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PLANNERS • SURVEYORS

August 13, 2007

Michael D. Weeks, P.E., P.S.
TranSystems Corporation
5747 Perimeter Drive, Suite 240
Dublin, OH 43017

Re: **Bearing Capacity and Settlement Evaluation**
        (Culvert at STA. 375+08)
        SCI-823-0.00 Portsmouth Bypass
        DLZ Job No.: 0121-3070.03
        Document #0065

Dear Mr. Weeks:

This letter includes the findings of preliminary evaluations of the proposed culvert at Station 375+08 on the above-referenced project. The findings of other culvert and embankment evaluations will be submitted in separate documents.

It is our understanding that a new culvert will be constructed at Station 375+08 for the above referenced project. The culvert will be a 96-inch Type A conduit in accordance with ODOT Item 707.03 (Structural Plate Corrugated Steel Structures). Preliminary plans indicate the flow line of the culvert varies from approximately 0 to 10 feet below existing grade along its alignment. It is therefore anticipated that a portion of the embankment fill will need to be placed prior to excavating for construction of the culvert (ODOT CMS Item 603.05 Method B). The maximum cover over the culvert at this location is approximately 44 feet. The inlet and outlet of the culvert will be supported by headwalls flush with the face of the pipe at both ends. At the time of preparing this letter no further information was available regarding the proposed culvert.

It should be noted that the results of these evaluations are based upon the findings of four borings (C-1 through C-4) located along the proposed alignment of the culvert. The borings were advanced to depths ranging between 9.5 and 20 feet below the ground surface. Logs of the borings, a plan and profile drawing showing the approximate locations of the borings, a legend of the boring log terminology and general information regarding the drilling procedures are attached. The surveyed ground elevations at the boring locations are reported on the logs.

Exploration Findings

The borings generally encountered 4.5 to 10 feet of soil overlying sandstone bedrock. In borings C-1 and C-2, the soil consisted of stiff to hard sandy silt (A-4a) to a depth ranging between 4.5 and 10 feet below the ground surface, where bedrock was encountered. In borings C-3 and C-4, the soil consisted of stiff silt (A-4b) underlain by very stiff to hard sandy silt (A-4a) to a depth

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ranging between 5.5 and 6.5 feet below the ground surface, where bedrock was encountered. The bedrock encountered in the borings consisted of medium hard to hard sandstone and was weathered and fractured to varying degrees.

General Recommendations

Preliminary plans indicate that the invert elevations at the inlet and outlet of the culvert are 645.58 and 621.71, respectively. Based on this information and the shallow bedrock conditions encountered in the borings, it is likely that bedrock will be encountered at locations along the culvert alignment during construction. Bedrock in the conduit foundation should be removed at least 6 inches (150 mm) below the bottom of the bedding and replaced with structural backfill. Bedding should conform to the requirements of ODOT CMS Item 603.06.

Bearing Capacity Evaluation

The bottoms of the headwall footings were assumed to be 4 feet below the invert elevations to place them below the frost zone and prevent scour of the headwall (Ohio BDM Section 200). Based on the results of borings C-1 and C-4, footings at these elevations will bear in stiff to hard sandy silt (A-4a) or sandstone. Footings bearing in the stiff or better material at this location may be designed based on an allowable bearing capacity of 3,000 pounds per square foot (psf). Footings bearing on the sandstone bedrock may be designed based on an allowable bearing capacity not greater than 20,000 psf.

Settlement Evaluation

Soil parameters for use in the settlement calculations were estimated using correlations with moisture content and Atterberg limits. Settlement below the centerline of the embankment was evaluated using the maximum cover of the embankment (approximately 44 feet) as the surcharge load and using the soil profile encountered in boring C-2. The settlement analysis indicated that the soil below the embankment will yield a total settlement of 1.8 inches. The analysis indicated that 80% of the consolidation settlement (1.5 inches) will occur within 15 days after the end of the embankment construction while the time required to achieve the total consolidation settlement (1.8 inches) will be approximately 3.5 months. Secondary compression of the foundation soils is expected to be negligible. Settlement at the ends of the culvert, due to the embankment loading, is also expected to be insignificant. Based on these analyses, differential settlement between the point of maximum embankment height and the ends of the culvert is expected to be approximately 1.8 inches. The settlement analysis is attached.

