GEODESIGN INCORPORATED

GEOTECHNICAL | CONSTRUCTION | ENVIRONMENTAL
ENGINEERS and SCIENTISTS

MEMORANDUM

To: Callie Ewald, P.E. – VTrans

From: Jacob F. Wimett, P.E.; Jason A. Gaudette, P.G. – Geo**Design**, Inc.

Date: October 31, 2016

Re: Geotechnical Design Recommendations Memo
Waterford BF 0225(5) - Geotechnical Recommendations Report

File No.: 750-09.22

INTRODUCTION

Geo**Design** is pleased to submit this memo providing culvert replacement foundation recommendations for Bridge #2 – VT Route 18 in the town of Waterford, VT. The project includes replacing an existing culvert with a new precast box culvert below Route 18 approximately 7.6 miles south of the intersection with Route 2 and just north of the Vermont/New Hampshire state line.

This memo includes recommendations for foundation design and construction in accordance with *AASHTO LRFD Bridge Design Specifications* as outlined in our proposal dated October 6th, 2016. Recommendations are based on a Conceptual Plan Set dated August 8th, 2016 and two boring logs prepared by VTrans. Refer to Attachment 1 for site plan (Sheet 5 of the Conceptual Plan Set). This memo incorporates VTrans comments from our October 26, 2016 draft submission and our follow up discussion with you.

FIELD INVESTIGATION

A field investigation was performed on August 10th and 11th, 2016 by VTrans personnel. See the VTrans Boring Logs in Attachment 1.

LABORATORY TESTING

Laboratory tests consisting of grain size sieve analyses and moisture content determinations were performed on all recovered soil samples. Testing results are shown on the boring logs included in Attachment 1.

SUBSURFACE CONDITIONS

Subsurface soils generally consisted of a layer of loose to very dense Sand and Gravel overlying an apparent Glacial Till (i.e., very dense gravelly sand and silt). Glacial till was encountered at approximately 25 feet deep in both borings, which is between approximate elevations 699 and 701. Groundwater was encountered between approximately 13 and 21 feet deep with a north to south gradient (similar to existing grades).

Refer to the boring logs (Attachment 1) for details of the subsurface conditions encountered in the borings and limitations related to the measured groundwater levels.

RECOMMENDATIONS

FOUNDATION DESIGN

We anticipate bottom of footing elevations for the culverts will range from approximately 695 to 706 per the Conceptual Plan Set. Wingwall design has not been provided for this project, but we have assumed the wingwall footings will bear a minimum of 5 feet below culvert invert elevations. We assume soils at foundation levels to be within the very dense natural Sand and Gravel layer, with the potential to locally transition to the Glacial Till layer.

On this basis, both a box culvert mat foundation (culvert) and spread footings (wingwalls) are appropriate foundations types for bearing on the natural soils or a working mat of Granular Backfill for Structures (VAOT 704.08A). We assumed a friction angle (φ) of 34 degrees and a unit weight (γ) of 125 pounds per cubic foot for natural Sand and Gravel below footing levels in our bearing resistance analysis.

