Willoughby-Eastlake WPCC Watermain Improvements

Geotechnical Subsurface Investigation

City of Willoughby

February 5, 2024

CT Project No. 23004301

CT Consultants, Inc.

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Mentor, OH 44060
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February 5, 2024

CT Project No. 23004301

City of Willoughby
1 East Spaulding Street
Willoughby, OH 44094

Geotechnical Subsurface Investigation
Willoughby-Eastlake WPCC Watermain Improvements
Eastlake, Ohio

Following is the report of the geotechnical subsurface investigation performed by CT Consultants, Inc. (CT) for the referenced project. This study was performed for the City of Willoughby in support of design services for the Willoughby-Eastlake WPCC Watermain Improvements Project.

This report contains the results of our study, our engineering interpretation of the results with respect to the project characteristics, design and construction recommendations for roadway reconstruction, as well as our recommendations for pavements and utility support.

Soil samples collected during this investigation will be stored at our laboratory for 90 days from the date of this report. The samples will be discarded after this time unless you request that they be saved or delivered to you.

Should you have any questions regarding this report or require additional information, please contact our office.

Sincerely,

CT Consultants, Inc.

Imad El Hajjar, EI
Geotechnical Project Manager

Curtis E. Roupe, P.E.
Vice President

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GEOTECHNICAL SUBSURFACE INVESTIGATION
WILLOUGHBY-EASTLAKE WPCC WATERMAIN IMPROVEMENTS
EASTLAKE, OHIO

FOR

CITY OF WILLOUGHBY
1 EAST SPAULDING STREET
WILLOUGHBY, OH 44094

SUBMITTED

FEBRUARY 5, 2024
CT PROJECT NO. 23004301

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1.0 INTRODUCTION

This geotechnical subsurface investigation report has been prepared for Willoughby-Eastlake WPCC Watermain project in Eastlake, Ohio. We understand that the improvements are planned generally along Hartford Rd through to the Willoughby Water Pollution Control Center (WPCC). The general project area is shown on the Site Location Map (Plate 1.0).

This report summarizes our understanding of the proposed construction, describes the investigative and testing procedures, presents the findings, discusses our evaluations and conclusions, and provides our design and construction recommendations for pavements and utility support.

The purpose of this investigation was to evaluate the subsurface conditions and laboratory data relative to the design and construction of pavements at the referenced site. This investigation included four (4) test borings, two of which having a monitoring well, field and laboratory soil and rock testing, and a geotechnical engineering evaluation of the test results. This report includes:

- A description of the subsurface soil, bedrock and groundwater conditions encountered in the borings.
- Design recommendations related to the pavements and utility support.
- Recommendations concerning soil- and groundwater-related construction procedures such as site preparation, earthwork, pavement subgrade preparation, and related field testing.

This investigation did not include an environmental assessment of the subsurface materials at this site.

2.0 INVESTIGATIVE PROCEDURES

This subsurface investigation included four (4) test borings drilled by CT on October 23, 2023. The test borings were located in the field by CT in accordance with a proposed boring location plan submitted with the proposal of this study. The approximate locations of the borings are shown on the Test Boring Location Plan (Plate 2.0).

The test borings were performed in general accordance with geotechnical investigative procedures outlined in ASTM Standard D 1452. The test borings performed during this investigation were drilled with a truck-mounted drill rig with utilizing 3¼-inch diameter hollow-stem augers. Ground Surface Elevations were depicted using field survey data and are reported to the nearest foot. Borings B-1 through B-3 were terminated to a depth of 15 feet below existing grades and Boring B-4 was terminated to a depth of 20 feet below existing grade.

During auger advancement, soil samples were collected at 2½-foot intervals. Split-spoon (SS) samples were obtained by the Standard Penetration Test (SPT) Method (ASTM D 1586), which consists of driving a 2-inch outside diameter split-barrel sampler into the soil with a 140-pound weight falling freely through a distance of 30 inches. The sampler was driven in three successive 6-inch increments with the number of blows per increment being recorded. The sum of the number of blows required to advance the sampler the second and third 6-inch increments is termed the Standard Penetration Resistance (N-value) and is presented on the Logs of Test Borings attached to this report. Additionally, long-term groundwater monitoring wells were installed in Borings B-2 and B-4 and are classified as MW-1 and MW-2.

The samples were sealed in jars and transported to our laboratory for further classification and testing. The pavement and soil conditions encountered in the pavement cores and test borings are presented in the Logs of Test Borings, along with information related to sample data, SPT results (and equivalent SPT results for the hand auger borings), water conditions observed in the borings, and laboratory test data. It should be noted that these logs have been prepared on the basis of soils laboratory classification and testing as well as field logs of the encountered pavements and soils.