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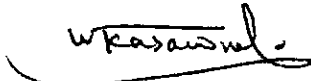August 13, 2007
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We appreciate having the opportunity to be of service to you on this project. Please do not hesitate to call if you have any questions concerning our preliminary findings.

Respectfully submitted,

DLZ OHIO, INC.

Wael Alkasawneh, P.E.
Geotechnical Engineer

Bryan Wilson, P.E.
Senior Geotechnical Engineer

Encl: As noted.

cc: J. Greg Brown, P.E. (TranSystems Corporation), File

GENERAL INFORMATION
DRILLING PROCEDURES AND LOGS OF BORINGS

Drilling and sampling were conducted in accordance with procedures generally recognized and accepted as standardized methods of investigation of subsurface conditions concerning geotechnical engineering considerations. Borings were drilled with either a truck-mounted or ATV-mounted drill rig.

Drive split-barrel sampling was performed in 1.5 foot increments at intervals not exceeding 5 feet. In the event the sampler encountered resistance to penetration of 6 inches or less after 50 blows of the drop hammer, the sampling increment was discontinued. Standard penetration data were recorded and one or more representative samples were preserved from each sampling increment.

In borings where rock was cored, NXM or NQ size diamond coring tools were used.

In the laboratory all samples were visually classified by a soils engineer. Moisture contents of representative fine-grained soil samples were determined. A limited number of samples, considered representative of foundation materials present, were selected for performance of grain-size analyses and plasticity characteristics tests. The results of these tests are shown on the boring logs.

The boring logs included in the Appendix have been prepared on the basis of the field record of drilling and sampling, and the results of the laboratory examination and testing of samples. Stratification lines on the boring logs indicating changes in soil stratigraphy represent depths of changes approximated by the driller, by sampling effort and recovery, and by laboratory test results. Actual depths to changes may differ somewhat from the estimated depths, or transitions may occur gradually and not be sharply defined. The boring logs presented in this report therefore contain both factual and interpretative information and are not an exact copy of the field log.

Although it is considered that the borings have disclosed information generally representative of site conditions, it should be expected that between borings conditions may occur which are not precisely represented by any one of the borings. Soil deposition processes and natural geologic forces are such that soil and rock types and conditions may change in short vertical intervals and horizontal distances.

Soil/rock samples will be stored at our laboratory for a period of six months. After this period of time, they will be discarded, unless notified to the contrary by the client.

S:\Dept\Geotech\Misc\Legends\Geninfo.eng

LEGEND - BORING LOG TERMINOLOGY

Explanation of each column, progressing from left to right

1. Depth (in feet) - refers to distance below the ground surface.

2. Elevation (in feet) - is referenced to mean sea level, unless otherwise noted.

3. Standard Penetration (N) - the number of blows required to drive a 2-inch O.D., 1-3/8 inch I.D., split-barrel sampler, using a 140-pound hammer with a 30-inch free fall. The blows are recorded in 6-inch drive increments. Standard penetration resistance is determined from the total number of blows required for one foot of penetration by summing the second and third 6-inch increments of an 18-inch drive.

   50/n - indicates number of blows (50) to drive a split-barrel sampler a certain number of inches (n) other than the normal 6-inch increment.

4. The length of the sampler drive is indicated graphically by horizontal lines across the "Standard Penetration" and "Recovery" columns.

5. Sample recovery from each drive is indicated numerically in the column headed "Recovery".

6. The drive sample location is designated by the heavy vertical bar in the "Sample No., Drive" column.

7. The length of hydraulically pressed "Undisturbed" samples is indicated graphically by horizontal lines across the "Press" column.

