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August 23, 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. 379+00 TW234 Ramp C)
SCI-823-0.00 Portsmouth Bypass
DLZ Job No.: 0121-3070.03
Document #0084

Dear Mr. Weeks:

This letter presents the findings of preliminary evaluations of the proposed culvert and embankment at Station 379+00 (TW 234 Ramp C) 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 379+00 (TW 234 Ramp C) for the above referenced project. The culvert will be a 42-inch Type A conduit in accordance with ODOT Item 707.01 (Metallic Coated Corrugated Steel Conduits and Underdrains). Preliminary plans indicate the culvert will be installed in new fill with the flow line as much as eight feet above existing grade. It is therefore anticipated that the culvert will be constructed in accordance with ODOT CMS Item 603.05 Method B. The inlet and outlet of the culvert will be supported by headwalls flush with the face of the pipe at each end. At the time of preparing this letter no further information was available regarding the culvert.

It should be noted that the results of this evaluation are based upon the findings of two borings (C-41 and C-42) located along the proposed alignment of the culvert. The borings were advanced to depths ranging between 15.0 and 21.5 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 ground elevations at the boring locations are reported on the logs.

Exploration Findings

The borings encountered between 3.0 to 13.0 feet of mainly cohesive overburden soil overlying sandstone bedrock. The soils were very stiff to hard in consistency. The bedrock was soft to medium hard, weathered and fractured to varying degrees, but generally improved in quality with depth.

Bearing Capacity Evaluation

Preliminary plans indicate that the invert elevations at the inlet and outlet of the culvert are 666.7 and 665.0, respectively. 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). The headwall footing at the inlet will bear in new embankment fill (ODOT CMS Item 203) and should be designed based on an allowable bearing capacity of 2,500 pounds per square foot (psf). Based on the results of boring C-41, the headwall footing at the culvert outlet will bear on highly weathered/decomposed sandstone. Footings bearing in the weathered/decomposed rock may be designed based on an allowable bearing capacity up to 10 tons per square foot (tsf).

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 embankment height (approximately 20 feet) as the surcharge load and using the soil profile encountered in boring C-42.

The settlement analysis indicated that the soil below the embankment will yield a total settlement of 6.5 inches. The analysis indicated that 80% of the consolidation settlement (5.2 inches) will occur within approximately forty days after application of the embankment load, while the time required to achieve the total consolidation settlement (2.3 inches) will be approximately six months.

Due to the relatively short consolidation periods, it is not anticipated that procedures to accelerate consolidation will be required. However, recommendations for the use of wick drains have been provided in the Report of Subsurface Investigation for the Shumway Hollow Road Interchange, dated November 29, 2006, presented separately.

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 center of the new embankment fill and the outlet of the culvert is expected to be approximately 6.5 inches. The settlement analysis is attached.

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

STATE OF OHIO
BRYAN E. WILSON
E-57007
REGISTERED
PROFESSIONAL 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.

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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.

