**Specification Title & Description:** (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

Micropiles

**Revision History:**

<table>
<thead>
<tr>
<th>Revision No.</th>
<th>Description</th>
<th>Date</th>
<th>Affected Pages</th>
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<tbody>
<tr>
<td>0</td>
<td>Issue for Construction</td>
<td>June 16, 2017</td>
<td>All</td>
</tr>
<tr>
<td>1</td>
<td>Update Contractor Qualification Requirements</td>
<td>May 4, 2018</td>
<td>All</td>
</tr>
</tbody>
</table>

**Document Review & Approval:**

**Originator:**

Harry W. Elliott, PE/Lead Structural Engineer

**Design Verification Complete:**

W. Laird Ellis, Jr. PE/Design Manager

**Approved:**

W. Laird Ellis, Jr. PE/Design Manager
PART 1      GENERAL

1.01 SCOPE OF WORK

A. The Work consists of furnishing all necessary supervision, labor, materials, and equipment to perform all work necessary to install and test the micropiles as per the specifications described herein, and as shown on the design Drawings. The micropile contractor shall determine the micropile diameters and lengths based on the loading criteria shown on the Drawings. The micropile load capacities and measurements shall be verified by testing as specified herein.

1.02 QUALIFICATIONS

A. The micropile contractor shall be fully experienced in all aspects of micropile design and construction, and shall furnish all necessary equipment, materials, skilled labor, and supervision to carry out the Contract.

A-B. The micropile contractor shall have a minimum of 5 years of successful experience on 10 projects of micropile design and installation in karstic limestone and dolomite bedrock with variable resistance to weathering resulting in cracks, voids, and irregular surfaces, creating the karstic topography.

B. Pre-qualified micropile contractors are listed below:

1. Nicholson Construction Company
   12 McClane Street
   Cuddy, PA 15031
   Contact: Dino Kartofilis
   Phone: (412) 221-4500

2. Hayward Baker, Inc.
   515 Nine North Court
   Alpharetta, GA 30004-3961
   Contact: John R. Wolosick
   Phone: (770) 442-1804

1.03 DEFINITIONS

A. Admixture: Substance added to the grout to either control bleed and/or shrinkage, improve flowability, reduce water content, retard setting time, or resist washout.
B. Alignment Load (AL): A nominal load applied to a micropile during testing to keep the testing equipment correctly positioned.

C. Apparent Free Micropile Length: The length of pile which is not apparently bonded to the surrounding ground, as calculated from the elastic load extension data during testing.

D. Bond Length: The length of the micropile that is bonded to the ground and which is conceptually used to transfer the applied axial loads to the surrounding soil or rock.

E. Casing: Steel pipe introduced during the drilling process to temporarily stabilize the drill hole.

F. Centralizer: A device to centrally locate the reinforcing element(s) within the borehole.

G. Contractor: The person/firm responsible for performing the micropile work.

H. Core Steel: Reinforcing bars or pipes used to strengthen or stiffen the pile, excluding any left-in drill casing.

I. Coupler: The means by which the load can be transmitted from one partial length of reinforcement to another.

J. Creep Movement: The movement that occurs during the creep test of a micropile under a constant load.


L. Duplex Drilling: A drilling system involving the simultaneous advancement of (inner) drill rod and (outer) drill casing. Flush from the inner drill rod is permitted to exit the borehole via the annulus between rod and casing.

M. Elastic Movement: The recoverable movement measured during a micropile test.

N. Free (unbonded) Length: The designed length of the micropile that is not bonded to the surrounding ground or grout during testing.

O. Micropile: A small diameter, bored, cast-in-place pile, in which most of the applied load is resisted by the steel reinforcement.

P. Post Grouting: The injection of additional grout into the bond length of a micropile after the Primary grout has set. Also known as regrouting or secondary grouting.

Q. PPE: Personal Protective Equipment.
R. Primary Grout: Portland cement based grout that is injected into the micropile hole prior to or after the installation of the reinforcement to provide the load transfer to the surrounding ground along the micropile and affords a degree of corrosion protection in compression.

S. Reinforcement: The steel component of the micropile which accepts and/or resists applied loadings.

T. Residual Movement: The non-elastic (non-recoverable) movement of a micropile measured during load testing.

U. Safety Factor: The ratio of the ultimate capacity to the working load used for the design of any component or interface.

V. Single Tube Drilling: The advancement of a steel casing through overburden usually aided by water flushing through the casing. Also known as “external flush.” The fluid may or may not return to the surface around the casing, depending largely on the permeability of the overburden.

W. Test Load (TL): The maximum load to which the micropile is subjected during testing.

X. Tremie Grouting: The placing of grout in a borehole via a grout pipe introduced to the bottom of the hole. During grouting, the exit of the pipe is kept at least 10 feet below the level of the grout in the hole.

