VILLAGE OF KENILWORTH
Kenilworth, Illinois

PROPOSAL FOR STRUCTURAL ENGINEERING SERVICES FOR
STRUCTURAL EVALUATION OF WATER TOWER

Burns Engineering, Inc.
September 12, 2016

Proposal No. OBE16-0473

I. PROJECT BACKGROUND AND DESCRIPTION

Burns Engineering, Inc. (Burns) received a request from the Village of Kenilworth (Village) in year 2014 to provide a review of the Village's water tower due to impacts of installation of new antennas proposed by Sprint and AT&T. These antennas will replace some of the antennas that were removed several years ago. These antennas are in addition to existing antennas from T-Mobil installed at the top of water tower.

Computations were performed by Burns to verify the adequacy of the tank and tank foundation under the combined impact of antennas from all the providers. Based on the calculations, the existing water tank capacity will be adequate to support the new loads, adhering to the following limitations:

During normal times, the tank can function without any limitations but under the wind loading condition, the tank foundations will be overstressed based on allowable bearing capacity of 6,000 psf as specified on Universal Tank & Iron Works, Inc. drawings. The bearing capacity will be within permissible limits by limiting a maximum of 160,000 gallons of water in the tank during high wind events on the order of 75 mph.

Burns recommended that the Village hire the services of a geotechnical engineer to evaluate the bearing capacity of the soil whether it can safely carry the calculated bearing pressure and also provide recommendations regarding suitable methods to increase the bearing capacity of the foundation soil. The Village hired Wang Engineering to provide recommendations on these items.

The Village has indicated that no additional antennas or replacement of any antenna have been done since the 2014 analysis.

II. PROPOSED SCOPE OF WORK

Burns will perform professional services based on the descriptions of the items noted below.

Task A – Tower Stability without Additional Antennas

1. Review the Geotechnical Report provided by Wang Engineering.
2. Review the year 2014 analysis on the overall stability of the water tower calculations and modify them to meet the latest code requirements.
3. Check the stability of water tower under the present loading and recommendations from the Geotechnical Report provided by Wang Engineering.
4. Check possibility of installing any additional antenna without foundation modifications.
5. Summarize the findings and present the results to the Village.

Task B – Evaluation of Water Tower Foundation under Additional Future Antenna Loads

1. Perform an analysis and evaluation of water tank foundation, and check the stability of the water tower based on the recommendations in the Geotechnical Report for additional antenna loads, if directed by the Village.
2. Provide a letter report that summarizes the findings of the structural evaluation.
3. Preparation of bid documents (drawings and specifications) are out of scope work.

III. SCHEDULE

We are committed to continuing a favorable relationship with the Village and we understand that timely performance of our services is critical. We are committed to completing the work in a time frame agreeable with the Village of Kenilworth.

IV. ENGINEERING FEES

We have prepared our fee based on the anticipated number of engineering hours necessary to complete the project within the scope of work indicated above. Estimated costs by tasks are as follows:

Task	Description	Engineering Fees
A	Tower Stability without Additional Antennas	
	• Review of information from Wang Engineering and coordination with Wang Engineering	$600
	• Tower stability evaluation relating to present antenna loading without foundation modification	$1,000
	Estimated Subtotal Cost	**$1,600** A
B.	Evaluation of Water Tower Foundation under Additional Antenna Loads	
	• Analysis and evaluation of water tank foundation, and checking stability of water tower under additional future antenna loads	$2,000
	• Report writing	$ 500
	Estimated Subtotal Cost	**$2,500**
	Estimated Total Cost	**$4,100**

PROCEED WITH TASK A.

GEOTECHNICAL REPORT
WATER TOWER FOUNDATION
SOIL ASSESSMENT
VILLAGE OF KENILWORTH
COOK COUNTY, ILLINOIS

for:

Village of Kenilworth

419 Richmond Road

Kenilworth, IL 60043

(847) 251-1666

submitted by:

Wang Engineering, Inc.