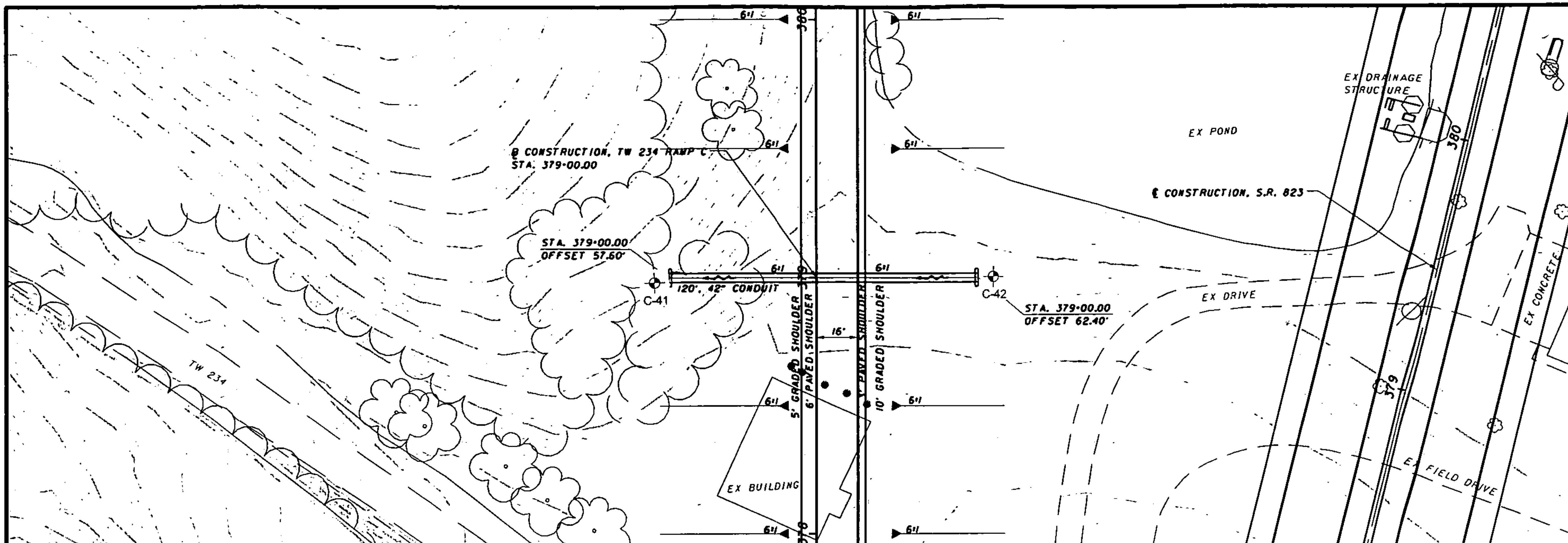
Term	Description
Very Soft	Difficult to indent with thumb nails; resembles hard soil but has rock structure
Soft	Resists indentation with thumb nail but can be abraded and pierced to a shallow depth by a pencil point.
Medium Hard	Resists pencil point, but can be scratched with a knife blade.
Hard	Can 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.

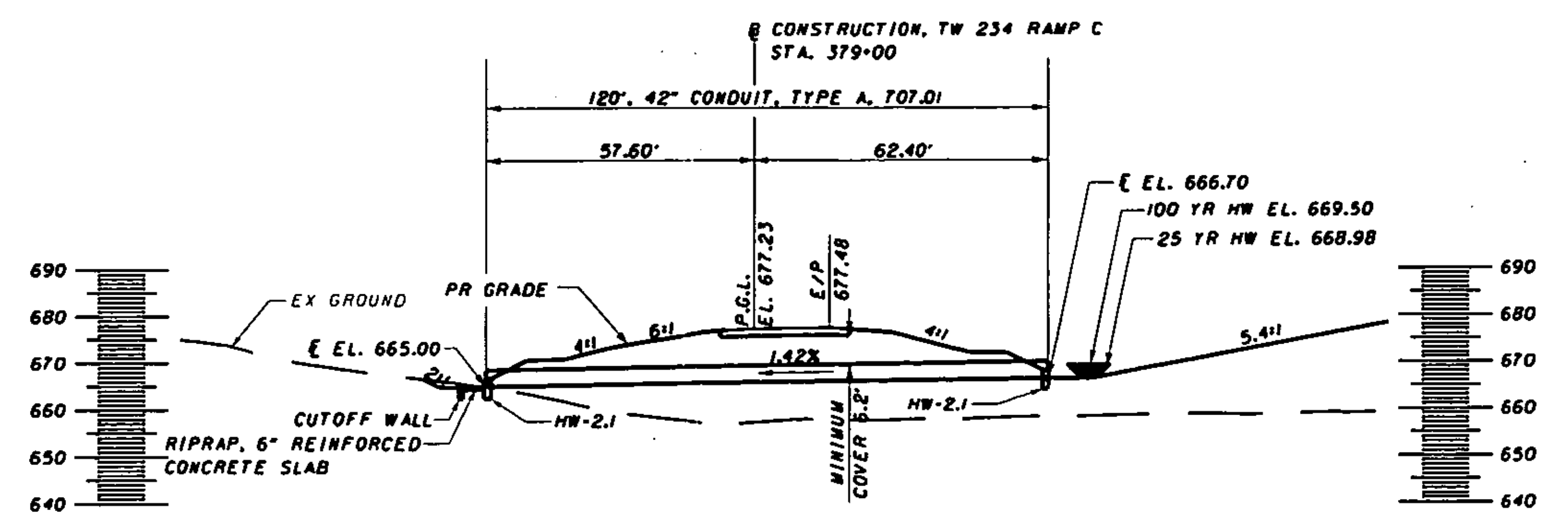
11. Gradation - when tests are performed, the percentage of each particle size is listed in the appropriate column (defined in Item 9c).

