AGENCY OF TRANSPORTATION **OFFICE MEMORANDUM**

To: Bruce Martin, P.E., Roadway Design Project Manager

ZMH CEE

From: Zachary M. Haffenreffer, Technician Apprentice IV via Callie Ewald, P.E. Geotechnical Engineering Manager

Date: October 20th, 2016

Subject: Granville STP SCRP(13) – Geotechnical Recommendations

1.0 INTRODUCTION

We have completed our geotechnical investigation for the subject project located on VT Route 100 in Granville, Vermont. The proposed project includes the replacement of the existing culvert located on VT Route 100 at approximately MM 7.59. Contained herein are the results of our subsurface investigation, geotechnical analysis, and design recommendations as determined using the 2014 AASHTO LRFD *Bridge Design Specifications.*

2.0 FIELD INVESTIGATION

The field investigation was conducted on August 18th and 19th, 2016. Two standard penetration borings were drilled to determine the subsurface profile in order to aid in design and construction of the new culvert. A summary of the boring locations can be found in Table 2.1 as well as in the attached boring location plan. The values for the Northings and Eastings are based on the Vermont State Plane Grid Coordinate System NAD 83, and were located by a handheld GPS. Elevations for the borings were then taken off a VTrans survey file. The locations and elevations of the borings should be considered accurate only to the degree implied by the method used to determine them.

Table 2.1: Boring Locations

Boring Number	Station	Offset (ft)	Northing (ft)	Easting (ft)	Elevation (ft)
B-101	400+77	14.10	561444.57	1552978.41	1383.0
B-102	400+45	-9.30	561411.28	1552957.33	1381.3

The borings were performed in general accordance with AASHTO T206, *Standard Method of Test for Penetration Test and Split-Barrel Sampling of Soils.* During boring operations, split spoon samples and standard penetration tests (SPT) were taken continuously to approximately 16 feet followed by 5 foot intervals thereafter until a depth of approximately 27 feet. Bedrock was not encountered in either of the borings. Soil samples were visually identified in the field and SPT blow counts were recorded on the boring logs. Soil samples were preserved and returned to the Construction and Materials Bureau Central Laboratory for testing and further evaluation. Upon completion of the laboratory testing, the boring logs were revised to reflect the results of the laboratory classification analysis.

3.0 FIELD AND LABORATORY TESTING

The standard penetration resistance of the in-situ soil is determined by the number of blows required to drive a 2 inch OD split barrel sampler into the soil with a 140 pound hammer dropped from a height of 30 inches, in accordance with procedures specified in AASHTO T206. During the standard penetration test (SPT), the sampler is driven for a total length of 2 feet, while counting the blows for each 6 inch increment. The SPT N-value, which is defined as the sum of the number of blows required to drive the sampler through the second and third increments, is commonly used with established correlations to estimate a number of soil parameters, particularly the shear strength and density of cohesionless soils. The N-values provided on the boring logs are raw values and have not been corrected for energy, borehole diameter, rod length, or overburden pressure. The VT Agency of Transportation has determined a hammer correction value, C_E, to account for the efficiency of the SPT hammer on the drill rig. For this project a CME 45C Skid Rig was used. The hammer energy correction factor for the CME 45C Skid Rig is 1.42. Laboratory tests were conducted on all samples to evaluate grain size, moisture content, and percent finer than No. 200 sieve. Results from this testing can be found on the attached boring logs.

4.0 SOIL PROFILE

Review of laboratory data and boring logs revealed the following information pertaining to the soil strata. It should be noted that groundwater elevations are subject to change given the fact that boreholes were generally left open for a short period of time. Because groundwater elevations can fluctuate seasonally and are affected by temperature and precipitation, groundwater may be encountered during construction when not previously noted in the logs

B-101 (Outlet) The ground surface elevation at B-101 was approximately 1383.0 feet. The groundwater was measured after drilling at a depth of 12.1 feet below the ground surface. No bedrock was encountered to a depth of 27.0 feet.

Depth (Below Ground Surface Elevation)	Soil Profile
0 – 6 feet	M. Dense Sandy Gravel
6 – 8 feet	Loose Gravelly Sand
8 – 27 feet	M. Dense Sandy Gravel/ Gravelly Sand

B-102 (Inlet) The ground surface elevation at B-102 was approximately 1381.3 feet. The groundwater was measured after drilling at a depth of 12.7 feet below the ground surface. No bedrock was encountered to a depth of 27.0 feet.