Y. Type A-D: Classification of micropiles based on method and pressure of grouting (see FHWA, 1997).


1.04 GROUND CONDITIONS

A. The subsurface conditions at the site are described in detail in the geotechnical data reports by GEOServices, LLC titled, “Report of Limited Geotechnical Exploration, Outfall 200 Mercury Treatment Facility, Y-12 National Security Complex” dated March 4, 2016 and Strata-G, LLC titled, “Geotechnical Report for Data Gap Characterization at the Proposed Outfall 200 Mercury Treatment Facility Site”, dated January 4, 2017. In general, the subsurface conditions in the area consist of clayey fill soils overlaying fine-grained alluvial soils. The alluvial soils are underlain by residuum soils before encountering bedrock.

B. The fill soils generally included clay fill or crushed aggregate used as granular fill. The clay fill was observe to be brown to grey lean clay with varying amounts of sand and limestone fragments. SPT N-values within the layer identified the layer to be firm to very stiff. Thickness of this layer ranged from
5 to 11 feet at the Headworks, and 6 to 20 feet at the Mercury Treatment Facility.

C. Alluvial soils consist of fine-grained silts and clays, with thin layers of coarse grained material and the occasional cobble or boulder present. SPT N-values indicate that the alluvial soils are firm to very stiff. The alluvial layer was observed to range in thickness from 5 to 20 feet.

D. The residuum soils are described as light brown to orange brown lean to fat clay with varying amounts of dolomite and limestone fragments. SPT N-values within the residuum indicate the soils are firm to very stiff. This layer was generally less than 10 feet thick when encountered. No cobbles or boulders were reported to be encountered within this layer.

E. The bedrock is described as dark gray to gray karstic limestone and dolomite. Laboratory testing performed on rock cores of the limestone indicate the unconfined compressive strength ranged from 8.5 to 20.6 kips per square inch (ksi). Retrieved rock cores indicate the rock is slightly to heavily fractured, with fresh to completely weathered zones. The top of rock varied across each site. At the Headworks, top of rock ranged from 915 feet to 931 feet in elevation, with an average top of rock elevation of 922 feet. At the Mercury Treatment Facility, top of rock ranged from 900 feet to 911 feet, with an average top of rock elevation of 909 feet. The variation in top of rock indicates pinnacled conditions in the bedrock.

F. Numerous voids were encountered within the limestone. Voids ranged in thickness of 2 inches to 10 feet. The soluble limestone varies in resistance to weathering, resulting in cracks, voids, and irregular surfaces, creating karstic topography.

1.05 REFERENCES

A. The following is a list of standards referenced in this section:

1. ASTM International (ASTM):

   a. SPEC 5CT, Specification for Casing and Tubing.
1.06 SUBMITTALS

A. Action Submittals:

1. The Contractor shall submit a detailed description of the construction procedures proposed for use to the Engineer for review. This shall include a schedule of major equipment resources.

2. The Contractor shall submit the micropile design calculations signed and sealed by an engineer registered in the State of Tennessee.

3. The Contractor shall submit certified mill test reports, properly marked, for the reinforcing steel, as the materials are delivered, to the Engineer for record purposes. The ultimate strength, yield strength, elongation, and composition shall be included. For steel pipe used as permanent casing, or core steel, the Contractor shall submit a minimum of two representative coupon tests or mill certifications (if available) on each load delivered to the Project.

4. The Contractor shall submit the grout mix designs, including details of all materials to be incorporated, and the procedure for mixing and placing the grout to the Engineer for approval. This submittal shall include certified test results verifying the acceptability of the proposed mix designs.

5. The Contractor shall submit detailed plans for the method proposed for testing the micropiles to the Engineer for review and acceptance prior to beginning load tests. This shall include all necessary Drawings and details to clearly describe the test method and equipment proposed.

6. The Contractor shall submit to the Engineer calibration reports for each test jack, pressure gauge, and master pressure gauge to be used. The calibration tests shall have been performed by an independent testing laboratory and tests shall have been performed within 1 year of the date submitted. Testing shall not commence until the Engineer has approved the jack, pressure gauge and master pressure gauge calculations.

7. Load testing results.

PART 2 PRODUCTS

2.01 WATER

A. Water for mixing grout shall be potable, clean and free from substances which may be in any way deleterious to grout or steel. If water is not potable, it shall be tested in accordance with AASHTO T26 for acceptability.

