with 110 lb. hammer, 6/9/14
6.5 852.6	Sand with silt, a little gravel and silty sand, brown, a little black (A-3) fill		35				
9.0 850.1	GRAVELLY SILTY SAND, fine to medium grained, brown, moist, medium dense (SM) (A-1-b) alluvium or fill		19				
11.5 847.6	SAND WITH SILT AND GRAVEL, fine to medium grained, brown, moist, dense (SP-SM) (A-1-b) alluvium		36				Water level measured at 10.6' deep with HSA to 14.5' deep (rose from 11.5' deep 10 minutes earlier)
14.0 845.1	SAND WITH GRAVEL, medium to coarse grained, brown, waterbearing, medium dense (SP) (A-1-b) alluvium		18				
19.0 840.1	GRAVELLY SAND, medium grained, brown, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	17 20				
40.5 818.6	SAND, fine grained, gray, waterbearing, medium dense (SP) (A-3) alluvium	PD PD PD PD PD PD PD PD PD	21 21 24 19 20 23 26 24 24				
	SAND WITH GRAVEL, medium to coarse grained, gray, waterbearing, medium dense to loose (SP) (A-1-b) alluvium	PD					

Index Sheet Code

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Soil Class: Rock Class: Edit: Date: 8/25/14

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LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

METROPOLITAN COUNCIL

MINNESOTA DEPARTMENT OF TRANSPORTATION

AMERICAN ENGINEERING TESTING, INC.

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UNIQUE NUMBER

U.S. Customary Units

SHEET 2 of 3

State Project	*Bridge No. or Job Desc.*	*Trunk Highway/Location*	*Boring No.*	*Ground Elevation*
	NCDL Bridge	**Southwest LRT, PEC East**	**1242 SB**	**859.1** *(Surveyed)*

DEPTH	*Depth / Elev.*	*Lithology*	*Classification*	*Drilling Operation*	*SPT N60 / REC (%)*	*MC (%) / RQD (%)*	*COH (psf) / ACL (ft)*	*γ (pcf) / Core Breaks*	*Soil / Rock*	*Other Tests Or Remarks / Formation or Member*
				☒	28					
				PD						
45			SAND WITH GRAVEL, medium to coarse grained, gray, waterbearing, medium dense to loose (SP) (A-1-b) alluvium *(continued)*	☒	21					
				PD						
				☒	10					
	49.0 810.1			PD						
50			SAND, a little gravel, medium grained, brownish gray, waterbearing, medium dense (SP) (A-1-b) alluvium	☒	16					
				PD						
	53.0 806.1									
55			SAND, a little gravel, medium to coarse grained, gray, medium dense (SP) (A-1-b) alluvium	☒	19					
				PD						
	58.0 801.1									
60			SAND, fine to medium grained, brownish gray, waterbearing, medium dense (SP) (A-3) alluvium	☒	16					
				PD						
	63.0 796.1									
65			SAND WITH GRAVEL, medium to fine grained, gray, waterbearing, medium dense, a lens of clayey sand (SP) (A-1-b) alluvium	☒	18					
				PD						
	68.0 791.1									
70				☒	13					
			SAND WITH GRAVEL, medium grained, gray, waterbearing, medium dense, lenses and laminations of clayey sand (SP) (A-1-b) alluvium	PD						
75				☒	16					
				PD						
	78.0 781.1									
80			GRAVELLY SAND, medium grained, gray, waterbearing, medium dense to loose (SP) (A-1-b) alluvium	☒	14					
				PD						

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LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

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U.S. Customary Units

SHEET 3 of 3

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	NCDL Bridge	**Southwest LRT, PEC East**	**1242 SB**	**859.1** (Surveyed)

DEPTH	Depth / Elev.	Lithology	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Soil / Rock	Other Tests Or Remarks / Formation or Member
85	88.0 771.1		GRAVELLY SAND, medium grained, gray, waterbearing, medium dense to loose (SP) (A-1-b) alluvium *(continued)*	PD ☒ PD	6					
90	91.0 768.1		CLAYEY SAND, a little gravel, brown, hard (SC/SM) (A-2-4) till	☒	51	9				
			END OF BORING							