Depth (Below Ground Surface Elevation)	Soil Profile
0 – 7 feet	M. Dense Sandy Gravel/ Gravelly Sand
7 – 11 feet	Very Loose to Loose Silty Sand
11 – 27 feet	M. Dense Gravelly Sand/ Sandy Gravel

5.0 ANALYSIS

5.1 Shallow Foundation Analysis

AASHTO's LRFD Bridge Design Specifications Manual (2014) was used as the reference for settlement and bearing resistance equations. Section 10.6.3.1.2 contains the equation used for bearing resistance. Neither depth factors nor load inclination factors were used in the analysis as they were not considered pertinent. Hough's Method, used to calculate settlement in normally consolidated cohesionless soils, can be found in section 10.6.2.4.2.

We recommend the bottom of the wingwall footings to be 4 feet below the ground surface based on frost susceptibility and bearing stratum at the site. This sits at 1371.7 feet and 1371.6 feet at the inlet and outlet, respectively. This results in the wingwalls bearing on the very loose to loose silty sand layer at the inlet and the medium dense sandy gravel/gravelly sand layer at the outlet. An embedment value of 4 feet was used for the strength limit state analysis and an embedment value of 0 feet was used for the service limit state analysis to account for potential scour conditions. A conservative groundwater elevation at the bottom of footing elevation was used in design.

As per section 10.5.5.1 of the 2014 AASHTO LRFD Bridge Design Specifications, a resistance factor of 1.0 should be applied to the unfactored bearing resistance for use in service limit state design. Service limit state design includes, but is not limited to, settlement and scour. Section 10.5.5.2.2 specifies that a resistance factor of 0.45 should be applied to the unfactored bearing resistance for use in strength limit state design for spread footings on rock and soil. Strength limit state design includes, but is not limited to, checks for bearing resistance, sliding and constructability. Potential for overturning is limited by controlling the location of the resultant of the reaction forces (eccentricity). Eccentricity, e, shall be limited as follows:

Foundations on soil:	$\|e\| < b/3$
Foundations on rock:	$\|e\| < 0.45b$

Eccentricity should be considered for settlement and bearing resistance design of spread footings by using effective footing widths based on AASHTO Section 10.6.1.3. All footing widths presented in this report are <u>effective</u> footing widths.

5.1: Bearing Resistance

Due to the similar soil strata found in both borings, one conservative profile was used in the analysis. However, about 18 inches of a four foot thick stratum of very loose silty sand was found to be below the elevation of the wingwall footings at the inlet. As this material results in very low bearing resistances, we recommend excavating out the loose material to the medium dense sandy gravel/gravelly sand layer below. We anticipate up to 18 inches of excavation and replacement of soil at the inlet location only. The maximum wingwall length used in analyses was assumed to be 8 feet based off the Preliminary Plans dated September 29, 2016. It was determined that the medium dense sandy gravel/gravelly sand has a friction angle $\phi = 35^{\circ}$ and a density, $\gamma = 125$ lb/ft^3. Figure 5.1 displays the minimum effective footing width per maximum bearing resistance, factored due to LRFD strength and service limit states for the medium dense sandy gravel/gravelly sand layer.

For effective footing widths of 2, 4, 6, and 8 feet, the maximum factored bearing resistances for the controlling service limit state are 2.7, 4.8, 6.3, and 7.2 kips/ft^2 (ksf), respectively, as seen in Figure 5.3.