All of the recovered samples of the subsoils were visually or manually classified in accordance with the Ohio Department of Transportation (ODOT) soil classification system and were tested in our laboratory for moisture content (ASTM D 2216). Unconfined compressive strength estimates were obtained for the intact cohesive samples using a calibrated hand penetrometer. A particle size analysis (ASTM D 6913 and D 7928) and an Atterberg limits test (ASTM D 4318) were performed on representative samples from Boring B-1 (SS-2) and B-3 (SS-4) to determine soil classification and soil index properties. The test results are presented on the Logs of Test Borings, Tabulation of Test Data sheets, and Grain Size Distribution sheet attached to this report.

Soil conditions encountered in the test borings are presented in the Logs of Test Borings, along with information related to sample data, SPT results, water conditions observed in the borings, and laboratory test data. It should be noted that these logs have been prepared on the basis of laboratory classification and testing as well as field logs of the encountered soils.

Experience indicates that the actual subsoil conditions at a site could vary from those generalized on the basis of pavement cores and test borings made at specific locations. Therefore, it is essential that a geotechnical engineer be retained to provide soil engineering services during the site preparation, excavation, and foundation phases of the proposed project. This is to observe compliance with the design concepts, specifications, and recommendations, and to allow design changes in the event subsurface conditions differ from those anticipated prior to the start of construction.

3.0 PROPOSED CONSTRUCTION

The proposed project consists of pavement and utility support design in Eastlake, Ohio. The proposed improvements cover approximately 1,300 lineal feet, primarily along Hartford Rd, with an additional segment turning west to establish a connection to the Willoughby Water Pollution Control Center (WPCC). We also understand that these underground utilities will be installed using an open-cut excavation technique with inverts on the order of 5 to 6 feet.

Pavements are anticipated to consist of flexible (asphalt) sections. Final design grades are assumed to approximate existing roadway grades. Traffic loads and volumes were not available at the time of preparing this proposal.

4.0 GENERAL SITE AND SUBSURFACE CONDITIONS

4.1 General Site Conditions

During our investigation, the project area encompassed residential properties, wooded areas, and landscaped areas. Ground surface elevations at the boring locations varied between Elevations 581 to 584 feet. The surface material encountered in all borings consisted of topsoil, approximately 6 to 8 inches thick.

Granular fill materials were encountered in Boring B-2 underlying the surface material and extended to 12 feet below existing grades. The granular fill consisted of coarse and fine sand (A-3a) mixed with varying portions of gravel, asphalt fragments, clay, and silt. SPT N-values ranged from 2 to 12 blows per foot (bpf) were recorded and are indicative of loose to medium dense consistency. Moisture contents ranged from 13 to 39 percent.

4.2 General Site Geology

Published geologic maps from the Ohio Department of Natural Resources (ODNR) indicate that the project site is located within the glaciated portion of Ohio. The geologic deposits covering the site consists of Holocene-age Alluvial deposits (a) consisting of alluvium and alluvial terraces, deposited in present and former floodplains, ranges from silty clay in areas of fine-grained deposits to coarse sand, gravel, or cobbles in areas of shallow bedrock.

Bedrock in the project area is broadly mapped on the "Geologic Map of Ohio" as Upper Devonian aged Shale of the Ohio Shale formations. The borings performed for this exploration did not encounter bedrock but can be encountered at elevation approximate Elevs. 550.

4.3 General Soil Conditions

Based on the results of our field and laboratory tests, the subsoils encountered underlying the topsoil and fill materials was characterized by a stratified stratum comprising interbedded layers of cohesive and granular alluvial soils. This stratified stratum overlay a distinct stratum of very stiff to hard cohesive till soils.

Stratum I consisted of predominantly granular and cohesive alluvial encountered underlying the surface material in Borings B-1, B-3 and B-4. Stratum I was encountered to depths of approximately 11 to 15 feet (Elev. 571± to 568±) below existing grades. Boring B-1 was terminated with8int his stratum at 15 feet.

The cohesive alluvial deposits consisted predominantly of **very soft to soft** silt and clay (ODOT A-6a) mixed with varying amounts of sand and gravel. SPT N values generally ranged from 0 to 4 blows per foot (bpf). Isolated zones exhibiting very stiff (SPT N-value = 16) and medium stiff (SPT N-value = 6) consistencies were encountered in Boring B-3 from 0.7 to 3 feet (Elev. 581± to 579±) and in Boring B-4 from 0.5 to 3½ feet (Elev. 578± to 575±) below existing grades. Unconfined compressive strengths ranged from 1,000 pounds per square foot (psf) to greater than 9,000 psf (maximum reading obtainable using a hand penetrometer). Moisture contents ranged from 19 to 40 percent.

The granular alluvial deposits consisted predominantly of loose to medium dense coarse and fine sand (ODOT A-3a) mixed with varying amounts of silt and clay. SPT N value range of 5 to 28 bpf. An isolated zone exhibiting **very loose** consistency (SPT N-value = 3) was encountered within Boring B-3 from 3 to 6 feet (Elev. 579± to 576±) Moisture contents ranged from 15 to 27percent.