8. Sample numbers are designated consecutively, increasing in depth.

9. Soil Description

   a.   The following terms are used to describe the relative compactness and consistency of soils:

Granular Soils - Compactness

Terms	Blows/Foot Standard Penetration
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	over 50

Cohesive Soils - Consistency

Term	Unconfined Compression tons/sq.ft.	Blows/Foot Standard Penetration	Hand Manipulation
Very Soft	less than 0.25	below 2	Easily penetrated by fist
Soft	0.25 - 0.50	2 - 4	Easily penetrated by thumb
Medium Stiff	0.50 - 1.00	4 - 8	Penetrated by thumb w/ moderate effort
Stiff	1.0 - 2.0	8 - 15	Readily indented by thumb but not penetrated
Very Stiff	2.0 - 4.0	15 - 30	Readily indented by thumb nail
Hard	over 4.0	over 30	Indented with difficulty by thumb nail

   b.   Color - If a soil is a uniform color throughout, the term is single, modified by such adjective as light and dark. If the predominant color is shaded by a secondary color, the secondary color precedes the primary color. If two major and distinct colors are swirled throughout the soil, the colors are modified by the term "mottled".

   c.   Texture is based on the ODOT Classification System. Soil particle size definitions are as follows:

Description	Size	Description	Size
Boulders	Larger than 8"	Sand-Coarse	2.00 mm. to 0.42 mm.
Cobbles	8" to 3"	-Fine	0.42 mm. to 0.074 mm.
Gravel-Coarse	3" to 3/4"	Silt	0.074 mm. to 0.005 mm.
-Fine	3/4" to 2.00" mm.	Clay	Smaller than 0.005 mm.

   d.   The main soil component is listed first. The minor components are listed in order of decreasing percentage of particle size.

e. Modifiers to main soil descriptions are indicated as a percentage by weight of particle sizes.

trace	- 0 to 10%
little	- 10 to 20%
some	- 20 to 35%
"and"	- 35 to 50%

f. The moisture content of cohesive soils (silts and clays) is expressed relative to plastic properties.

Term	Relative Moisture or Appearance
Dry	Powdery
Damp	Moisture content slightly below plastic limit
Moist	Moisture content above plastic limit, but below liquid limit
Wet	Moisture content above liquid limit

g. Moisture content of cohesionless soils (sands and gravels) is described as follows:

Term	Relative Moisture or Appearance
Dry	No moisture present
Damp	Internal moisture, but none to little surface moisture
Moist	Free water on surface
Wet	Voids filled with free water

10. Rock hardness and rock quality description.

a. The following terms are used to describe the relative hardness of the bedrock.

Term	Description
Very Soft	Difficult to indent with thumb nails; resembles hard soil but has rock structure
Soft	Resists indentation with thumb nail but can be abraded and pierced to a shallow depth by a pencil point.
Medium Hard	Resists pencil point, but can be scratched with a knife blade.
Hard	Can be deformed or broken by light to moderate hammer blows.
Very Hard	Can be broken only by heavy blows, and in some rocks, by repeated hammer blows.

b. Rock Quality Designation, RQD - This value is expressed in percent and is an indirect measure of rock soundness. It is obtained by summing the total length of all core pieces which are at least four inches long, and then dividing this sum by the total length of the core run.

11. Gradation - when tests are performed, the percentage of each particle size is listed in the appropriate column (defined in Item 9c).

12. When a test is performed to determine the natural moisture content, liquid limit moisture content, or plastic limit moisture content, the moisture content is indicated graphically.

13. The standard penetration (N) value in blows per foot is indicated graphically.

S.R. 823 STA. 375+08 LEFT

PHASE I HEADWALL LOCATION SUBMITTAL

SCI-823-0.00

NOT FOR CONSTRUCTION

HYDRAULIC DESIGN DATA

DRAINAGE AREA : _____ AC.

Q_{10} : _____ CFS
Q_{100} : _____ CFS
HW_{10} : _____
HW_{100} : _____
V_{10} : _____ FPS
V_{100} : _____ FPS

STA. 376+08.61
OFFSET 265.33

C-1

C-2

C-3

6'2", 96" CONDUIT

32.75° L.F.