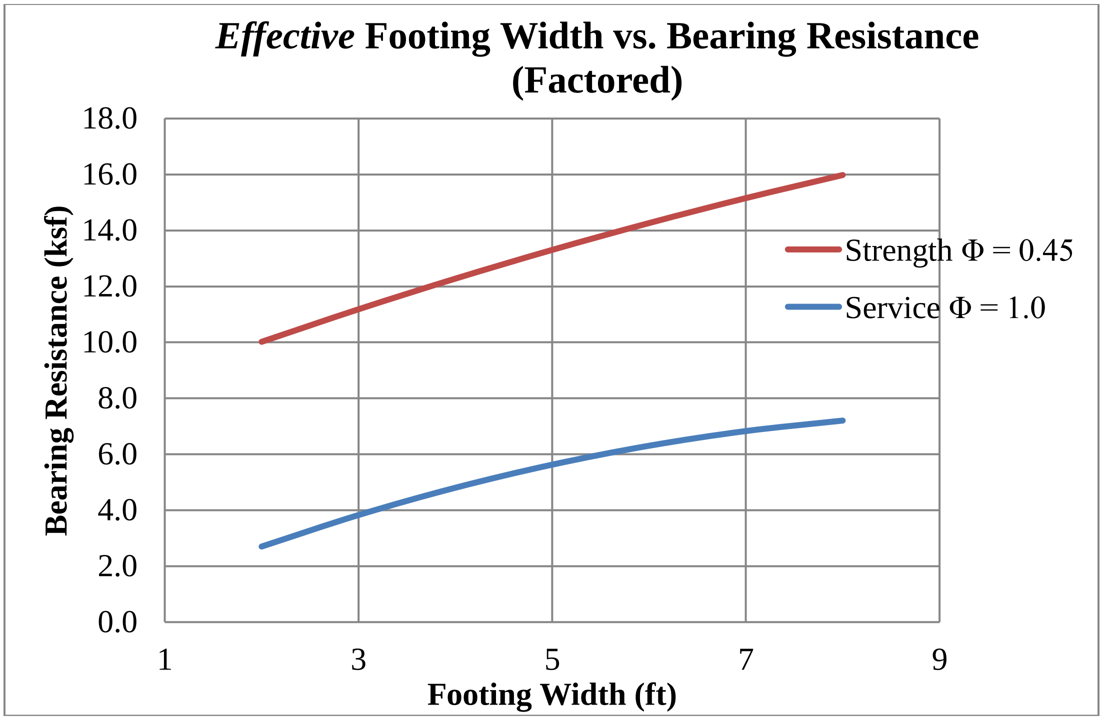


Figure 5.1: *Effective* Footing Width vs. Bearing Resistance for Culvert Wingwalls

Soil settlement values were calculated for various footing widths based on the nominal bearing pressure. Found in Figure 5.2 are the settlement values for effective footing widths of 2 to 7 feet for the wingwalls.