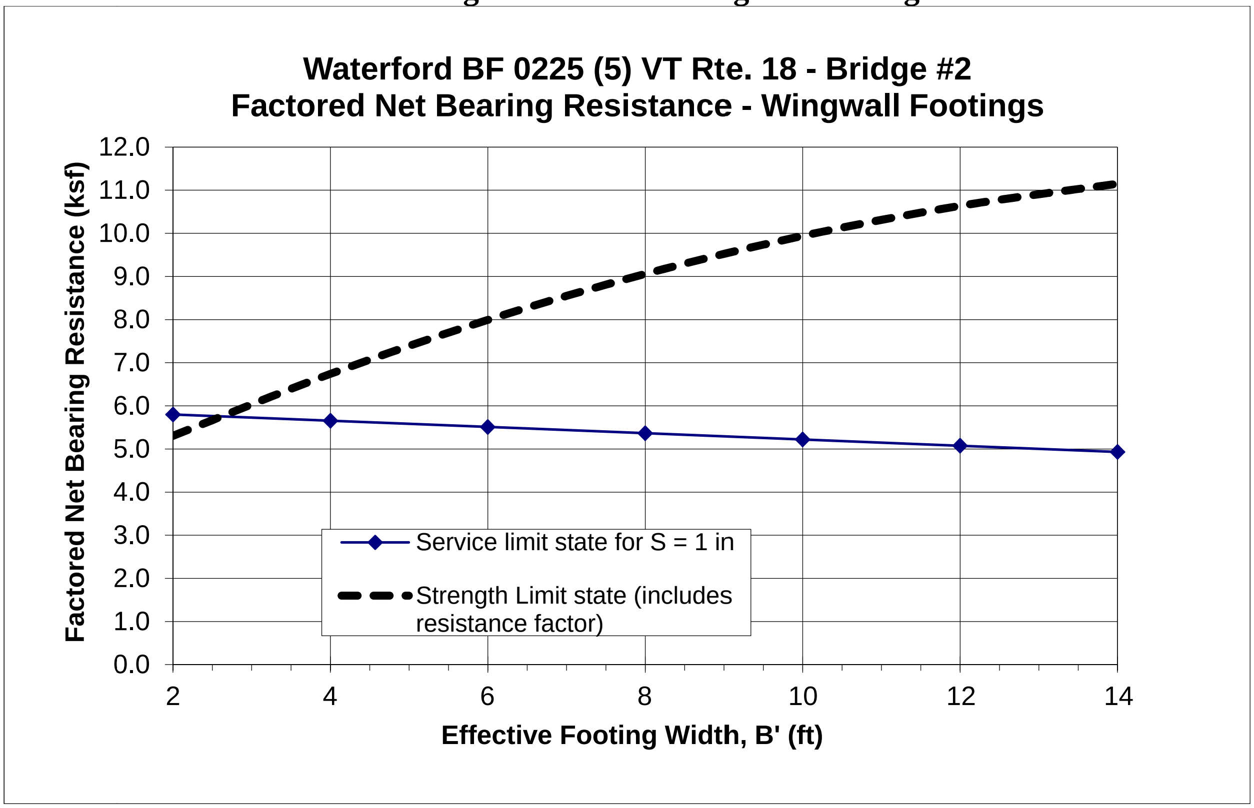
Culvert Foundation Design

Assuming a 16-foot wide by 122-foot long culvert depicted in the Conceptual Plan Set, we recommend a factored net bearing resistance of 14.9 kips per square foot (ksf) for strength limit state and a factored net bearing resistance of 4.8 ksf for service limit state (based on estimated settlement of 1 inch). Bottom of the concrete culvert is assumed to be founded 4 feet below stream bed (as shown on the Conceptual Plan Set). We recommend the culvert be underlain with a minimum of 12 inches of Granular Backfill for Structures for frost protection.

Wingwall Foundation Design

We assumed a length of 10 feet for the wingwalls based on the Conceptual Plan Set, with the effective footing width to be determined in final design. The factored net bearing resistance for the wingwalls will be dependent on the effective footing width, and is presented in Figure 1 below.

FIGURE 1 – Factored Net Bearing Resistance at Wingwall Footings



We recommend founding wingwall footings at least 5 feet below grade for frost protection.

LATERAL EARTH PRESSURE AND SLIDING FRICTION CRITERIA

We recommend the following earth pressure criteria for free draining compacted granular backfill (e.g., Granular Backfill for Structures - VAOT 704.08A):

- Use equivalent fluid unit weights provided for “dense sand or gravel” in *AASHTO LRFD Bridge Design Specifications* Table 3.11.5.5-1.
- Select values for either active or at-rest conditions depending on wall movement restraint.
- Select values for either level backfill, backfill slope of 25 degrees, or interpolate for slope angles between level and 25 degrees.
- Where the equivalent wall pressure is less than 240 pounds per square foot (i.e., near the top of wall), use a uniform pressure of 240 pounds per square foot until wall pressure reaches this value, to account for locked in compaction stresses.
- Reliance on passive pressure in front of wingwalls is not recommended due to scour potential.

- Load factors for earth pressures should be taken from Table 3.4.1-2 in *AASHTO LRFD Bridge Design Specifications*.

We recommend the following sliding resistance criteria for mass (cast-in-place) and formed (pre-cast) concrete placed on compacted granular backfill (e.g., Granular Backfill for Structures - VAOT 704.08A):

Coefficient of friction, (ultimate) ***f,***

- Formed (pre-cast) concrete: 0.4
- Mass (cast-in-place) concrete: 0.55
- Resistance factors for sliding resistance should be taken from Table 10.5.5.2.2-1 in *AASHTO LRFD Bridge Design Specifications*.