1145 North Main Street

Lombard, IL 60148

(630) 953-9928

September 7, 2016

Technical Report Documentation Page

1. Title and Subtitle Geotechnical Report, Water Tower Foundation Soil Assessment, Village of Kenilworth, Cook County, Illinois		**2. Report Date** September 7, 2016 **3. Report Type** ☒ SGR ☐ RGR ☒ Draft ☐ Final ☐ Revised
4. Route / Section / County NA / NA / Cook		**5. IDOT Job / Contract No.** **NA**
6. PTB / Item No. NA	**7. Existing Structure Number(s)** **NA**	**8. Proposed Structure Number(s)** **NA**
9. Prepared by Wang Engineering, Inc. 1145 N Main Street Lombard, IL 60148	**Contributor(s)** Author: Mickey L. Snider, P.E. QC/QA: Liviu Iordache, P.G.	**Contact Phone Number** (630) 953-9928 x 1027 msnider@wangeng.com
10. Prepared for Village of Kenilworth 419 Richmond Road Kenilworth, IL 60043	**Project Manager** Nadim Badran	**Contact Phone Number** (847) 251-1666

11. Abstract

Improvements to the existing Village of Kenilworth water tower at the corner of Roger Avenue and Exmoor Road require a reassessment of the allowable soil bearing capacity. The plans provided from the original tower construction in 1976 note an allowable bearing pressure of 6,000 psf. Following a new investigation of the subsurface conditions, we have re-examined the bearing capacity of the existing footings and provided recommendations for new foundations, if necessary.

The soil profile beneath the existing shallow foundation ring consists of a 5-foot thick crust of hard, brown and gray lean clay over 50 feet of very stiff, gray lean clay. Groundwater was not encountered during drilling; however, at the completion of drilling, minor seepage was recorded within the borehole at a depth of about 16 feet below grade. Two TEXAM pressuremeter tests were performed within the foundation soil at 14 and 24.5 feet below the ground surface.

Based on the results of pressuremeter testing the foundation soils for the water tower have a maximum allowable net bearing capacity of 8,000 psf,. Under the maximum allowable pressure, the soils would undergo 0.5 inch of long-term settlement.

If the bearing capacity is insufficient to support improvements on the existing foundations, we recommend retrofitting a deep foundation system to the existing ring footing. The recommended foundation systems may be micropiles with grouted bond lengths of 20 to 30 feet, or helical anchors with an appropriate number of blades torqued into the very stiff lean clay. We estimate 8- to 10-inch diameter micropiles could provide 36 to 68 kips of allowable capacity per pile for 20 to 30 foot lengths. A single, 16-inch diameter helical anchor blade would provde 12 kips of allowable capacity.

12. Path to archived file

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Wang Engineering

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SOIL ASSESSMENT
VILLAGE OF KENILWORTH
COOK COUNTY, ILLINOIS
FOR
VILLAGE OF KENILWORTH

1.0 INTRODUCTION

This report presents the results of our subsurface investigation, laboratory testing, and geotechnical evaluations and recommendations to support improvements to the existing water storage tank at the corner of Roger Avenue and Exmoor Road in Kenilworth, Illinois. A *Site Location Map* is presented as Exhibit 1.

1.1 Proposed Improvements

Wang Engineering, Inc. (Wang) understands the existing water tower has an operational restriction to reduce the capacity from the maximum of 200,000 gallons to 160,000 gallons due to insufficient bearing capacity of the foundation soil. The Village of Kenilworth is exploring options to either eliminate the restrictions or modify the foundation to accept additional loading. The purpose of our investigation was to characterize the site soil and groundwater conditions, perform geotechnical analyses, and provide recommendations for the bearing capacity of the water storage tank.

1.2 Existing Structure

The original 1976 construction plans provided by the Village of Kenilworth, show a 116-foot tall spheroid tank supported on shaft and bell sections. The bell section measures 24 feet in diameter and is supported on a shallow, reinforced concrete ring footing. The footing was installed at 7.75 feet below the surrounding grade elevation, and has a stem height of 6.25 feet and footing thickness of 1.5 feet. The footing is 5.5 feet wide. The plans indicate the foundation soil has an allowable bearing capacity of 6.0 ksf at a depth of 6 feet below grade.