CONTINUED ON NEXT SHEET

€ CONSTRUCTION, S.R. 823
STA. 374+10.00
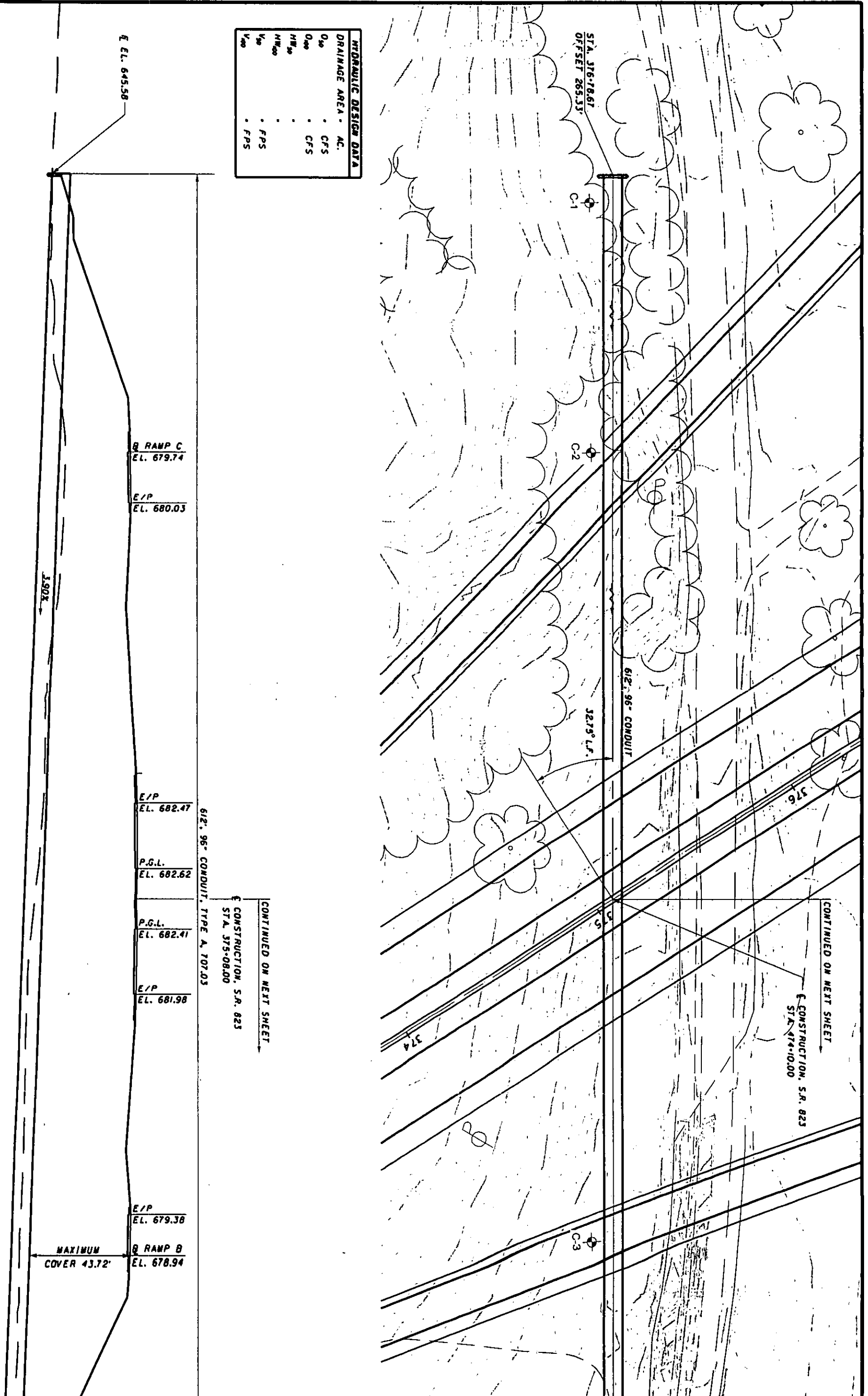
€ EL. 645.58