OVERALL STABILITY OF WINGWALLS

We evaluated the overall stability of the wingwalls using the SLIDE 7.0 limit equilibrium slope stability analysis program by Rocscience. We analyzed the wingwall at a section along Sta. 4+25 that showed the least favorable geometry. Per Section 11.6.2.3 in the *AASHTO LRFD Bridge Design Specification*, a maximum resistance factor of 0.65 is acceptable for a slope which supports a structural element, and 0.75 is acceptable for a slope which does not.

As discussed previously, the wingwall details have not been fully developed in the design. As such, we assumed the proposed ground elevations behind the wingwalls would approximately match existing grades, and used the proposed culvert invert elevations in front of the wingwalls for our overall stability analysis.

We computed the resistance factor as the inverse of the factor of safety determined in SLIDE 7.0 and determined that it is effectively equal to the maximum acceptable value of 0.65 for slip surfaces below the wingwall (refer to Figure 2 in Attachment 2). Therefore, based on the wingwall locations shown on the Conceptual Plan Set and the grading assumed above, we conclude that overall stability of the proposed wingwalls is adequate.

However, given the steep existing grades behind the wingwall locations (~1.5H:1V) our analysis shows that the slope behind the wingwall at Sta. 4+25 exceeds the maximum 0.75 resistance factor for slopes not supporting a structural element. As such, we modeled a slope with an approximately 2-foot thick stone armoring and found that this was sufficient to obtain a resistance factor less than 0.75 (refer to Figure 3 in Attachment 2).

Note that our conclusions on overall stability are dependent on the geometry we have assumed. We recommend Geo**Design** review, and reevaluate if needed, the results of our analyses if final design geometry of the wingwall and associated grading differs from our stated assumptions.

SOIL MATERIAL

Geo**Design** recommends using Granular Backfill for Structures (VAOT - 704.08A) as a base course below the culvert and as free-draining structural backfill within 5 feet of culvert walls and wing walls. The material should be compacted to requirements in the 2011 VTrans Standard Specifications for Construction.

Excavated on site material may be used as backfill beyond the free-draining structural backfill required behind the culvert and wingwalls and below the road base courses. The material should be compacted to requirements in the 2011 VTrans Standard Specifications for Construction.

CONSTRUCTION CONSIDERATIONS

Dewatering and stream diversion will be required to maintain a reasonably dry excavation and subgrade. It appears from the Conceptual Plan Set that the proposed replacement culvert alignment matches the existing culvert alignment, and therefore stream diversion will be required. For support of excavation, driving sheeting to below proposed foundation levels will likely not be feasible due to very dense, gravelly soils encountered in the soil borings.

Maintaining relatively undisturbed foundation subgrades is important for suitable foundation performance and limiting settlement. From the boring logs, we anticipate that natural soil subgrades have the potential to be silty, and therefore care should be taken to avoid disturbance to the subgrades from excessive foot traffic or equipment. Disturbed subgrade materials should be removed and replaced with compacted granular fill. We recommend proof-rolling final subgrades prior to placing the base layer of Granular Backfill for Structures or footing concrete where subgrades reside in the natural Sand and Gravel. Proof-rolling will not be required in areas that the subgrades transition to natural Glacial Till soils.

CONSTRUCTION DOCUMENT REVIEW AND FIELD OBSERVATION

To maintain continuity between the design and construction phases, Geo**Design** recommends that we be given the opportunity to review the final construction documents. We also recommend that Geo**Design** provides construction observation for foundation subgrade preparations. This will provide us the opportunity to evaluate that the subgrades are as anticipated, and to recommend adjustments as warranted.

LIMITATIONS

This report is subject to limitations presented in Attachment 3.

ATTACHMENT 1

Conceptual Plan Set Sheet 5
(August 8, 2016)

VTrans Boring Logs B-101 and B-102
(August 10 & 11, 2016)

EXISTING BRIDGE DATA
96″ CGMPP, 122′ LONG
50 SQ FT WATERWAY
BUILT 1981

LAYOUT SHEET

SCALE 1″ = 20′-0″
20 0 20

GM2 ASSOCIATES

PROJECT NAME: WATERFORD	
PROJECT NUMBER: BF 0225(5)	
FILE NAME: z15b05layout.dgn	PLOT DATE: 8/8/2016
PROJECT LEADER: T. LEVINS	DRAWN BY: A. KURDEKAR
DESIGNED BY: A. KURDEKAR/ J. MERCER	CHECKED BY: T. LEVINS
LAYOUT	SHEET 5 OF 15