Soil Class: Rock Class: Edit: Date: 8/25/14

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UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	NCDL Bridge	**Southwest LRT, PEC East**	**1243 SB**	**857.4** (Surveyed)

Location **, , ft. LT**
Co. Coordinate: X=518589 Y=164316 (ft.)
Latitude (North)=44.9674836 Longitude (West)=-93.3115169

Drill Machine **68C**
Hammer **CME Automatic Calibrated**
SHEET 1 of 2
Drilling Completed **6/12/14**

Depth / Elev.	Classification	Drilling Operation	SPT N60 / REC (%)	MC (%) / RQD (%)	COH (psf) / ACL (ft)	γ (pcf) / Core Breaks	Other Tests Or Remarks / Formation or Member
2.0 / 855.4	Mixture of silty sand and clayey sand with organic fines, a little gravel, pieces of brick, trace roots, black (A-2-4) fill		11				Hammer Calibration: 68% efficiency with 110 lb. hammer, 6/9/14
4.0 / 853.4	Silty sand with gravel, dark brown (A-1-b) fill		27				
6.5 / 850.9	Sand with silt, a little gravel and clayey sand, brown (A-1-b) fill		29				
9.0 / 848.4	SAND WITH GRAVEL, medium to coarse grained, light brown, moist, medium dense (SP) (A-1-b) alluvium		20				Water level measured at 8.2' deep with HSA to 9.5' deep (rose from 8.4' deep 10 minutes earlier)
19.0 / 838.4	SAND, medium grained, brown to light brown, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	14 18 14 14				
21.5 / 835.9	SAND WITH SILT, a little gravel, possible cobble, medium grained, light brown, waterbearing, medium dense (SP-SM) (A-1-b) alluvium	PD	20				
26.5 / 830.9	SAND, a little gravel, medium to coarse grained, brown to gray, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	17 18				
31.5 / 825.9	SAND WITH GRAVEL, medium to coarse grained, gray, waterbearing, medium dense (SP) (A-1-b) alluvium	PD	18 19				
41.5	SAND, a little gravel, medium grained, gray, waterbearing, loose to medium dense (SP) alluvium	PD	10 15 15 15				

Index Sheet Code

(Continued Next Page)

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN
ENGINEERING
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This boring was taken by American Engineering Testing

METROPOLITAN
COUNCIL

MINNESOTA DEPARTMENT OF TRANSPORTATION

UNIQUE NUMBER

U.S. Customary Units

SHEET 2 of 2

State Project	*Bridge No. or Job Desc.*	*Trunk Highway/Location*	*Boring No.*	*Ground Elevation*
	NCDL Bridge	**Southwest LRT, PEC East**	**1243 SB**	**857.4** *(Surveyed)*

DEPTH	*Depth* *Elev.*	*Lithology*	*Classification*	*Drilling Operation*	*SPT N60* *REC (%)*	*MC (%)* *RQD (%)*	*COH (psf)* *ACL (ft)*	*γ (pcf)* *Core Breaks*	*Soil* *Rock*	*Other Tests Or Remarks* *Formation or Member*
	815.9		SAND WITH GRAVEL, medium to fine grained, gray, waterbearing, medium dense, a lens of sand with silt (SP) (A-1-b) alluvium *(continued)*	☒	17					
	44.0 813.4			PD						
45			SAND, a little gravel, medium to fine grained, gray, waterbearing, loose (SP) (A-1-b) alluvium	☒	10					
	46.0 811.4		**END OF BORING**							

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

METROPOLITAN COUNCIL

MINNESOTA DEPARTMENT OF TRANSPORTATION

AMERICAN
ENGINEERING
TESTING, INC.