2.0 GEOLOGICAL SETTING

The project area is located in the northeastern part of Cook County. On the USGS 7.5 minute series *Evanston Quadrangle* map, the site lies in the NE ¼ of Section 28, Tier 42 N, Range 13 E.

The following brief review of published information on bedrock and glacial geology covers northeastern Illinois in general and Cook County in particular. This review is meant to place the results of our subsurface investigation within a regional geological framework to confirm their reliability and evaluate potential geological factors that may influence location, design, and construction of the proposed improvements.

2.1 Glacial Cover

In the project area, quaternary glacigenic deposits unconformable overlie Paleozoic bedrock. The site lies on a glacial lake plain located immediately east of the Highland Park Moraine's tapering, southern terminus. The center of this narrowing section of the moraine is notably and appropriately traced by Ridge Road (Bretz 1955). The wave flattened glacial sediments that underlie the site consist of diamicton attributed to the Wadsworth Formation of the Wedron Group. The Wadsworth Formation contains relatively homogeneous and massive, gray till, with clay to silty clay matrix, a high content of black shale clasts, and occasional silt and sand lenses. In the Cook County area, the Wadsworth Formation averages about 50 to 100 feet thick (Hansel and Johnson 1996; Willman 1971). From an engineering viewpoint, the Wadsworth diamicton includes low plasticity clay to silty clay with medium to low moisture content, medium to very stiff consistency, poor permeability, and low compressibility (Bauer et al 1991).

2.2 Bedrock

The uppermost section of bedrock that underlies northeastern Illinois consists primarily of Silurian-age dolostone (Willman et al. 1975). The bedrock is overlain by approximately 100-foot thick Quaternary deposits, with the top of bedrock at an elevation of approximately 500 feet (Herzog et al. 1994). No major, active faults have been identified in the area.

Our subsurface investigation results fit into the local geologic context. The boring drilled in the project area revealed that native sediments at the project site consist of brown (oxidized) to gray (unweathered) clayey diamicton. The boring did not reach the top of the bedrock.

3.0 METHODS OF INVESTIGATION

The following section outlines the subsurface and laboratory investigations performed by Wang.

3.1 Subsurface Investigation

The subsurface investigation consisted of one structure boring, designated as B-4, and one pressuremeter test boring, designated as B-4PMT, drilled by Wang on August 22, 2016. The borings were drilled 8 feet apart from an approximate elevation of 621.7 feet. The structure boring was advanced to 60 feet bgs; the pressuremeter tests were performed at 14 and 24.5 feet bgs. Northing, easting, and elevation data were obtained with a mapping-grade GPS. The boring location data is included in the *Boring Logs* (Appendix A) and the as-drilled location is shown in the *Boring Location Plan* (Exhibit 2).

A truck-mounted drill rig, equipped with hollow stem augers, was used to advance and maintain an open borehole. Soil sampling was performed according to ASTM D 1586, "*Penetration Test and Split Barrel Sampling of Soils*." The soil was sampled at 2.5-foot intervals to 30 feet bgs and at 5.0-foot intervals to the boring termination depth. Soil samples from each interval were placed in sealed jars for further laboratory testing. The in-situ testing was performed in accordance with ASTM D 4719 with a TEXAM pressuremeter employing an N-sized, 3-inch diameter probe (Briaud 1986).

Field boring logs, prepared and maintained by a Wang engineer, include lithological descriptions, visual-manual soil classifications (ASTM D 2487), results of Rimac and pocket penetrometer unconfined compressive strength tests, and results of Standard Penetration Tests (SPT), recorded as blows per 6 inches of penetration.

Groundwater observations were made during and at the completion of drilling operations. The borings were backfilled with soils cuttings after completion.

3.2 Laboratory Testing

The soil samples were tested in the laboratory for moisture content (ASTM D 2216). Atterberg limits (ASTM D 2216) and particle size (ASTM D 422) analyses were performed to classify selected samples. Tested soils were classified according to the United Soil Classification System (USCS, ASTM D 2487) and the visual-manual descriptions were verified in the laboratory. The laboratory results are shown in the *Boring Logs* (Appendix A) and in the *Laboratory Test Results* (Appendix B).