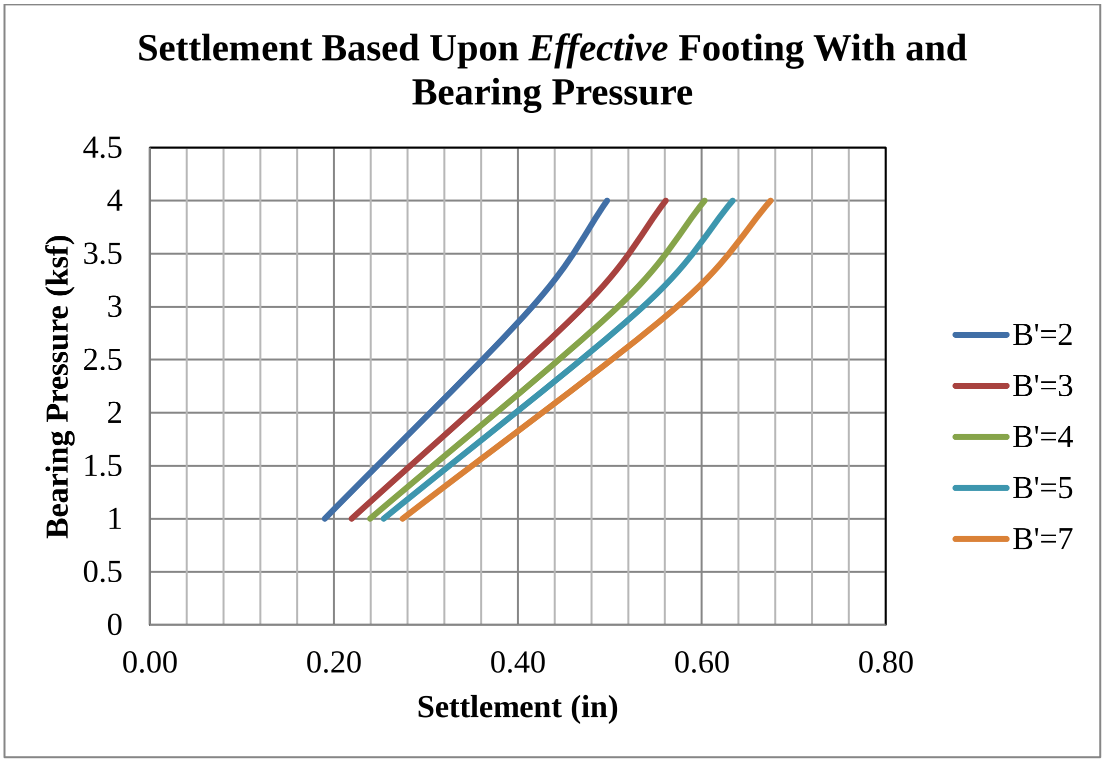


Figure 5.2: Settlement vs. Nominal Bearing Pressure

6.0 RECOMMENDATIONS

Shallow foundations appear to be feasible for the bottom of box elevation as well as for the proposed bottom of footing elevation at the wingwalls. For the footing of the wingwalls at the inlet, we recommend over-excavating 18 inches of the very loose material in order achieve the bearing resistances shown in this report. All wing wall footings should bear on a medium dense sand and gravel stratum. Factored bearing resistances were calculated for various footing widths of the wingwalls and can be found in Figure 5.1. The settlement is expected to occur during or immediately after construction. These calculations are based on the geometric and geotechnical assumptions outlined in Section 5.0. Sections 10.5.2 and 10.5.3 of AASHTO outline all design states relevant to spread footing design and their respective resistance factors. Eccentricity should be considered for settlement and bearing resistance design of spread footings by using effective footing widths based on AASHTO Section 10.6.1.3. Table 6.1 shows the appropriate resistance factors for various design states.

Table 6.1: Summary of resistance factors

Design State	Resistance Factor, φ
Settlement	1.0
Scour	1.0
Bearing Resistance	0.45
Sliding	0.80

6.1 Construction Considerations

6.1.1 Cofferdams/Temporary Earthwork Support: The Contractor should be reminded that Section 208.07 of VTrans' *2011 Standard Specifications for Construction* indicates that "The Contractor shall prepare detailed plans and a schedule of its operation for each cofferdam specified in the Contract. The design and structural details of the cofferdam shall be signed, stamped, and dated by a Professional Engineer (Structural or Civil)."

6.1.2 Construction Dewatering: The bottom of footing elevation for the culvert is estimated to be near the water table. Therefore, temporary construction dewatering may be required to construct the foundation. Temporary dewatering will also be necessary to limit disturbance to and maintain the integrity of the bearing surface.

Temporary dewatering can likely be accomplished by open pumping from shallow sumps, temporary ditches, and trenches within and around the excavation limits. Sumps should be provided with filters suitable to prevent pumping of fine-grained soil particles. The water trapped by the temporary dewatering controls should be discharged to settling basins or an approved filter "sock" so that the fine particles suspended in the discharge have adequate time to "settle out" prior to discharge. All effluent, or discharge, should comply with all applicable permits and regulations.

Sumps and trenches should lie outside a 1V:1H line extending downward and outward from the edge of footing. Installation and operation of the Contractor's dewatering system should be integrated with other earthwork operations and sequence of cutting, filling, foundation construction, and backfilling.

6.1.3 Placement and Compaction of Soils: Fills should be placed systematically in horizontal layers not more than 12 inches in thickness, prior to compaction. Cobbles larger than 8 inches should be removed from the fill prior to placement. Compaction equipment should preferably consist of large, self-propelled vibratory rollers. Where hand-guided equipment, such as a small vibratory plate compactor, is used the loose lift thickness shall not exceed 6 inches. Cobbles larger than 4 inches should be removed from the fill prior to placement.

Embankment fills should be compacted to a dry density of at least 95% of the maximum dry density determined in accordance with AASHTO T-99. The current specification calls for 90%, however we are in the process of revising it to be 95% as recommended above. Granular Backfill for Structures, or other select materials placed within the roadway base section shall be compacted to a dry density equal to 95% of the maximum dry density as determined in accordance with AASHTO T-99.