This boring was taken by American Engineering Testing

UNIQUE NUMBER

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	NCDL Bridge	**Southwest LRT, PEC East**	**1244 SB**	**856.0** (Surveyed)

Location **, , ft. LT**

Co. Coordinate: X=518705 Y=164244 (ft.)

Latitude (North)=44.9672858 Longitude (West)=-93.3110690

Drill Machine **91C**

Hammer **CME Automatic Calibrated**

SHEET 1 of 2

Drilling Completed **6/13/14**

Depth	Elev.	Classification
0.5	855.5	Silty sand with organic fines, a little gravel, trace roots, dark brown (A-2-4) fill
2.0	854.0	Sand with silt and gravel, a little clayey sand, brown (A-1-b) fill
4.0	852.0	Silty sand, a little gravel and clayey sand, brown (A-2-4) fill
9.0	847.0	Mixture of gravelly sand with silt and clayey sand, grayish brown and brown (A-2-4) fill
11.5	844.5	CLAYEY SAND, a little gravel, brown and gray, stiff, laminations of waterbearing sand and lean clay (SC) (A-2-6) alluvium
13.0	843.0	SAND, medium grained, brown, a little gray, waterbearing, loose, a lamination of clayey sand (SP) (A-1-b) alluvium
14.0	842.0	SILT, brownish gray, wet, loose (ML) (A-4) alluvium
19.0	837.0	SAND, a little gravel, medium grained, brown, a little gray, waterbearing, medium dense to loose, a lens of sandy silt at 15', a lens of sand with silt at 15½' (SP) (A-1-b) alluvium
22.0	834.0	SANDY LEAN CLAY, a little gravel, brownish gray, a little brown, hard, a lens of waterbearing sand with silt (CL) till
23.0	833.0	CLAYEY SAND, a little gravel, brownish gray, stiff, a lens of waterbearing sand with silt (SC) (A-2-6) till
24.0	832.0	LEAN CLAY WITH SAND, a little gravel, dark brownish gray, stiff (CL) (A-7-6) till
27.0	829.0	SAND, medium grained, gray, waterbearing, medium dense, a lens of sandy silt at 25' (SP) (A-1-b) alluvium
34.0	822.0	No samples recovered but drillers described as gravelly per drill tool action
36.5	819.5	SAND WITH GRAVEL, medium grained, gray, waterbearing, medium dense (SP) (A-1-b) alluvium
		SAND, a little gravel, medium to fine grained, grayish brown, waterbearing, medium dense, a lens of sandy silt at 41' (SP) (A-1-b) alluvium

▼ (7.3')

Drilling Operation	SPT N60	MC (%)
☒	20	
☒	28	
☒	38	
☒	94	
☒	10	12
☒	8	25
☒	19	
☒	8	
☒	32	20
PD		
☒	13	16 21
PD		
☒	11	
PD		
☒	27	
PD		
☒	10	
PD		
☒	15	
PD		
☒	19	
PD		
☒	14	
PD		
☒	16	
PD		

SPT N60 / REC (%); MC (%) / RQD (%); COH (psf) / ACL (ft); γ (pcf) / Core Breaks; Soil / Rock; Other Tests Or Remarks / Formation or Member

Other Tests Or Remarks:

Hammer Calibration: 68% efficiency with 110 lb. hammer, 5/27/14

Water level measured at 7.3' deep with SS to 8.5' deep

Index Sheet Code

(Continued Next Page)

Soil Class: Rock Class: Edit: Date: 8/25/14

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LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

AMERICAN ENGINEERING TESTING, INC.