4.0 RESULTS OF FIELD AND LABORATORY INVESTIGATION

Detailed descriptions of the soil conditions encountered during the subsurface investigation are presented in the attached *Boring Logs* (Appendix A). Please note that strata contact lines represent approximate boundaries between soil types. The actual transition between soil types in the field may be gradual in horizontal and vertical directions.

4.1 Soil Conditions

At the surface, the boring encountered 4 inches of lean clay topsoil. In descending order, the general lithologic succession includes 1) man-made ground (fill); 2) hard lean clay; and 3) very stiff lean clay.

1) Man-made ground (Fill)

Beneath the topsoil, the boring encountered 5 feet of medium stiff to stiff, brown lean clay with sand fill. The fill has unconfined compressive strength (Q_u) values of 0.8 to 1.5 tsf and moisture content values of 18 to 22%. This material represents moderately compacted fill used to bring the site back up to level after construction of the tower foundation. It will have minimal impact on the bearing capacity.

2) Hard lean clay

A 5-foot thick crust of hard, brown and gray lean clay with traces of gravel underlies the fill. The crust, which represents the immediate foundation soil for the shallow ring footing, has Qu values as high as 8.5 tsf and moisture contents of 14 to 16%.

3) Very stiff lean clay

The primary foundation bearing material revealed during the investigation consists of very stiff, gray lean clay with traces of gravel. The upper 10 feet of the layer has Q_u values of 3.2 to 3.6 tsf and moisture content values of 13 to 18%; below about 18 feet, the Qu values decrease slightly to about 2.4 to 2.9 tsf, and the moisture content values increase to average about 19 to 20%.

Two pressuremeter tests were performed within this layer: one test within the upper section at 14 feet bgs and the second within the lower section material at 24.5 feet bgs. The pressuremeter results, shown in Figure 1 and summarized in Table 1, correlate well to the soil parameters shown in the boring logs. The lift-off pressure (P_o), which generally correlates to the in-situ, horizontal earth pressure was 1.3 and 1.1 tsf and the corresponding coefficient of earth pressure at rest about 0.8 to 1.0 and represents over-consolidated cohesive soils. The yield pressures (P_f) of 6.7 to 6.3 tsf indicate the loads at which the soils would be expected to begin showing larger deformations. For basic shallow structure footings we tend to calculate settlements of about 0.8 to 1.2 inches at these loads, with the settlement estimations increasing quickly with any additional load applied above P_f. The limit pressures (P_L) of these tests were 14.5 and 10.2 tsf and theoretically represents the pressure corresponding to infinite expansion of the probe. This infinite expansion obviously cannot be reached, and the limit pressure is therefore estimated from the end of the testing curve. The P_L in the current tests correlates to very stiff cohesive soils.