€ RAMP C
EL. 679.74

E/P
EL. 680.03

3.90%

E/P
EL. 682.47

P.G.L.
EL. 682.62

P.G.L.
EL. 682.41

E/P
EL. 681.98

E/P
EL. 679.38

MAXIMUM
COVER 43.72'

€ RAMP B
EL. 678.94

6'2", 96" CONDUIT, TYPE A, 707.03

€ CONSTRUCTION, S.R. 823
STA. 375+08.00

CONTINUED ON NEXT SHEET

CALCULATED
JGB

CHECKED
HJS

HORIZONTAL
SCALE IN FEET

DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

Client: TranSystems, Inc.	Project: SCI-823-0.00	Job No. 0121-3070.03

LOG OF: Boring C-1 Location: Sta. 376+79.2, 265.1 ft. LT of SR 823 CL   Date Drilled: 06/07/06

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Press / Core	Hand Penetro-meter (tsf)	WATER OBSERVATIONS: Water seepage at: None / Water level at completion: None (prior to coring) / 2.0'(includes drilling water) / DESCRIPTION	GRADATION % Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	STANDARD PENETRATION (N)
0 / 0.5	646.7 / 646.2						Topsoil - 6"							
		4 6 5	11	1		--	Stiff to very stiff mottled brown and gray SANDY SILT (A-4a), little clay, little gravel; contains roots and sandstone fragments; damp.	14	16	--	14	45	11	
4.5 / 5	642.2	6 50/3	7	2		--	Medium hard to hard gray SANDSTONE; very fine grained, unweathered to slightly weathered, thinly bedded to medium bedded, moderately fractured.							50+
		Core 60"	Rec 49"	RQD 85%	R-1									
9.5 / 10	637.2						Bottom of Boring - 9.5'							
15														
20														
25														
30														

FILE: 0121-3070-03 (4/20/2007 10:14 AM)

Client: TranSystems, Inc.	Project: SCI-823-0.00	Job No. 0121-3070.03
LOG OF: Boring C-2	Location: Sta. 376+25.4, 180.0 ft. LT of SR 823 CL Date Drilled: 06/07/06	

WATER OBSERVATIONS:
Water seepage at: Not reported
Water level at completion: 9.0'(with augers removed, includes drilling water)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay	STANDARD PENETRATION (N)
0	650.0													
0.4	649.6						Topsoil - 5"							
		7 / 7 / 14	13	1		--	Very stiff to hard brown SANDY SILT (A-4a), little to some clay, trace to little gravel; damp. @ 1.0'-5.0', contains sandstone fragments and roots.	15	15	--	16	35	19	
5		9 / 18 / 19	9	2		--		5	9	--	18	48	20	
		11 / 10 / 11	5	3		--		2	6	--	16	47	29	
		5 / 12 / 49	13	4		--		1	8	--	29	45	17	
10.0	640.0													
10.3	639.7						Medium hard brown SANDSTONE; fine grained, slightly weathered, thinly bedded, highly fractured.							
		Core 60"	Rec 50"	RQD 80%	R-1		Hard gray SANDSTONE; very fine grained, slightly weathered, argillaceous, thinly bedded to thickly bedded, moderately fractured. @ 10.5', 11.5', rust stained fractures.							
15														
		Core 60"	Rec 59"	RQD 88%	R-2									
20.0	630.0						Bottom of Boring - 20.0'							
25														
30														

Client: TranSystems, Inc.	Project: SCI-823-0.00	Job No. 0121-3070.03

LOG OF: Boring C-3	Location: Sta. 374+20.2, 134.7 ft. RT of SR 823 CL	Date Drilled: 06/08/06

WATER OBSERVATIONS:
Water seepage at: None
Water level at completion: None

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├───────┤ LL
Blows per foot - ○