This boring was taken by American Engineering Testing

UNIQUE NUMBER

U.S. Customary Units

METROPOLITAN COUNCIL

MINNESOTA DEPARTMENT OF TRANSPORTATION

SHEET 2 of 2

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
	NCDL Bridge	**Southwest LRT, PEC East**	**1244 SB**	**856.0** (Surveyed)

Depth / Elev.	Classification	Drilling Operation	SPT N60	MC (%)	COH (psf)	γ (pcf)	Other Tests Or Remarks
49.5 806.5	SAND, a little gravel, medium to fine grained, grayish brown, waterbearing, medium dense, a lens of sandy silt at 41' (SP) (A-1-b) alluvium *(continued)*	☒ PD ☒ PD ☒ PD	15 13 14				
58.0 798.0	GRAVEL WITH SILT AND SAND, grayish brown, waterbearing, medium dense (GP) (A-1-b) alluvium	☒ PD ☒ PD	16 12				
62.5 793.5	CLAYEY SAND, a little gravel, brown, medium dense, laminations of waterbearing sand (SC) (A-6) till	☒ PD	26	13			
80.5 775.5	SILTY SAND WITH GRAVEL, brown, medium dense to loose to very dense, a lens of waterbearing sand with silt at 71' (SM) (A-2-4) till	☒ PD ☒ PD ☒ PD ☒	22 8 29 82				

END OF BORING

Soil Class: Rock Class: Edit: Date: 8/25/14

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EXPLORATION/CLASSIFICATION METHODS

SAMPLING METHODS

Split-Spoon Samples (SS) - Calibrated to N_{60} Values

Standard penetration (split-spoon) samples were collected in general 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. Our method uses a modified hammer weight, which is determined by measuring the system energy using a Pile Driving Analyzer (PDA) and an instrumented rod.

In the past, standard penetration N-value tests were performed using a rope and cathead for the lift and drop system. The energy transferred to the split-spoon sampler was typically limited to about 60% of its potential energy due to the friction inherent in this system. This converted energy then provides what is known as an N_{60} blow count.

Most of today's drill rigs incorporate an automatic hammer lift and drop system, which has higher energy efficiency and subsequently results in lower N-values than the traditional N_{60} values. By using the PDA energy measurement equipment, we are able to determine actual energy generated by the drop hammer. With the various hammer systems available, we have found highly variable energies ranging from 55% to over 100%. Therefore, the intent of AET's hammer calibrations is to vary the hammer weight such that hammer energies lie within about 60% to 65% of the theoretical energy of a 140-pound weight falling 30". The current ASTM procedure acknowledges the wide variation in N-values, stating that N-values of 100% or more have been observed. Although we have not yet determined the statistical measurement uncertainty of our calibrated method to date, we can state that the accuracy deviations of the N-values using this method are significantly better than the standard ASTM Method.

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, and they may 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 based on the Unified Soil Classification (USC) system. The USC system is described in ASTM: D2487 and D2488. Where laboratory classification tests (sieve analysis or Atterberg Limits) have been performed, accurate classifications per ASTM: D2487 are possible. Otherwise, soil classifications shown on the boring logs are visual-manual judgments. Charts are attached which provide information on the USC system, the descriptive terminology, and the symbols used on the boring logs.

Visual-manual judgment of the AASHTO Soil Group is also noted as a part of the soil description. A chart presenting details of the AASHTO Soil Classification System is also attached.

The boring logs include descriptions of apparent geology. The geologic depositional origin of each soil layer is interpreted primarily by 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 level measurements/comments are shown on the boring logs in the remarks section. 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

Unless notified to do otherwise, we routinely retain representative samples of the soils recovered from the borings for a period of 30 days.

BORING LOG NOTES

DRILLING AND SAMPLING SYMBOLS

Symbol	Definition
AR:	Sample of material obtained from cuttings blown out the top of the borehole during air rotary procedure.
B, H, N:	Size of flush-joint casing
CAS:	Pipe casing, number indicates nominal diameter in inches
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
DP:	Direct push drilling; a 2.125 inch OD outer casing with an inner 1½ inch ID plastic tube is driven continuously into the ground.
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
PD:	Plug Drilling (same as RDF)
PQ:	PQ wireline core barrel
RDA:	Rotary drilling with compressed air and roller or drag bit.
RDF:	Rotary drilling with drilling fluid and roller or drag bit
REC:	In split-spoon (see notes), direct push 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.
SS:	Standard split-spoon sampler (steel; 1.5" 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 "falling" through drilling fluid
WH:	Sampler advanced by static weight of drill rod and hammer
WR:	Sampler advanced by static weight of drill rod
94mm:	94 millimeter wireline core barrel
▼:	Water level directly measured in boring
▽:	Estimated water level based solely on sample appearance