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

BORING LOG

Waterford
BF 0225(5)
VT 18 Br. 2

Boring No.: **B-101**
Page No.: 1 of 1
Pin No.: 15b051
Checked By: END

Boring Crew: Judkins, Gomes
Date Started: 8/11/16 Date Finished: 8/11/16
VTSPG NAD83: N 673406.24 ft E 1799772.82 ft
Station: 3+52.29 Offset: -12.88
Ground Elevation: 724.4 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
08/11/16	21.2	W.T. during drilling

Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %
0.0		Asphalt Pavement, 0.0 ft - 0.2 ft					
		A-1-b, SaGr, brn, Moist, Rec. = 1.0 ft, Lab Note: Broken rock was within sample	9-18-15 (27)	6.3	43.8	40.4	15.8
		A-2-4, GrSiSa, brn, Moist, Rec. = 1.3 ft	20-38-14-11 (52)	8.8	21.0	55.4	23.6
		Field Note:, BXDC, Cleaned out casing					
5		Field Note:, No Recovery	12-12-10-12 (22)				
		A-2-4, GrSa, brn, Moist, Rec. = 1.4 ft	12-9-11-12 (20)	12.6	20.8	59.4	19.8
		A-2-4, Sa, brn, Moist, Rec. = 1.2 ft	8-6-4-5 (10)	11.4	12.2	69.7	18.1
10		A-2-4, Sa, brn, Moist, Rec. = 1.0 ft	8-8-8-9 (16)	10.3	8.2	79.8	12.0
		A-1-b, Sa, brn, Moist, Rec. = 1.0 ft	4-3-3-2 (6)	14.9	10.0	83.4	6.6
15		A-3, Sa, brn, Moist, Rec. = 0.1 ft	2-1-3-3 (4)	17.4	14.5	77.3	8.2
		A-1-b, SaGr, brn, Moist, Rec. = 0.6 ft	3-2-5-3 (7)	13.2	52.8	37.7	9.5
		Field Note:, No Recovery	4-6-11-7 (17)				
20		Field Note:, BXDC, Cleaned out casing					
		A-1-a, SaGr, brn, Moist, Rec. = 0.5 ft	6-9-7-4 (16)	9.7	62.3	26.7	11.0
25		Field Note:, BXDC, Cleaned out casing					
		A-2-4, SaSiGr, gry, Moist, Rec. = 1.2 ft, Lab Note: Broken rock was within sample	24-23-21-20 (44)	10.1	37.1	31.0	31.9
30		A-4, SaSi, gry, Moist, Rec. = 0.6 ft, Lab Note: Broken rock was within sample	17-R@2.5" (R)	12.0	19.0	32.6	48.4
35		Field Note:, BXDC, Cleaned out casing					
		A-4, SaGrSi, gry, Moist, Rec. = 0.9 ft, Lab Note: Broken rock was within sample	42-R@5" (R)	14.3	25.2	22.1	52.7
40		Field Note:, BXDC, Cleaned out casing					
		A-4, SaSi, gry, Moist, Rec. = 0.9 ft	32-R@5" (R)	8.1	13.3	35.7	51.0
		Hole stopped @ 40.9 ft					
45							

Remarks:
Hole collapsed at 1.9 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.

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BORING LOG

Waterford
BF 0225(5)
VT 18 Br. 2

Boring No.: **B-102**
Page No.: 1 of 1
Pin No.: 15b051
Checked By: END

Boring Crew: Judkins, Gomes
Date Started: 8/10/16 Date Finished: 8/10/16
VTSPG NAD83: N 673461.06 ft E 1799766.83 ft
Station: 4+3.18 Offset: 9.12
Ground Elevation: 726.2 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
09/10/16	12.8	W.T. during drilling