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0 — 631.8													
1.0 — 630.8		5 4 5	12	1		--	Topsoil - 5" Stiff brown SILT (A-4b), little to some clay, little fine to coarse sand; damp.	0	3	--	12	65	20
3.5 — 628.3		8 11 19	12	2		--	Very stiff to hard brown SANDY SILT (A-4a), little clay, trace gravel; damp.	9	25	--	19	32	15
5 —													
6.5 — 625.3		50/4	4	3		--	Medium hard brown and gray SANDSTONE; very fine grained, slightly to moderately weathered, laminated to medium bedded, moderately fractured.						
8.6 — 623.2							Medium hard to hard gray SANDSTONE; very fine grained, unweathered, thinly bedded to thickly bedded, moderately fractured.						
10 —		Core 102"	Rec 96"	RQD 76%	R-1		@ 9.5', rust stained fracture. @ 13.2'-13.5', high angle rust stained fracture.						
15 —							@ 15.0'-16.0', highly fractured zone.						
		Core 60"	Rec 49"	RQD 43%	R-2		@ 17.8'-18.9', highly fractured zone.						
20.0 — 611.8							Bottom of Boring - 20.0'						
25 —													
30													

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Client: TranSystems, Inc.	Project: SCI-823-0.00	Job No. 0121-3070.03
LOG OF: Boring C-4	Location: Sta. 373+44.7, 252.0 ft. RT of SR 823 CL Date Drilled: 06/08/06	

WATER OBSERVATIONS: Water seepage at: Not reported
Water level at completion: 4.5' (with augers removed)

GRADATION

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├———————┤ LL
Blows per foot - ○

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Press / Core	Hand Penetro-meter (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	621.6												
0.5	621.1						Topsoil - 6"						
		9 / 10 / 9	9	1		--	Very stiff dark gray SILT (A-4b), little clay, trace gravel; contains roots; damp.	5	11	--	11	58	15
3.5	618.1												
		8 / 15 / 17	8	2		--	Hard mottled brown and gray SANDY SILT (A-4a), little clay, little gravel; contains roots; damp.	15	15	--	22	35	13
5													
5.5	616.1						Medium hard brown SANDSTONE; very fine to fine grained, moderately weathered, laminated to medium bedded, highly fractured.						
		Core 60"	Rec 45"	RQD 33%	R-1								
10													
10.5	611.1						Bottom of Boring - 10.5'						
15													
20													
25													
30													

FILE: 0121-3070-03 (4/20/2007 10:14 AM)

Base analysis on results of borings C-1 and C-4.

q_u = 2.0   tsf for stiff to very stiff cohesive soil

c = 2000   psf

Factor of Safety (FS) = 3   (ODOT BDM 202.2.3.1)

For cohesive foundation soil:

Meyerhof's Method

$q_u = c*N_c*s_c*d_c + q*N_q$ $q = \gamma*D$ **Can be neglected since footing depth is less than 5 ft**

Since footing dimensions are not known assume S_c = 1.0. For ϕ = 0, use N_c = 5.14 and N_q = 1

$q_a = q_u/FS$ = 3426.7 psf

Use q_a < 3427   psf

For footings bearing in sandstone bedrock, use presumptive allowable bearing of 20,000 psf.

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Client	TranSystems Inc.	JOB NUMBER	0121-3070.03		
Project	Portsmouth Bypass	SHEET NO.	1	OF	3
Item	Culvert at STA. 375+08	COMP. BY	WMA	DATE	8/7/2007
		CHECKED BY	BEW	DATE	8/13/2007

Calculations Data

Boring	Sample	w	PL	LL	PI	Cc[1]	Cr[2]	e_o[3]
C-1	1	19	21	24	3	0.04	0.031	0.9920
C-2	1	12	16	23	7	0.09	0.029	0.9571
C-2	2	13	18	23	5	0.07	0.029	0.9743
C-2	3	14	17	25	8	0.11	0.032	0.9645
C-2	4	18	21	24	3	0.04	0.031	0.9913
C-3	1	16	17	22	5	0.07	0.028	0.9825
C-3	2	12	19	21	2	0.03	0.027	0.9878
C-4	1	17	24	29	5	0.07	0.037	0.9842
C-4	2	11	17	19	2	0.03	0.024	0.9848
					Average	0.06	0.030	0.9798
					Maximum	0.11	0.037	0.9920