TEST SYMBOLS

Symbol	Definition
COH:	Cohesion, psf (0.5 x q_u)
CONS:	One-dimensional consolidation test
γ:	Wet density, pcf
DST:	Direct shear test
E:	Pressuremeter Modulus, tsf
HYD:	Hydrometer analysis
LL:	Liquid Limit, %
LP:	Pressuremeter Limit Pressure, tsf
MC:	Moisture Content, %
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, remolded (field), psf
VSU:	Vane shear strength, undisturbed (field), psf
%-200:	Percent of material finer than #200 sieve

STANDARD PENETRATION TEST NOTES

(Calibrated Hammer Weight)

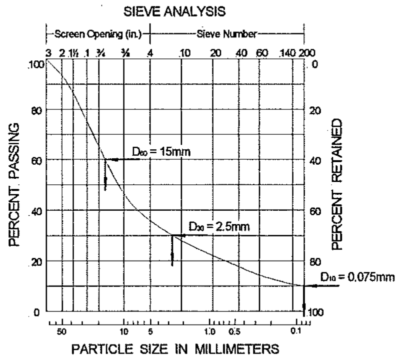
The standard penetration test consists of driving a split-spoon sampler with a drop hammer (calibrated weight varies to provide N_{60} values) and counting the number of blows applied in each of three 6" increments of penetration. If the sampler is driven less than 18" (usually in highly resistant material), 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 "REC" 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").

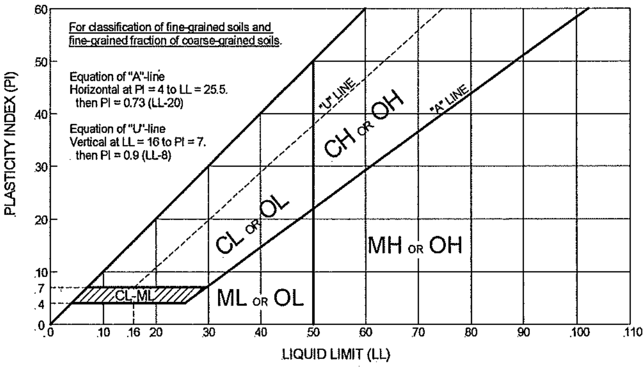
UNIFIED SOIL CLASSIFICATION SYSTEM
ASTM Designations: D 2487, D2488

AMERICAN ENGINEERING TESTING, INC.

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification	
				Group Symbol	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/or $1>Cc>3$[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	Liquid limit–oven dried <0.75 Liquid limit – not dried	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	Liquid limit–oven dried <0.75 Liquid limit – not dried	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]



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



Plasticity Chart

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 ≥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 ≥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 ≥30% plus No. 200, predominantly sand, add "sandy" to group name.

[M] If soil contains ≥30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI≥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.

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):	Absence 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.

Peat Description

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

Organic 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 Liquid Limit properties. *Slightly organic* used for borderline cases.

Root Inclusions

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.

AASHTO SOIL CLASSIFICATION SYSTEM

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS

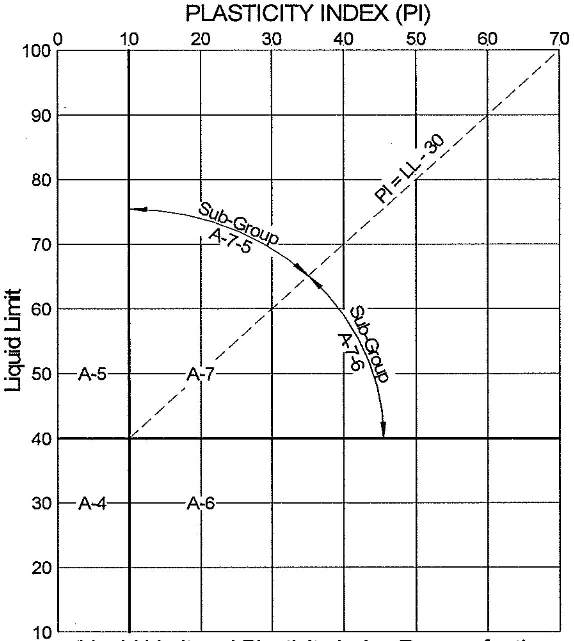
Classification of Soils and Soil-Aggregate Mixtures