2.02 GROUT

A. The Contractor shall provide a stable, homogenous, neat cement grout or a sand cement grout with a minimum 28-day unconfined compressive strength of 5,000 psi. The grout shall not contain lumps or any other evidence of poor or incomplete mixing. Admixtures, if used, shall be mixed in accordance with manufacturer’s recommendations.
2.03 ADMIXTURES

A. Admixtures shall conform to the requirements of ASTM C494 (AASHTO M194). Admixtures which control bleed, improve flowability, reduce water content, and retard set may be used in the grout subject to the review and acceptance of the Engineer. Expansive admixtures shall only be added to the grout used for filling sealed encapsulations. Admixtures shall be compatible with the grout and mixed in accordance with the manufacturer’s recommendations. Their use will only be permitted after appropriate field tests on fluid and set grout properties. Admixtures with chlorides shall not be permitted.

2.04 CEMENT

A. All cement shall be Portland cement conforming to ASTM C150 (AASHTO M85) Type I, II, III, or V, and shall be the product of one manufacturer. If the brand or type of cement is changed during a project, additional grout mix tests shall be conducted to ensure consistency of quality and performance in situ.

2.05 FILLERS

A. Inert fillers such as sand may be used in the grout in special situations (e.g., presence of large voids in the ground, when grout take and travel are to be limited) as approved by the Engineer.

2.06 BAR REINFORCEMENT

A. Reinforcing steel, if used, shall be deformed bars meeting the requirements of ASTM A722, Type II, with minimum yield strength of 80 percent of the ultimate strength of 150 ksi.

B. For cases of tensile loading, bar couplers, if required, shall develop the ultimate tensile stress of the bar, without any evidence of failure. For compressive loading, the coupler shall be compatible with efficient load transfer and overall reinforcement performance requirements.

2.07 PIPE/CASING

A. Pipe/casing shall meet the tensile requirements of API-N80, with a minimum yield stress of 80 ksi.

B. Pipe/casing shall have minimum length as shown in the Drawings without field welding.

C. Casing sections shall be joined by manufactured thread joints constructed to develop at least the required compressive, tensile, and/or bending structural strength used in the micropile design.
2.08 CENTRALIZERS

A. Centralizers, if required, shall be fabricated from plastic, steel, or material that is non-detrimental to the reinforcing steel. Wood shall not be used.

PART 3 EXECUTION

3.01 INSTALLATION

A. The micropile installation technique shall be such that it is consistent with the geotechnical, logistical, environmental, and load carrying conditions of the Project. The micropile contractor shall select the drilling method and the grouting procedures used for the installation of the micropiles, subject to the approval of the Engineer.

B. The drilling equipment and methods shall be suitable for drilling through the conditions to be encountered, with minimal disturbance to these conditions or any overlying or adjacent structure or service. The borehole must be open to the defined nominal diameter, full length, prior to placing grout and reinforcement.

C. The drilling equipment shall be configured to collect all cuttings returned to surface into containers for inspection.

D. Centralizers shall be provided at 10-foot maximum vertical spacing on central reinforcement. The uppermost centralizer shall be located a maximum of 5 feet from the top of the micropile. Centralizers shall permit the free flow of grout without misalignment of the reinforcement.

E. The central reinforcement steel with centralizers shall be lowered into the stabilized drill holes to the desired depth without difficulty. Partially inserted reinforcing bars shall not be driven or forced into the hole in order to eliminate interconnection or damage to piles in which the grout has not achieved final set.

3.02 GROUTING

A. The Contractor shall provide systems and equipment to measure the grout quality, quantity, and pumping pressure during the grouting operations. This information is to be measured and recorded by the Contractor.

B. After drilling, the hole shall be flushed with water and/or air to remove drill cuttings and/or other loose debris.

C. The pump shall be equipped with a pressure gauge to monitor grout pressures. The pressure gauge shall be capable of measuring pressures of at least 150 psi or twice the actual grout pressures used by the Contractor, whichever is greater. The grouting equipment shall be sized to enable the grout to be
pumped in one continuous operation. The grout should be kept in constant agitation prior to pumping.

D. The grout shall be injected from the lowest point of the drill hole (by tremie methods) until clean, pure grout flows from the top of the micropile. The tremie grout may be pumped through grout tubes, hollow stem augers, or drill rods. Subsequent to tremie grouting, all grouting operations associated with, for example, extraction of drill casing and pressure grouting, must ensure complete continuity of the grout column. The use of compressed air to directly pressurize the fluid grout is not permissible. The grout pressures and grout takes shall be controlled to prevent excessive heave in cohesive soils or fracturing of soil or rock formations. The entire pile shall be grouted to the design cut-off level.

E. Upon completion of grouting, the grout tube may remain in the hole, but it shall be filled with grout. Grout tubes shall be installed prior to the tremie grouting.

F. Grout within the micropiles shall be allowed to attain the minimum design strength prior to being loaded.

G. If the Contractor uses a post-grouting system, all relevant details including grouting pressure, volume, location and mix design, shall be submitted as part of the installation records.