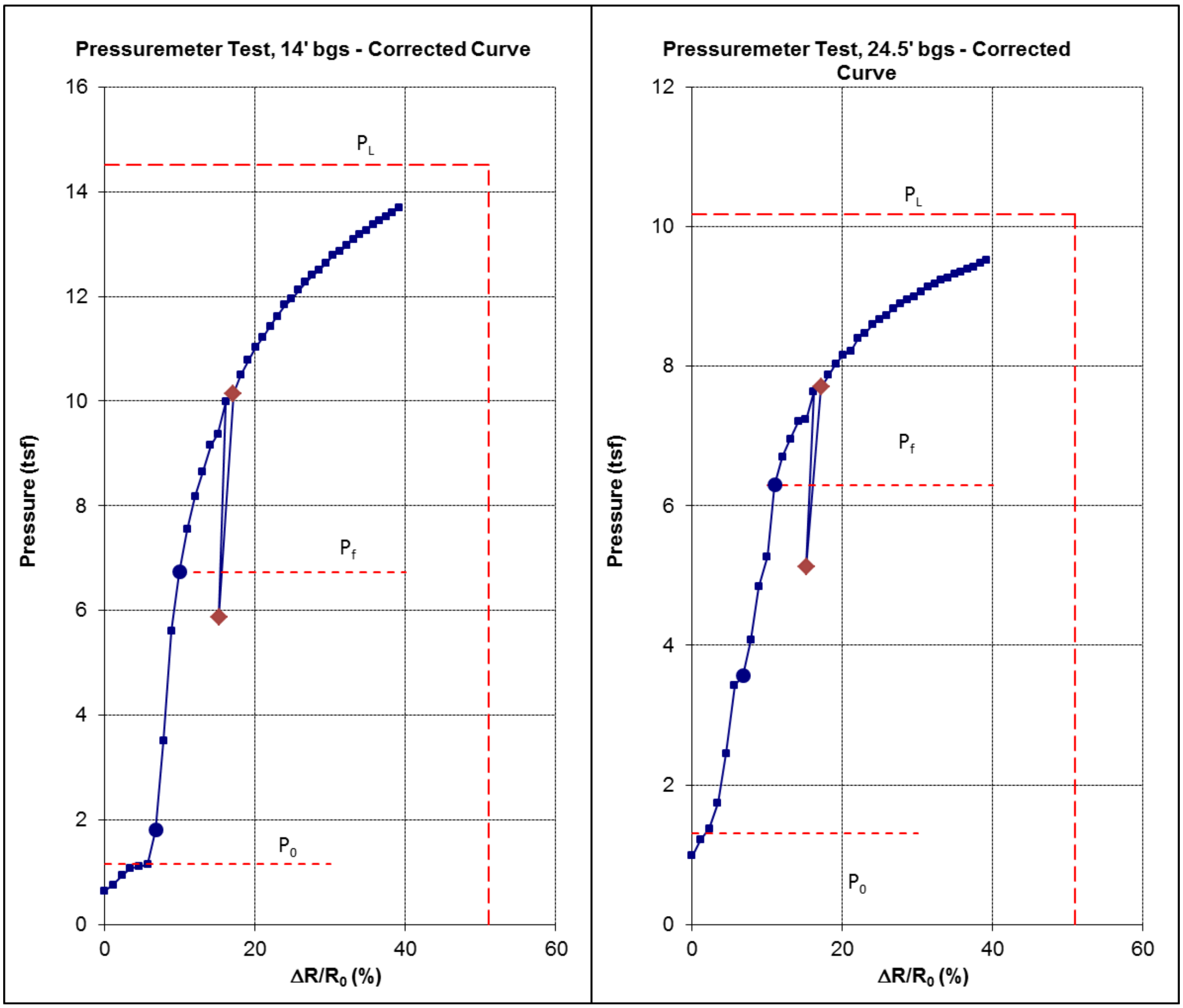

Figure 1: Pressuremeter Test Curves

The two modulus values obtained during the data reduction, the pressuremeter modulus (E_o) and reload modulus (E_R), which are used to evaluate the elastic and long-term settlements of the foundation, are within the stiff to very stiff range. The lower modulus value of the test performed at 24.5 feet likely indicates a higher degree of saturation and lower over-consolidation ratio, which is expected for an over-consolidated soil layer.

Table 1: Summary of Pressuremeter Testing

Test ID	Sample Depth (feet)	Sample Elevation (feet)	Lift-off Pressure, P_0 (tsf)	Yield Pressure, P_f (tsf)	Limit Pressure, P_L (tsf)	PMT Modulus, E_O (tsf)	Reload Modulus, E_R (tsf)	E_O/ E_R
PMT-1	14.0	607.7	1.1	6.7	14.5	230	348	0.66
PMT-2	24.5	597.2	1.3	6.3	10.2	94	206	0.46

4.2 Groundwater Conditions

During drilling the borehole was found dry and the samples were recovered dry. During auger removal, however, water was noted on the outside of the augers and was observed seeping into the borehole at a depth of approximately 16 feet. There are likely some very thin sand seams dividing the individual sublayers within the lean clay. After 10 minutes the seepage was not sufficient enough to fill the borehole; therefore, we estimate these potential thin sand seams will not impact the bearing capacity or settlement performance of the structure.

5.0 FOUNDATION ANALYSIS AND RECOMMENDATIONS

Bearing capacity and settlement evaluations for the shallow ring foundation are presented in the following sections. The evaluations have been performed assuming the foundation has been constructed as shown in the Universal Tank and Iron Works plan set, dated 1976, and provided by the Village of Kenilworth. The base of the foundation is estimated at an elevation of 614.2 feet, and the foundation is shown in the plans as being 5.5 feet wide.