General Classification	Granular Materials (35% or less passing No. 200 sieve)							Silt-Clay Materials (More than 35% passing No. 200 sieve)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis, Percent passing:											
No. 10 (2.00 mm)	50 max.	....	....	....	....	....	....	....	....	....	....
No. 40 (0.425 mm)	30 max.	50 max.	51 min.	....	....	....	....	....	....	....	....
No. 200 (0.075 mm)	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of Fraction Passing No. 40 (0.425 mm)											
Liquid limit	....		....	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.		N.P.	10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min.
Usual Types of Significant Constituent Materials	Stone Fragments, Gravel and Sand		Fine Sand	Silty or Clayey Gravel and Sand				Silty Soils		Clayey Soils	
General Ratings as Subgrade	Excellent to Good							Fair to Poor			

The placing of A-3 before A-2 is necessary in the "left to right elimination process" and does not indicate superiority of A-3 over A-2.

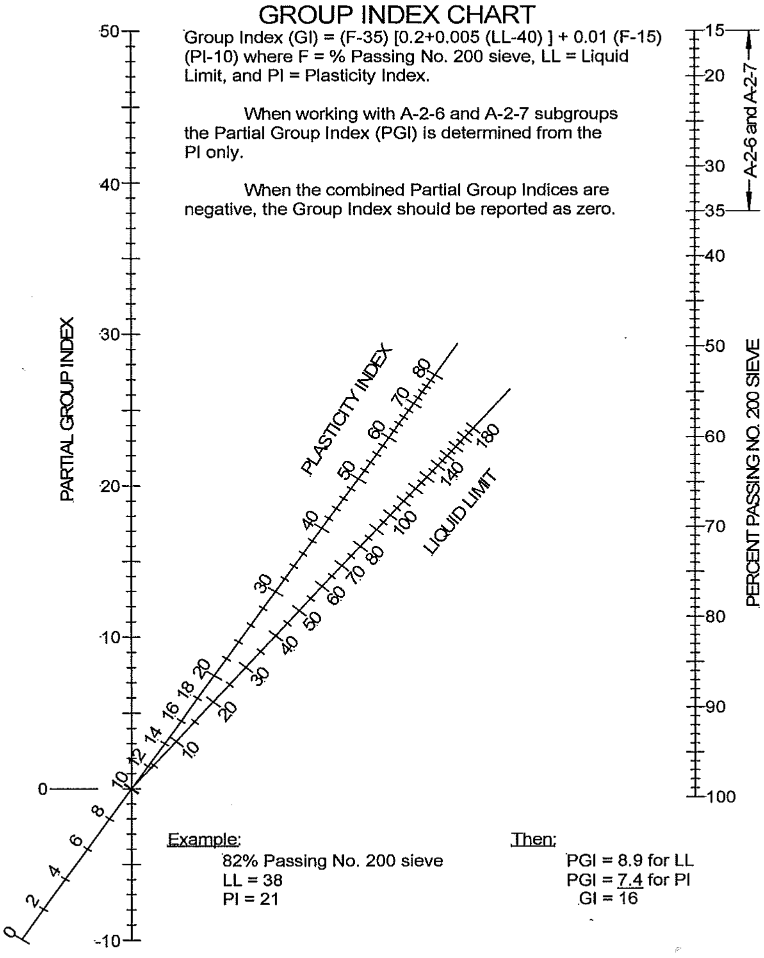
Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30.