6.2 Design Parameters

Table 6.2 highlights the geotechnical design parameters. These values should be used when designing the substructure units. It is recommended that values of K_o be used for calculating earth pressures where the structure is not allowed to deflect longitudinally, away from or into the retained soil mass. Values for K_a should be utilized for an active earth pressure condition where the structure is moving away from the soil mass and K_p where the structure is moving toward the soil mass. The design earth pressure coefficients are based on horizontal surfaces (non-sloping and backfill) and a vertical wall face.

Table 6.2: Design Parameters

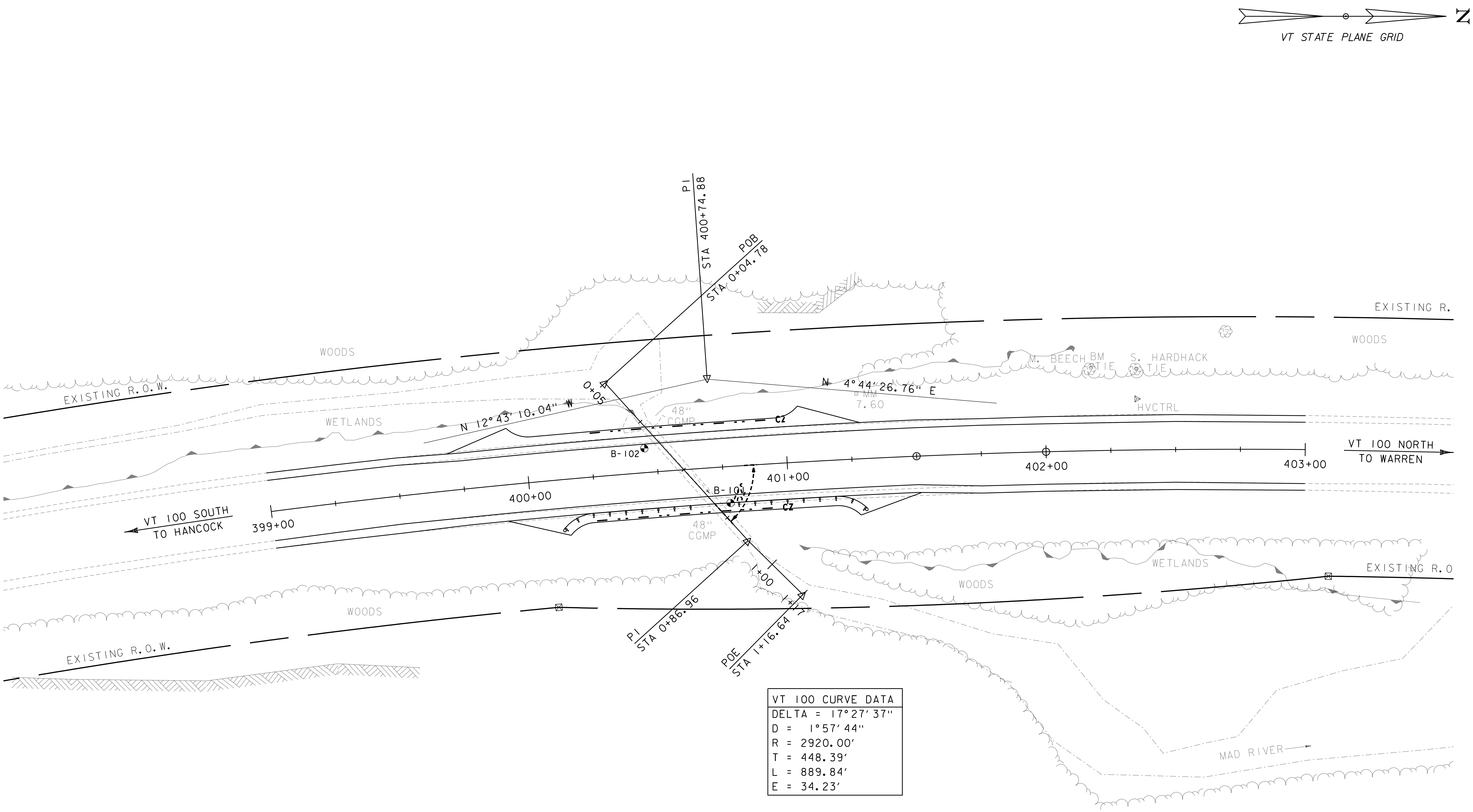
	703.01A - Granular Borrow	**704.08 - Granular Backfill for Structures**	**M. Dense Gravelly Sand/ Sandy Gravel**
Density (lb/ft^3):	130	140	125
Internal Friction Angle, φ (degrees)	32	34	35
Coefficient of Friction			
- soil against mass concrete	0.50	0.55	0.57
- soil against formed concrete	0.40	0.45	0.46
Active Earth Pressure Coefficient, K_a:	0.31	0.28	0.27
Passive Earth Pressure Coefficient, K_p:	3.22	3.54	3.69
At-Rest Earth Pressure Coefficient, K_o:	0.47	0.44	0.43