Depth (ft)	Strata (1)	CLASSIFICATION OF MATERIALS (Description)	Blows/6" (N Value)	Moisture Content %	Gravel %	Sand %	Fines %
		Asphalt Pavement, 0.0 ft - 0.35 ft					
		A-1-a, SaGr, Rec. = 0.8 ft, Lab Note: A lot of broken rock was within sample	--8-9-10 (17)	5.6	66.1	23.3	10.6
		A-1-a, Gr, Rec. = 0.3 ft, Lab Note: A lot of broken rock was within sample	10-R@5" (R)	1.6	79.9	13.6	6.5
		Field Note:, BXDC, Cleaned out casing					
5		Field Note:, No Recovery	12-11-7-6 (18)				
		Field Note:, BXDC, Cleaned out casing					
		Field Note:, No Recovery	5-5-7-6 (12)				
		Field Note:, No Recovery	4-3-4-6 (7)				
10		A-1-b, Sa, Rec. = 0.5 ft	7-11-7-7 (18)	14.3	7.9	82.4	9.7
		Field Note:, BXDC, Cleaned out casing					
		A-3, Sa, Rec. = 0.7 ft	5-3-2-6 (5)	14.5	5.8	87.3	6.9
15		A-2-4, Sa, Rec. = 0.3 ft	3-4-3-3 (7)	17.2	8.0	81.1	10.9
		A-2-4, Sa, Rec. = 0.3 ft	2-3-1-6 (4)	17.1	9.5	73.8	16.7
		A-1-b, SiSaGr, Rec. = 0.6 ft, Lab Note: Broken rock was within sample	18-8-11-23 (19)	11.1	52.8	26.8	20.4
20		Field Note:, BXDC, Cleaned out casing					
		Field Note:, No Recovery, Rock stuck in end of sampler	6-7-6-6 (13)				
25		Field Note:, BXDC, Cleaned out casing					
		A-4, GrSaSi, Rec. = 1.0 ft, Lab Note: Broken rock was within sample	30-28-30-R@2.5" (58)	11.2	26.1	29.5	44.4
30		A-4, GrSaSi, Rec. = 0.9 ft, Lab Note: Broken rock was within sample	45-R@5" (R)	11.1	20.6	34.0	45.4
35		Field Note:, BXDC, Cleaned out casing					
		A-2-4, SiGrSa, Rec. = 1.0 ft, Lab Note: Broken rock was within sample	22-46-R@3.5" (R)	9.7	34.5	35.5	30.0
40		Field Note:, BXDC, Cleaned out casing					
		A-4, GrSaSi, Rec. = 0.9 ft	34-R@5" (R)	8.3	20.1	27.7	52.2
		Hole stopped @ 40.9 ft					
45		Remarks: Hole Collapsed at 16.6 feet.					

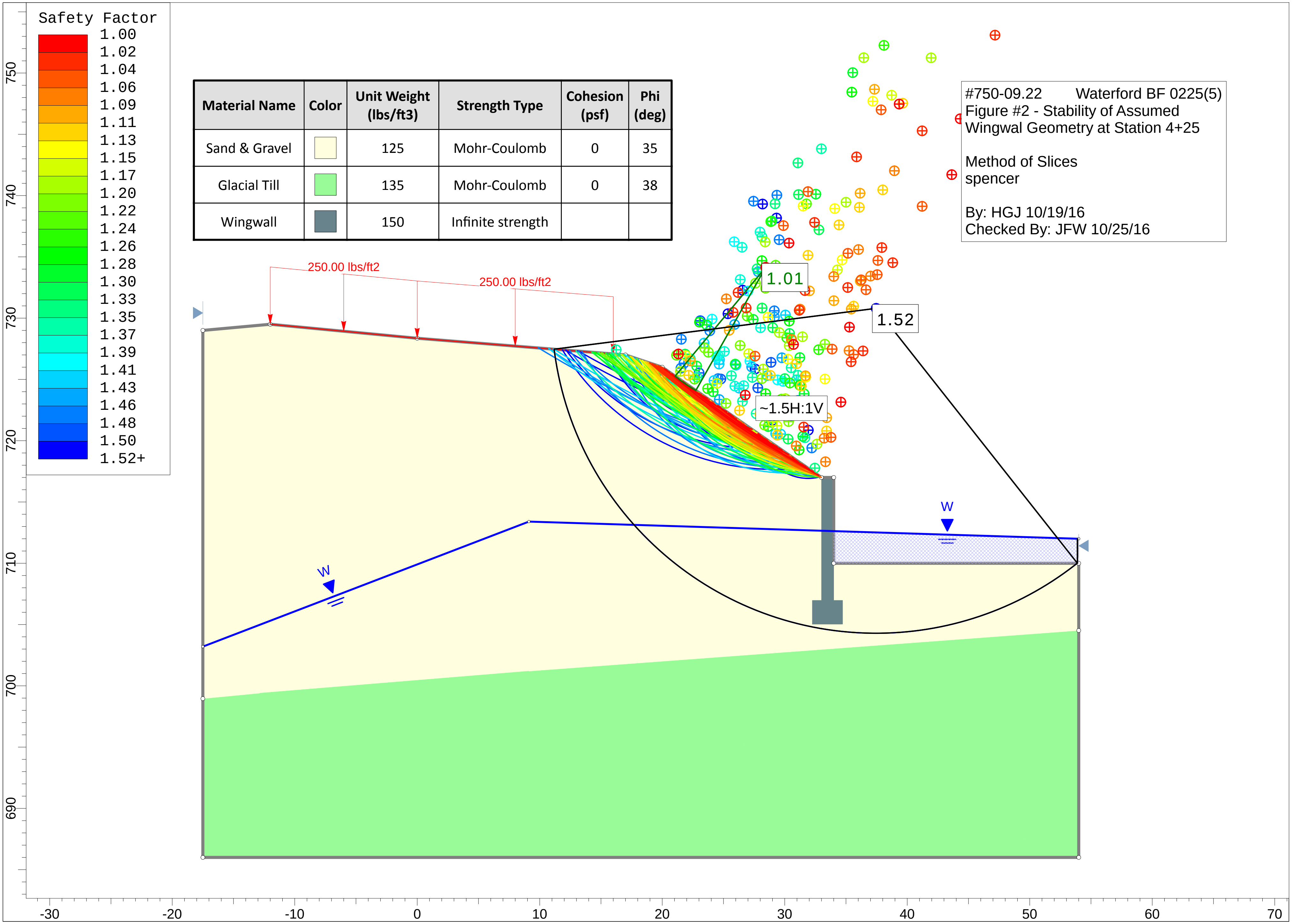
Notes:
1. Stratification lines represent approximate boundary between material types. Transition may be gradual.
2. N Values have not been corrected for hammer energy. C_E is the hammer energy correction factor.
3. Water level readings have been made at times and under conditions stated. Fluctuations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