Group A-8 soils are organic clays or peat with organic content >5%.



Liquid Limit and Plasticity Index Ranges for the A-4, A-5, A-6 and A-7 Subgroups

GROUP INDEX CHART



Group Index (GI) = (F-35) [0.2+0.005 (LL-40)] + 0.01 (F-15) (PI-10) where F = % Passing No. 200 sieve, LL = Liquid Limit, and PI = Plasticity Index.

When working with A-2-6 and A-2-7 subgroups the Partial Group Index (PGI) is determined from the PI only.

When the combined Partial Group Indices are negative, the Group Index should be reported as zero.

Example:

82% Passing No. 200 sieve
LL = 38
PI = 21

Then:

PGI = 8.9 for LL
PGI = 7.4 for PI
GI = 16

Definitions of Gravel, Sand and Silt-Clay

The terms "gravel", "coarse sand", "fine sand" and "silt-clay", as determinable from the minimum test data required in this classification arrangement and as used in subsequent word descriptions are defined as follows:

GRAVEL - Material passing sieve with 3-in. square openings and retained on the No. 10 sieve.

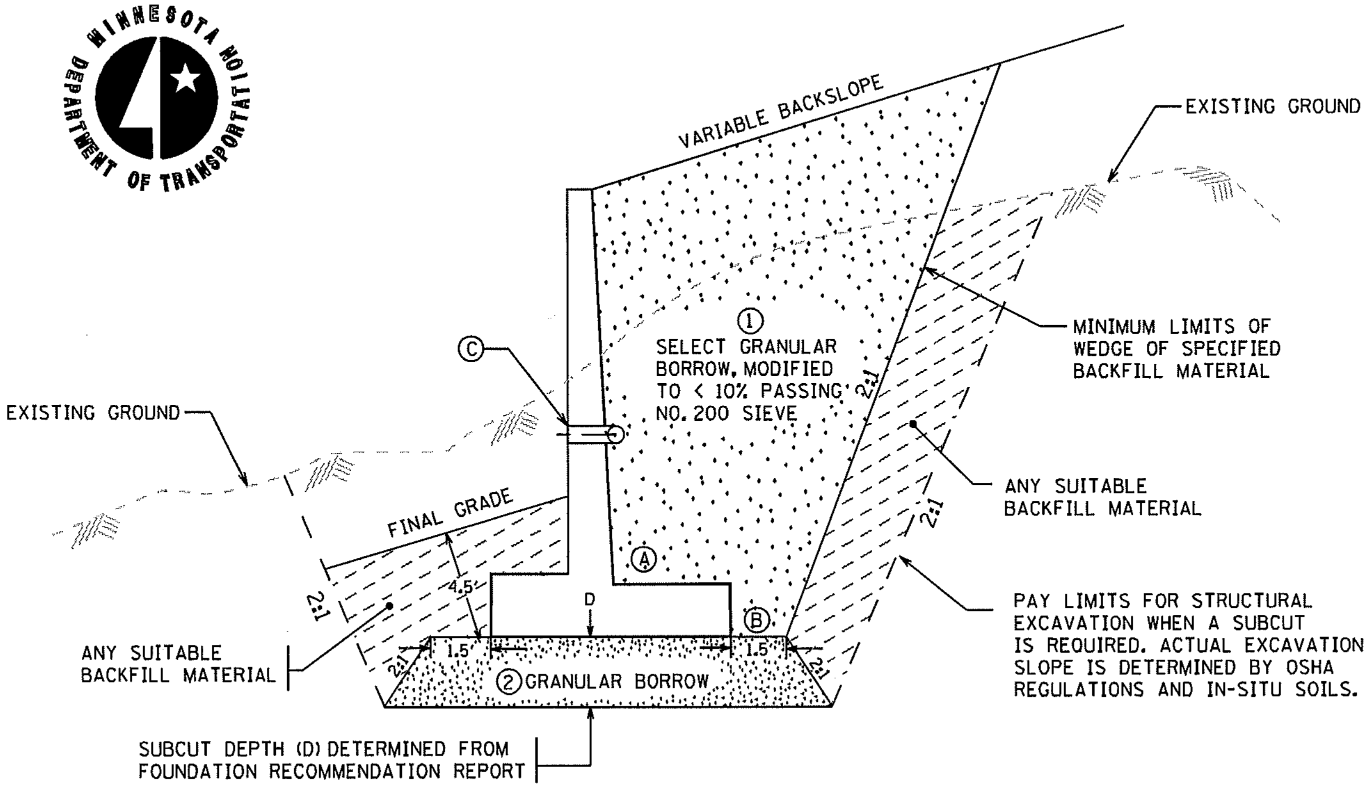
COARSE SAND - Material passing the No. 10 sieve and retained on the No. 40 sieve.