7.0 CONCLUSION

If you would like to discuss this report, please contact us at (802) 828-2561. Computer generated boring logs are attached and available in the *M:\Projects\16d009\MaterialsResearch* folder.

Attachments: Boring Location Plan (1 page)
Boring Logs (2 pages)

cc: Matt Gamelin, VTrans Roadway
Electronic Read File/DJH
Project File/CEE
ZMH



VT 100 CURVE DATA
DELTA = 17°27′37″
D = 1°57′44″
R = 2920.00′
T = 448.39′
L = 889.84′
E = 34.23′

0 20 40
SCALE IN FEET

PROJECT NAME: GRANVILLE	
PROJECT NUMBER: STP SCRP(13)	
FILE NAME: d16d009bdr.dgn	PLOT DATE: $$$$DATE$$$
PROJECT LEADER: B. MARTIN	DRAWN BY: M. GAMELIN
DESIGNED BY: M. GAMELIN	CHECKED BY: A. KEMPTON
PLAN SHEET	SHEET $S#$ OF $T#$

STATE OF VERMONT
AGENCY OF TRANSPORTATION
CONSTRUCTION AND
MATERIALS BUREAU
CENTRAL LABORATORY

BORING LOG

Granville
STP SCRP(13)
VT 100 Culvert

Boring No.: **B-101**

Pin No.: 16d009
Checked By: ZMH

Boring Crew: Emerson, Judkins, Nieto
Date Started: 8/18/16 Date Finished: 8/19/16
VTSPG NAD83: N 561444.57 ft E 1552978.41 ft
Station: 400+77 Offset: 14.10
Ground Elevation: 1383.0 ft

	Casing	Sampler
Type:	WB	SS
I.D.:	3 in	1.5 in
Hammer Wt:	N.A.	140 lb.
Hammer Fall:	N.A.	30 in.
Hammer/Rod Type:		Auto/AWJ
Rig:	CME 45C SKID	C_E = 1.42

Groundwater Observations

Date	Depth (ft)	Notes
08/19/16	12.1	W.T. after drilling
08/19/16	N/A	W.T. before drilling

Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %
		Asphalt Pavement, 0.0 ft - 0.45 ft					
		A-1-b, SaGr, brn, Moist, Rec. = 0.7 ft	5-6-6 (12)	9.1	45.9	41.9	12.2
		A-1-b, SaGr, Dk/gry-brn, Moist, Rec. = 1.0 ft	1-3-5-6 (8)	11.3	44.5	36.1	19.4
5		A-1-b, SaGr, brn, Moist, Rec. = 1.3 ft	4-6-6-8 (12)	9.8	46.4	41.9	11.7
		A-1-b, GrSa, gry, Moist, Rec. = 1.5 ft, Lab Note: Pieces of wood were within sample.	6-1-2-3 (3)	33.9	37.0	45.7	17.3
		Field Note:, BXDC, Cleaned out casing					
		A-1-b, GrSa, gry, Moist, Rec. = 0.4 ft	5-6-10-29 (16)	14.5	40.0	44.7	15.3
		A-1-b, GrSa, blk-Dk/brn, Moist, Rec. = 0.7 ft		17.8	36.9	45.7	17.4
10		A-1-b, GrSa, blk-Dk/brn, Moist, Rec. = 1.6 ft	24-27-20-14 (47)	15.2	42.8	43.2	14.0
		A-1-b, SaGr, brn, Moist, Rec. = 0.7 ft	10-7-9-10 (16)	12.6	46.1	38.9	15.0
15		A-3, GrSa, brn, Moist, Rec. = 1.6 ft	8-5-5-10 (10)	18.9	26.5	63.0	10.5
		Field Note:, BXDC, Cleaned out casing					
20		A-1-a, SaGr, brn, Moist, Rec. = 0.7 ft	9-13-16-13 (29)	11.1	56.6	30.2	13.2
		Field Note:, BXDC, Cleaned out casing					
25		Field Note:, No Recovery	5-12-10-9 (22)				

Hole stopped @ 27.0 ft

30

Remarks:
Hole collapsed at 12.3 feet.