1) $Cc = PI/74$
2) $Cr = 0.000463 \times LL \times Gs$
3) Based on CR below

Boring	Sample	LL	C_v*(ft²/day)	C_v*(ft²/sec)
C-1	1	24	1.07	1.24E-05
C-2	1	23	1.21	1.40E-05
C-2	2	23	1.21	1.40E-05
C-2	3	25	0.96	1.11E-05
C-2	4	24	1.07	1.24E-05
C-3	1	22	1.38	1.59E-05
C-3	2	21	1.57	1.82E-05
C-4	1	29	0.63	7.24E-06
C-4	2	19	2.09	2.42E-05
		Minmum	0.63	7.24E-06
		Average	1.24	1.44E-05
		Maximum	2.09	2.42E-05

*Cv(ft2/day) = 9343.5*LL^(-2.8542)   (Kulhawy and Mayne- 1990)

Typical Values
Source: Holtz and Kovacs (1981)/ Terzaghi, Peck and Mesri (1995)

Soil	C_a/C_c
Organic Silts	0.035-0.06
Amorphous and Fibrous Peat	0.035-0.085
Organic Clays and Silts	0.04-0.06
Granular Soils	0.01-0.03
Shale and mudstones	0.02-0.04
Silty Clay	0.03-0.06
Peat	0.05-0.07

Correlation Values-Source: Lamb and Whitman (1969)

w%	$CR=(C_c/1+e_o)$
9.983	2.389
11.785	2.547
14.487	3.016
17.099	3.825
19.816	4.892
25.352	6.931
28.328	8.079
34.174	10.369
42.400	13.490
51.139	16.388
79.829	23.326
152.740	33.469
341.288	46.114
501.494	52.174

Correlation: $CR = -4E-09w^4 + 5E-06w^3 - 0.0021w^2 + 0.4695w - 3.1337$
$R^2 = 0.9992$

Boring	Sample	w	PL	LL	PI	LI	Consolidation*
C-1	1	19	21	24	3	-0.67	Overconsolidated
C-2	1	12	16	23	7	-0.57	Overconsolidated
C-2	2	13	18	23	5	-1.00	Overconsolidated
C-2	3	14	17	25	8	-0.38	Overconsolidated
C-2	4	18	21	24	3	-1.00	Overconsolidated
C-3	1	16	17	22	5	-0.20	Overconsolidated
C-3	2	12	19	21	2	-3.50	Overconsolidated
C-4	1	17	24	29	5	-1.40	Overconsolidated
C-4	2	11	17	19	2	-3.00	Overconsolidated

*Overconsolidated when LI<0.7
Ref: Soils and Foundations Workshop Reference Manual- NHI-00-045 (p. 6.11)

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SUBJECT			
Client	TranSystems, Inc.	JOB NUMBER	0121-3070.03
Project	SCI-823-0.00	SHEET NO.	2 OF 3
Item	Culvert at STA.375+08	COMP. BY	WMA DATE 08/07/07
Based on Boring C-2		CHECKED BY	BEW DATE 08/13/07

SETTLEMENT ANALYSIS - EMBANKMENT

Embankment Information:
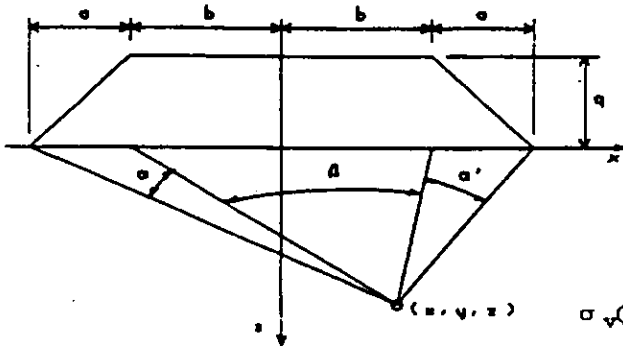
Groundwater Table:	$D =$	50.0	ft
Embankment Height:	$H =$	44	ft
Fill Unit Weight:	$\gamma_{emb} =$	120	pcf $q =$ 5,280 psf
Width of Slope:	$a =$	108	
Top half-width of Emb:	$b =$	198	
Distance from CL:	$x =$	0	
Output Range:	$z =$	0	to 20 ft