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.



HYDRAULIC DESIGN DATA	
DRAINAGE AREA	= 10.04 AC.
Q_{25}	= 19.82 CFS
Q_{100}	= 28.89 CFS
HW_{25}	= 668.98
HW_{100}	= 669.50
V_{25}	= 11.0 FPS
V_{100}	= 9.8 FPS



CULVERT DETAIL
TW 234 RAMP C STA. 379+00

HORIZONTAL SCALE IN FEET

CALCULATED MDC
CHECKED HJS

SCI-823-0.00

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

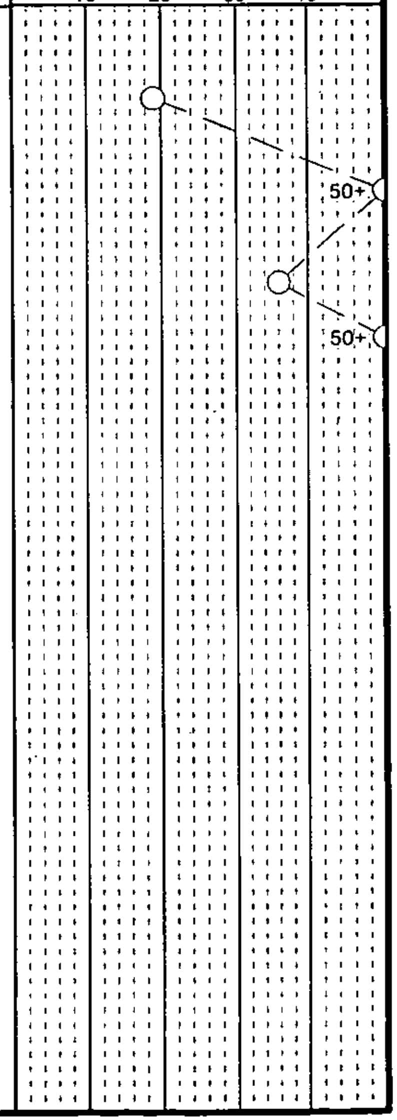
Client: TranSystems, Inc. | *Project:* SCI-823-0.00 | *Job No.* 0121-3070.03

LOG OF: Boring C-41 | *Location:* Sta. 378+99.8, 57.4 ft. LT of TR 234 Ramp C BL | *Date Drilled:* 09/07/06

WATER OBSERVATIONS: Water seepage at: None
Water level at completion: None (prior to coring)
3.0' (includes drilling water)

Depth (ft)	Elev. (ft) 664.9	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0.3	664.6						Topsoil - 4"						
		7 9 10	13	1		4.5+	Hard brown SANDY SILT (A-4a), trace clay, trace gravel, dry to damp.						
3.0	661.9	15 44 50/5	8	2		--	Soft to medium hard brown SILTSTONE; arenacous, highly weathered to decomposed. @ 4.5', encountered possible sandstone cobble.						
		7 16 20	12	3		--							
8.5	656.4	50/5	5	4		--	Severely weathered brown SANDSTONE.						
10.0	654.9	Core 60"	Rec 56"	RQD 58%	R-1		Soft to medium hard brown SANDSTONE; fine grained to very fine grained argillaceous, highly weathered to decomposed, broken.						
12.3	652.6						Medium hard gray SANDSTONE; very fine to fine grained, moderately weathered, thinly bedded to medium bedded, highly fractured. @ 12.8', 13.0', 13.4', 13.5', clay seams.						
15.0	649.9						Bottom of Boring - 15.0'						

STANDARD PENETRATION (N)
Natural Moisture Content, % - ●
PL ├──┤ LL
Blows per foot - ○
10 20 30 40



Depth scale: 0, 5, 10, 15, 20, 25, 30

FILE: 0121-3070-03 [4/20/2007 10:14 AM]