5.1 Existing Foundation Assessment

For a base elevation of 614.2 feet, the foundation is constructed within the hard lean clay crust (Layer

1) and approximately 3 feet above the very stiff lean clay (Layer 2). The soils within the zone 2 times the width of the foundation have an average Q_u value of 3.2 tsf; the net allowable bearing capacity estimated from the Q_u values is 6,200 psf, or approximately equivalent to the allowable pressure provided in the 1976 construction notes. Based on the results of the in-situ testing, however, we estimate the foundation soils have an ultimate net bearing capacity of 24,000 psf and a net allowable bearing capacity is increased to 8,000 psf for a factor of safety of 3.0 (Briaud 1986, Appendix C). The settlement evaluations, also performed considering the results of the pressuremeter testing, show the foundation will undergo approximately 0.5 inches of total long-term settlement under the allowable net bearing pressure of 8,000 psf.

5.2 Recommendations for Additional Capacity

If the allowable bearing pressure calculated from the pressuremeter testing remains insufficient for support of the water tank improvements, we recommend retrofitting a deep foundation system around the perimeter of the ring foundation. The bearing capacity could be increased by installing either micropiles or helical anchors. These systems would require excavation adjacent to the ring foundation to develop a structural connection between the two systems.

Micropiles should be designed based on the grout-to-ground bond strengths ($\alpha_{\text{bond ultimate strength}}$) summarized in Table 2 and the design methods provided in Federal Highway Administration Publication SA-97-070, *Micropile Design and Construction Guidelines* (FHWA 2000). Micropiles typically have diameters of 8 to 10 inches, and we estimate they will achieve the factored resistances shown in Table 3 considering a FOS of 2.5.

Table 2: Soil Grout-to-Ground Nominal Strength for Micropiles

Soil Description (Borings CB-01 and CB-02)	Approximate Elevation Range (feet)	Grout-to-Ground Bond Ultimate Strengths ($\alpha_{\text{bond ultimate strength}}$) (psi)
V Stiff to Hard LEAN CLAY	590 to 560	15.0

Table 3: Summary of Micropile Capacities at Various Depths

Micropile Diameter (inches)	Cap Base Elevation (feet)	Bond Length (feet)	Ultimate Capacity (kips)	Allowable Capacity (kips)	Estimated Tip Elevation (feet)
8	614	20	90	36	560
10	614	20	114	46	560
8	614	30	136	54	560
10	614	30	170	68	560

Helical anchors are screw-type foundation systems that are torqued into the foundation soil from the surface (Helical Anchors, Inc 2014). The anchors have multiple blades, spaced at or greater than 3-blade diameters apart that provide vertical bearing capacity based on the number and size of the blades. The blades vary in diameter from 6 to 16 inches and anchor shafts can be extended to lengths exceeding 50 feet. The initial blade should be installed a minimum of 6 blade diameters below the base of the footing. A single, 16-inch diameter blade installed with the very stiff foundation soil encountered beneath the existing water tower would provide approximately 30 kips of ultimate bearing capacity and 12 kips of allowable bearing capacity considering a FOS of 2.5. A smaller, 12-inch diameter blade would provide 17 kips of ultimate and 7 kips of allowable capacity. There are a number of different helical anchor manufacturers and installation Contractors; therefore, the final helical anchor design should be performed by the Contractor.

6.0 QUALIFICATIONS

The analysis and recommendations submitted in this report are based upon the data obtained from the borings drilled at the locations shown in the boring logs and in Exhibit 2. This report does not reflect any variations that may occur between the borings or elsewhere on the site, variations whose nature and extent may not become evident until the course of construction. In the event that any changes in the design and/or location of the developments are planned, we should be timely informed so that our recommendations may be adjusted accordingly.

It has been a pleasure to assist the Village of Kenilworth on this project. Please call if there are any questions, or if we can be of further service.

Respectfully Submitted,

WANG ENGINEERING, INC.

Mickey L. Snider, P.E.	Liviu Iordache, P.G.
Senior Geotechnical Engineer	QA/QC Reviewer

REFERENCES

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