ATTACHMENT 2

Overall Stability of Wingwalls
SLIDE 7.0 Output

Figure 2 – Proposed Wingwall Stability at Section 4+25
(Assumed Geometry Without Stone Armoring)

Figure 3 – Proposed Wingwall Stability at Section 4+25
(Assumed Geometry With Stone Armoring)



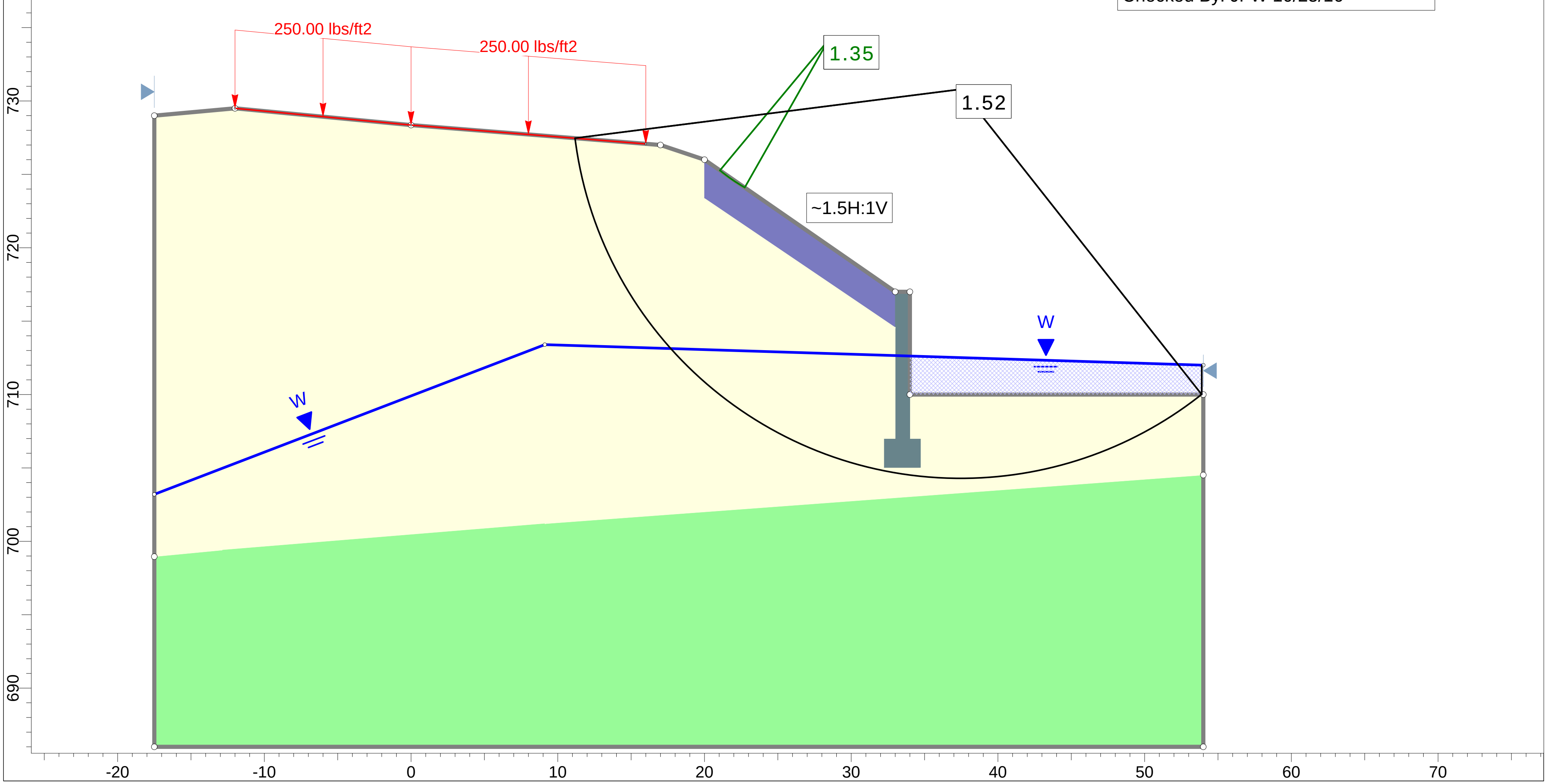
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Sand & Gravel		125	Mohr-Coulomb	0	35
Glacial Till		135	Mohr-Coulomb	0	38
Wingwall		150	Infinite strength		