$$\sigma_v(z) := \left(\frac{q}{\pi \cdot a}\right) \left(a \cdot (\alpha(z) + \beta(z) + \alpha'(z)) + b \cdot (\alpha(z) + \alpha'(z)) + x \cdot (\alpha(z) - \alpha'(z)) \right)$$

$$\beta(z) := atan\left[\frac{(b-x)}{z}\right] + atan\left[\frac{(b+x)}{z}\right] \qquad \alpha'(z) := atan\left[\frac{(a+b-x)}{z}\right] - atan\left[\frac{(b-x)}{z}\right] \qquad \alpha(z) := atan\left[\frac{(a+b+x)}{z}\right] - atan\left[\frac{(b+x)}{z}\right]$$

Reference: US Army Corps of Engineers EM 1110-1-1904 "Settlement Analysis", Table C-1

Soil Properties: *Settlement is calculated at mid-point of layer*

No.	Bot. of Layer		Soil Type	γ_{soil} (pcf)	σ'_c (psf)	σ'_o (psf)	$\Delta\sigma_z$ (psf)	σ'_f (psf)	Cohesionless Soils C'	Cohesive Soils C_r	C_c	e_o
1	10.0	ft	Sandy Silt	120	6,000	600	5,280	5,880	0.0	0.03	0.06	0.950
1	0.0				0	0			0.0	0.00	0.00	0.000
2	0.0				0	0			0.0	0.00	0.00	0.000
4	0.0				0	0						
5	0.0				0	0						
6	0.0				0	0						
7	0.0				0	0						
8	0.0				0	0						
9	0.0				0	0						
10	0.0				0	0						

No.	Settlement:
1	0.152 ft
2	**0.152 ft**
3	
4	
5	**1.8 in**
6	
7	
8	
9	
10	

Total Settlement

Reference: Geotechnical Engineering Principles and Practices; Coduto, 1999

Overconsolidated Soils - Case I ($\sigma'_0 < \sigma'_c$) Eqn:11.24

$$(\delta_c)_{ult} = \sum \frac{C_r}{1+e_0} H \log\left(\frac{\sigma'_f}{\sigma'_0}\right)$$

Overconsolidated Soils - Case II ($\sigma'_0 < \sigma'_c < \sigma_f$) Eqn:11.25

$$(\delta_c)_{ult} = \sum \left[\frac{C_r}{1+e_0} H \log\left(\frac{\sigma'_c}{\sigma'_0}\right) + \frac{C_c}{1+e_0} H \log\left(\frac{\sigma'_f}{\sigma'_c}\right) \right]$$

Normally Consolidated Soils ($\sigma'_0 = \sigma'_c$) Eqn: 11.23

$$(\delta_c)_{ult} = \sum \frac{C_c}{1+e_0} H \log\left(\frac{\sigma'_f}{\sigma'_0}\right)$$

Cohesionless Soils ($\sigma'_0 = \sigma'_c$)

$$(\delta_c)_{ult} = \sum \frac{1}{C'} H \log\left(\frac{\sigma'_f}{\sigma'_0}\right)$$

DLZ

SUBJECT						
Client	TranSystems, Inc.		JOB NUMBER	0121-3007.03		
Project	SCI-823-0.00		SHEET NO.	3	OF	3
Item	Culvert at STA.375+08		COMP. BY	WMA	DATE	08/07/07
Based on Boring C-2			CHECKED BY	BEW	DATE	08/13/07

TIME RATE SETTLEMENT

Coeffecient of consolidation (c_v) = 7.24E-06 ft^2/s

Assumed Life Time = 5 yrs

Drainage Path Condition = 1 (0 for single drainage; 1 for double drainage)

Thickness of Layer = 10.0 ft

Maximum Time Rate Settlement = 1.83 inches

Settlement at (U% =80%) = 1.46 inches   15 days after the end of construction

Time Rate Settlement vs. Time