3.03 PILE SPLICES

A. Pile splices shall be constructed to develop the required design strength of the pile section.

B. Lengths of casing and reinforcing steel to be spliced shall be secured in proper alignments and in such a manner that no eccentricity between the axes of the two lengths spliced or angle between them results.

3.04 QUALITY CONTROL

A. Installation Records:

1. Pile drilling duration and observations (e.g., flush return).
2. Information on soil and rock encountered, including description of strata, water, voids, void infilling, etc.
3. Approximate final tip elevation.
6. Description of unusual installation behavior, conditions.
7. Any deviations from the intended parameters.
8. Grout pressures attained, where applicable.
11. Micropile test records, analysis, and details.

3.05 TOLERANCES

A. Centerline of piling shall not be more than 6 inches from indicated plan location.
B. Pile-hole alignment shall be within 2 percent of design alignment.
C. Centerline of core reinforcement shall not be more than 3/4 inch from centerline of piling.

3.06 PILE LOAD TESTING

A. Verification pile load tests shall be performed to verify the adequacy of the design of the pile system, and the proposed construction procedures prior to installation of production piles. The number of piles, their location, and the type(s) of loading direction are shown on the Drawings.
B. The Contractor shall submit for review and acceptance the proposed micropile load testing procedure. This micropile verification load testing proposal shall be in general conformance with ASTM D1143, and shall indicate the minimum following information:

1. Type and accuracy of apparatus for measuring load.
2. Type and accuracy of apparatus for applying load.
3. Type and accuracy of apparatus for measuring the pile deformation.
4. Type and capacity of reaction load system, including sealed design Drawings.
5. Hydraulic jack calibration report.
C. The drilling and grouting methods, casing and other reinforcement details, and depth of embedment for the test pile shall be as assumed and determined by the micropile design calculations.
D. The design load (DL) of the piles to be tested will be as shown on the Drawings. The tested micropiles shall be loaded to 250 percent of the compression design load (i.e., 2.5 DL) during verification testing. The jack shall be positioned at the beginning of the test such that the unloading and repositioning of the jack during the test will not be required. An Alignment Load (AL), if required, may be applied to the pile prior to setting the movement recording devices. This Alignment Load shall be no more than 10 percent of Design Load (i.e., 0.1 DL). Dial gauges shall be zeroed after applying the AL.
E. Verification load tests shall be made by loading the micropile in the following load increments:

<table>
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F. Measurement of pile movement shall be obtained at each increment. The load hold period shall start as soon as the test load is applied and the pile movement, with respect to a fixed reference, shall be measured and recorded at 1 minute, 2, 3, 4, and 5, and 10 minutes (load cycle maxima only). If the creep rate is greater than defined, the test load shall be held for an additional 50 minutes. The total movement between 6 and 60 minutes shall be recorded and compared to the Creep Rate Criterion.

3.07 PILE LOAD TEST ACCEPTANCE

A. Acceptance Criteria for Verification Tests:
   1. The pile shall sustain the compression design load (1.0 DL) with no more than 0.4 inches of total vertical movement at the top of the pile. If an Alignment Load is used, then the allowable movement shall be reduced by multiplying by a factor of (DL-AL)/DL to conservatively account for the movement in reaching AL.
   2. Test piles shall have a Creep Rate at the end of the 1.3 DL increment which is not greater than 0.040 inch per log cycle of time from 1 to 10 minutes or 0.080 inch per log cycle of time from 6 to 60 minutes and has a linear or decreasing creep rate.

B. Verification Tests shall satisfy the previous Acceptance Criteria as well as the following additional criterion:
   1. Failure does not occur at the 2.5 DL maximum compression load. Failure is defined as a slope of the load versus deflection (at end of increment) curve exceeding 0.025 inches per kip.

C. If a micropile fails to meet the acceptance criteria for a verification test, the Contractor shall modify the design and/or the construction procedure. The modifications may include the installation method, increasing the bond length, or changing the type or size of the micropile. Any failed verification test piles shall be cutoff a minimum of 12 inches below the building subgrade elevation.

3.08 PILE LOAD TEST REPORTING

A. The Contractor shall provide the Engineer with the following information within 7 working days after completion of the load testing:
1. Pile Installation Records for reaction and test piles.
2. Dial gauge readings and other survey data used for monitoring pile head movement for each load applied as well as for each increment during hold periods of individual loads.
3. Strain gage readings at all the same increments as the dial gauge readings.
4. Jack pressure and load cell readings at all the loading increments.
5. Reduction of the data showing plots of pile head movement versus applied load as well as plots of the load at each strain gauge for each load increment.
6. Estimate of the ultimate bond stress or ultimate load transfer between the micropile and the ground.
7. Suggested modifications to the installation procedure for better constructability and to maximize ultimate pile capacity.

END OF SECTION