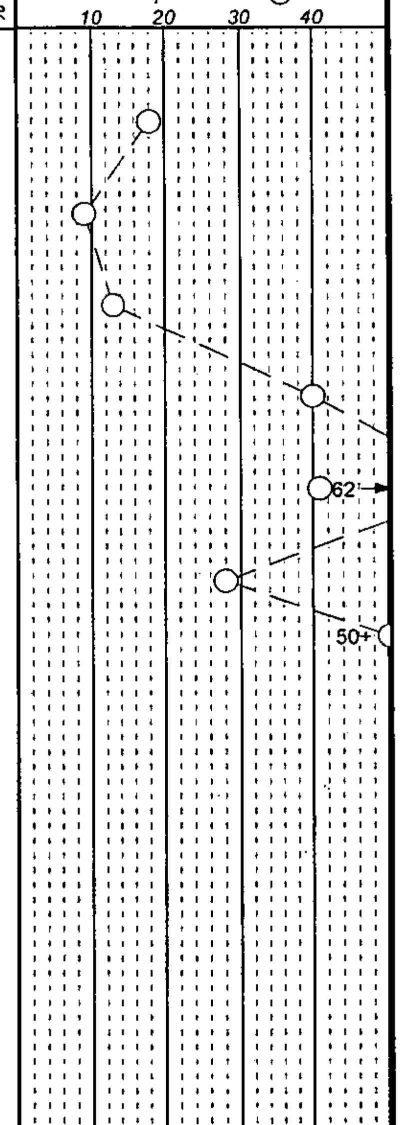
DLZ OHIO INC. * 6121 HUNTLEY ROAD, COLUMBUS, OHIO 43229 * (614)888-0040

Client: TranSystems, Inc.	Project: SCI-823-0.00	Job No. 0121-3070.03
LOG OF: Boring C-42	Location: Sta. 378+99.5, 63.7 ft. RT of TR 234 Ramp C BL	Date Drilled: 09/08/06

WATER OBSERVATIONS: Water seepage at: 12.0' - 15.0'
Water level at completion: 14.5' (prior to coring)
6.6' (includes drilling water)

Depth (ft)	Elev. (ft)	Blows per 6"	Recovery (in)	Sample No. Drive	Sample No. Press / Core	Hand Penetrometer (tsf)	DESCRIPTION	% Aggregate	% C. Sand	% M. Sand	% F. Sand	% Silt	% Clay
0	658.5						Topsoil - 11"						
0.9	657.6	12 10 8	18	1		4.5+	Very stiff to hard brown SANDY SILT (A-4a), trace to little clay, contains trace organic material, damp to moist. @ 3.5'-5.0', little to some clay, trace gravel.						
		4 5 4	16	2		3.5							
		4 6 7	10	3		2.0							
8.0	650.5	5 6 34	18	4		3.0	Very stiff brown CLAY (A-7-6), trace to little silt, damp. @ 9.0', light gray.						
10.5	648.0	15 36 26	18	5		--	Very dense brown COARSE AND FINE SAND (A-3a), little to some silty clay, trace to little gravel, damp to moist.						
13.0	645.5	7 11 17	15	6		--	Soft to medium hard gray SANDSTONE; highly weathered to decomposed.						
		50/3	3	7		--							
16.5	642.0	Core 60"	Rec 60"	RQD 86%	R-1		Medium hard gray SANDSTONE; fine grained, slightly weathered, thinly bedded to medium bedded, moderately fractured. @ 19.5', 19.6', 20.3', clay seams.						
21.5	637.0						Bottom of Boring - 21.5'						

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



Depth scale (ft): 0, 5, 10, 15, 20, 25, 30

Base analysis on results of borings C-41 and C-42.

For new Item 203 embankment, conservatively assume unconfined strength of 1.5 tons per square foot.

q_u = 1.5 tsf

c = 1500 psf

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

For cohesive foundation soil:

Meyerhof's Method

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

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

$q_a = q_u/FS$ = 2570 psf

Use $q_a <$ 2570 psf

For footings bearing in weathered bedrock, use presumptive allowable bearing of 10 tsf.