Notes:
1. Stratification lines represent approximate boundary between material types. Transition may be gradual.
2. N Values have not been corrected for hammer energy. C_E is the hammer energy correction factor.
3. Water level readings have been made at times and under conditions stated. Fluctuations may occur due to other factors than those present at the time measurements were made.

VTrans Working to Get You There — Vermont Agency of Transportation STATE OF VERMONT AGENCY OF TRANSPORTATION CONSTRUCTION AND MATERIALS BUREAU CENTRAL LABORATORY	**BORING LOG** **Granville** **STP SCRP(13)** **VT 100 Culvert**	Boring No.: **B-102** Page No.: 1 of 1 Pin No.: 16d009 Checked By: ZMH

Boring Crew: Emerson, Judkins, Nieto
Date Started: 8/18/16 Date Finished: 8/18/16
VTSPG NAD83: N 561411.28 ft E 1552957.33 ft
Station: 400+45 Offset: -9.30
Ground Elevation: 1381.3 ft

	Casing	Sampler
Type:	WB	SS
I.D.:	3 in	1.5 in
Hammer Wt:	N.A.	140 lb.
Hammer Fall:	N.A.	30 in.
Hammer/Rod Type:	Auto/AWJ	
Rig:	CME 45C SKID	C_E = 1.42

Groundwater Observations

Date	Depth (ft)	Notes
08/18/16	12.7	W.T. after drilling

Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %
		Asphalt Pavement, 0.0 ft - 0.95 ft					
		A-1-b, GrSa, brn, Moist, Rec. = 0.9 ft	13-13-11-8 (24)	9.5	36.7	46.7	16.6
		A-1-b, GrSa, brn, Moist, Rec. = 1.4 ft	7-4-4-5 (8)	12.5	40.9	45.4	13.7
5		A-1-a, SaGr, brn, Moist, Rec. = 0.8 ft, Lab Note: Broken rock was within sample	4-8-4-4 (12)	11.9	51.0	37.5	11.5
		A-2-4, SiSa, gry-brn, Moist, Rec. = 1.0 ft, Lab Note: Some clay and pieces of wood were within sample. Sample tested non-plastic Field Note:, BXDC, Cleaned out casing	1-1-1-2 (2)	16.8	16.0	57.6	26.4
10		A-1-b, SiSaGr, gry, Moist, Rec. = 1.2 ft, Lab Note: A small amount of clay was within sample. Sample tested non-plastic	3-1-3-8 (4)	16.9	42.3	37.4	20.3
		Visual Description:, Broken Rock, gry, Moist, Rec. = 0.3 ft, Lab Note: Insufficient sample size to perform grain size analysis Field Note:, BXDC, Cleaned out casing	9-12-10-13 (22)	5.0			
		A-1-b, SiSaGr, Dk/brn-Lt/brn, Moist, Rec. = 1.1 ft	7-13-8-9 (21)	15.1	43.3	31.6	25.1
15		A-1-b, SaGr, Dk/brn, Moist, Rec. = 1.0 ft	7-6-7-8 (13)	14.1	44.5	39.7	15.8
20		Field Note:, BXDC, Cleaned out casing Field Note:, No Recovery	6-7-7-7 (14)				
		A-1-b, GrSa, gry, Moist, Rec. = 0.3 ft, Lab Note: Broken rock was within sample Field Note:, BXDC, Cleaned out casing	3-4-4-5 (8)	13.7	23.0	65.7	11.3
25							

Hole stopped @ 27.0 ft

Remarks:
Hole collapsed at 14.8 feet.

Notes:
1. Stratification lines represent approximate boundary between material types. Transition may be gradual.
2. N Values have not been corrected for hammer energy. C_E is the hammer energy correction factor.
3. Water level readings have been made at times and under conditions stated. Fluctuations may occur due to other factors than those present at the time measurements were made.