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Sand & Gravel		125	Mohr-Coulomb	0	35
Glacial Till		135	Mohr-Coulomb	0	38
Wingwall		150	Infinite strength		
Stone Fill		125	Mohr-Coulomb	0	43

#750-09.22 Waterford BF 0225(5)
Figure #3 - Stability of Assumed Wingwal Geometry at Station 4+25 With Slope Armoring

Method of Slices
spencer

By: DTH 10/20/16
Checked By: JFW 10/25/16



ATTACHMENT 3

Limitations

GEOTECHNICAL LIMITATIONS

Explorations

1. The analyses and recommendations submitted in this report are based in part upon the data obtained from widely spaced subsurface explorations. The nature and extent of variations between these explorations may not become evident until construction. If variations then appear evident, it will be necessary to reevaluate the recommendations of this report.

2. The generalized soil profile described in the text is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized and have been developed by interpretations of widely spaced explorations and samples; actual soil transitions are probably more erratic. For specific information, refer to the boring logs.

3. Water level readings and moisture conditions have been made in the explorations, and from the samples at times and under conditions stated on the logs. These data have been reviewed and interpretations have been made in the text of this report. However, it must be noted that fluctuations in the level of the groundwater and moisture condition may occur due to variations in rainfall, temperature, and other factors occurring since the time measurements were made.

Review

4. In the event that any changes in the nature, design or location of the proposed structures is planned, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed and conclusions of this report modified or verified in writing by Geo**Design**, Inc. We recommend that we be provided the opportunity to review and comment on the finalized project design and relevant construction specifications in order that earthwork and foundation recommendations may be properly interpreted and implemented in the design and specifications.

Use of Report

5. This report has been prepared for the exclusive use of Client, for specific application to the project, as described in Geo**Design**'s scope of services/ contract and related documents, in accordance with generally accepted soil and foundation engineering practices. No other warranty, express or implied, is made.

6. This report has been prepared for this specific project by Geo**Design**, Inc. This report is for design purposes only and is not sufficient to prepare an accurate bid. Contractors wishing a copy of the report may secure it with the understanding that its scope is limited to design considerations only, unless otherwise specified in the report.

7. Unless otherwise noted, the scope of our services did not include environmental assessment or investigation for the presence of hazardous or toxic materials in the soil, surface water, groundwater or air, on, below, or around this site.