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Client: TranSystems Inc.	JOB NUMBER: 0121-3070.03		
Project: Portsmouth Bypass	SHEET NO.: 1	OF: 3	
Item: Culvert at STA. 379+00	COMP. BY: WMA	DATE: 8/10/2007	
	CHECKED BY: BEW	DATE: 8/23/07	

Calculations Data

Boring	Sample	w	PL	LL	PI	Cc[1]	Cr[2]	e_o[3]
C-42	2	16	15	29	14	0.19	0.037	0.9510
C-42	4	26	23	53	30	0.41	0.067	0.9476
C-42	5	11	NP	NP				
					Average	0.30	0.052	0.9493
					Maximum	0.41	0.067	0.9510

1)Cc=PI/74
2)Cr=0.000463xLLxGs
3) Based on CR below

Boring	Sample	LL	C_v*(ft²/day)	C_v*(ft²/sec)
C-42	2	16	3.42	3.96E-05
C-42	4	26	0.85	9.89E-06
C-42	5	11		
		Minmum	0.85	9.89E-06
		Average	2.14	2.47E-05
		Maximum	3.42	3.96E-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_α/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-42	2	16	15	29	14	0.07	Overconsolidated
C-42	4	26	23	53	30	0.10	Overconsolidated
C-42	5	11	NP	NP			

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

*Assume σ_c' ≈ 1396 psf. Taken from Shumway Hollow Interchange Report, Ramp C Analysis

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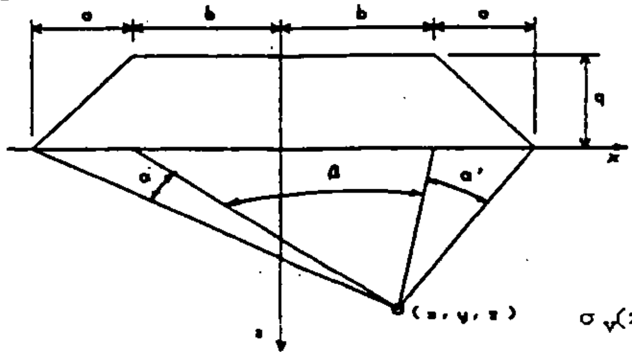
SUBJECT			
Client: TranSystems, Inc.	JOB NUMBER 0121-3070.03		
Project: SCI-823-0.00	SHEET NO. 2	OF 3	
Item: Culvert at STA.379+00 TW 234 Ramp C	COMP. BY WMA	DATE 08/10/07	
Based on Boring C-42	CHECKED BY BEW	DATE 08/23/07	

SETTLEMENT ANALYSIS - EMBANKMENT

Embankment Informaiton:



Groundwater Table:	D=	12.0	ft		
Embankment Height:	H =	20	ft		
Fill Unit Weight:	γ_{emb} =	120	pcf	q =	2,400 psf
Width of Slope:	a =	54			
Top half-width of Emb:	b =	20			
Distance from CL:	x =	0			
Output Range:	z =	0	to	20	ft

**See Data output Attached*

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

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

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	8.0	ft	Sandy Silt	120	1,396	480	2,399	2,879	0.0	0.04	0.19	0.951
2	10.5	ft	Clay	120	1.396	1,110	2,385	3,495	0.0	0.07	0.41	0.948
3	14.0	ft	Sand	0	0	1,244	2,368	3,612	140.0	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	0.315	ft
2	0.218	ft
3	0.012	ft
4		
5		
6		
7		
8		
9		
10		

Total Settlement

0.545 ft

6.5 in

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

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

C' from FHWA Soils and Foundations Workshop Reference Manual, NHI-00-045 page 6-9, Figure 6-6.

DLZ

SUBJECT			
Client	TranSystems, Inc.	JOB NUMBER	0121-3007.03
Project	SCI-823-0.00	SHEET NO.	3 OF 3
Item	Culvert at STA.379+00 TW 234 Ramp	COMP. BY	WMA DATE 08/10/07
Based on Boring C-42		CHECKED BY	BEW DATE 08/23/07

TIME RATE SETTLEMENT

Coeffecient of consolidation (c_v) = 4.27E-06 ft^2/s

Assumed Life Time = 1 yrs

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

Thickness of Layer = 10.5 ft

Maximum Time Rate Settlement = 6.5 inches

Settlement at (U% =80%) = 5.23 inches 41 days after the end of construction