FINE SAND - Material passing the No. 40 sieve and retained on the No. 200 sieve.

COMBINED SILT AND CLAY - Material passing the No. 200 sieve

BOULDERS (retained on 3-in. sieve) should be excluded from the portion of the sample to which the classificaiton is applied, but the percentage of such material, if any, in the sample should be recorded.

The term "silty" is applied to fine material having plasticity index of 10 or less and the term "clayey" is applied to fine material having plasticity index of 11 or greater.



NOT TO SCALE

All slope dimensions shown as V:H

THE RECOMMENDATIONS MAY BE MODIFIED AS PER THE ATTACHED FOUNDATIONS INVESTIGATION AND RECOMMENDATION REPORT

EXCAVATION AND BACKFILL NOTES:

① Mn/DOT SPEC. 3149.2B2 MODIFIED TO 10% PASSING THE NO. 200 SIEVE COMPACT BACKFILL TO SPECIFIED DENSITY METHOD Mn/DOT SPEC. 2105.3F1

② IF SUBCUT IS REQUIRED, BACKFILL WITH GRANLAR BORROW, Mn/DOT SPEC. 3149.2B1. COMPACT BACKFILL TO 100% OF STANDARD PROCTOR (T-99). REFER TO FOUNDATION RECOMMENDATION LETTER FOR SUBCUT DEPTHS.

DRAINAGE SYSTEM NOTES:

PROVIDE WALL DRAINAGE SYSTEM A, B OR C

Ⓐ Ⓑ PLACE A 6 IN. I.D. NON-STEEL PERFORATED PIPE(Mn/DOT SPEC. 3245) WRAPPED WITH A TYPE I GEOTEXTILE FABRIC (Mn/DOT SPEC. 3733) RUNNING THE ENTIRE LENGTH OF THE WALL AND LAID A MINIMUM OF 2 IN. ABOVE THE TOP OF FOOTING (OPTION A) OR BOTTOM ELEVATION OF THE FOOTING (OPTION B). STRUCTURAL BACKFILL MATERIALS SHALL COMPLETELY SURROUND THE PIPE. AT ALL TIMES, THE SLOPE OF THE PIPE SHALL BE CHECKED TO ENSURE POSITIVE DRAINAGE. FREQUENT TIES (SPACED APPROXIMATELY 200 FT. APART) SHALL BE MADE FROM THE PIPE TO THE INPLACE OR PROPOSED DRAINAGE SYSTEM.

Ⓒ PROVIDE WEEP HOLES AS SPECFIED IN THE BRIDGE STANDARD PLANS MANUAL, STANDARD SHEET 5-297.621 TO 5-297.623.

STATE OF MINNESOTA DEPARTMENT OF TRANSPORTATION
STRUCTURAL BACKFILL, FOOTING SUBCUT & DRAINAGE SYSTEM TREATMENT
(STANDARD CANTILEVER RETAINING WALL DESIGN)

November 2005

PREPARED BY THE FOUNDATIONS UNIT

GEOTECHNICAL ENGINEERING SECTION - OFFICE OF MATERIALS

DIAGRAM NO.

F–1