Stratum II consisted of predominantly very stiff to hard native cohesive soils encountered in all the borings except Boring B-1. Stratum II was encountered underlying the fill materials in Borings B-2 and underlying stratum I in Borings B-3 and B-4. These borings were terminated within this stratum at 15 to 20 feet (Elev. 566± to 559±). These cohesive soils consisted of silt and clay (A-6a) mixed with varying amounts of sand and gravel. SPT N-values ranged from 19 to 50 blows per foot (bpf). Unconfined compressive strengths ranged from 6,000 to greater than 9,000 psf. Moisture contents ranged from 10 to 12 percent.

Additional descriptions of the stratigraphy encountered in the borings are presented on the Logs of Test Borings.

4.4 Groundwater Conditions

Groundwater was initially encountered both during and upon completion of the drilling operations at the same depths. Specifically, it was observed at a depth of 8 feet (Elev. 576±) in Boring B-1, at 4 feet (Elev. 577±) in Boring B-2, and at 9 feet in Boring B-4 (Elev. 575±). It is noteworthy that all boreholes were drilled and backfilled within the same day, and the establishment of stabilized water levels is improbable within this limited time frame. Subsequent to the drilling, long-term groundwater monitoring wells, specifically piezometers, were installed in Borings B-2 and B-4. Stabilized groundwater levels were observed during four distinct instances spanning from October 2022 to January 2023.

In Boring B-2, groundwater levels fluctuated within the range of approximately 1 to 6½ feet below existing grades (Elev. 580.1± to 574.6±). Similarly, in Boring B-4, groundwater levels varied from approximately 1½ to 7½ feet below existing grades (Elev. 582.4± to 576.7±). It is important to note that these observations were made after the completion of drilling activities and provided insights into the groundwater conditions over the specified period. The report incorporates a concise overview of the measured water readings, complemented by a hydrograph, which is provided in detail within Appendix E.

Based on the soil characteristics and groundwater conditions encountered in the borings, it is our opinion that the "normal" long-term groundwater table will be generally encountered at depths ranging from 1 to 4 feet below existing grades However, groundwater elevations can fluctuate with seasonal and climatic influences. In particular, "perched" groundwater may be encountered within, the pavement base materials, fill materials and granular soils. Therefore, the groundwater conditions may vary at different times of the year from those encountered during this exploration.

The contractor should be mindful of the likelihood of water percolation through the drain-free granular soils, specifically consisting of sand at the site. This percolation poses the risk of generating an unstable bottom within the excavated trenches which are expected to extend 5 to 6 feet below existing grades.

5.0 DESIGN RECOMMENDATIONS

The following conclusions and recommendations are based on our understanding of the proposed construction and on the data obtained during the field investigation. If the project information or location as outlined is incorrect or should change significantly, a review of these recommendations should be made by CT. These recommendations are subject to the satisfactory completion of the recommended site and subgrade preparation and fill placement operations described in Section 6.0, "Construction Recommendations".

5.1 Pipe Support

We understand that the underground utility improvements for this project will include the installation of a new watermain line. Per current stage of design, the watermain pipes will consist of a 8 inch-diameter PVC pipes with inverts of 5 to 6 feet below existing grades. We also understand that these underground utilities will be installed using an open-cut excavation technique.

Based on our project understanding, the proposed watermain lines are anticipated to predominantly be supported on the present alluvial cohesive and granular soils. All of these subsoils are considered generally suitable for support of the proposed water line. It is important to highlight that the Stratum I cohesive soils may exhibit **soft to very soft** consistencies at pipe invert elevations. Similarly, the Stratum I granular soils may exhibit **loose to very loose** compactness at pipe invert elevations. According to the findings from Boring B-2, there is a possibility of encountering loose granular fill at the proposed invert elevation. **The fill materials, loose to very loose granular soils and soft to very soft cohesive soils, may necessitate over-excavation, as elaborated upon in the following discussion.**

Where poor existing fill conditions, such as encountered in Boring B-2, are present at the pipe invert elevation, they should be over-excavated and replaced with new engineered fill. **Where soft to very soft/loose to very soils or other unsuitable soils are encountered at the invert elevations, they should be undercut as follows. As a minimum, unsuitable soils should be undercut to a depth of one pipe diameter below invert, or 12 inches, whichever is greater. The undercut zones should be replaced** with engineered fill, properly placed and compacted as outlined in Section 5.4 of this report prior to placement of the bedding and haunching material.

In any case, It will be critical to maintain a sufficient thickness of bedding and haunching to provide adequate support and protection for the underground utilities. Bedding and haunching materials should conform to pipe manufacturer specifications and recommendations. In the absence of specific criteria for bedding and haunching materials, we recommend the use of dense graded aggregate meeting Ohio Department of Transportation (ODOT) Item 304 specifications, or alternately, ODOT 703 coarse aggregate meeting No. 57 or No. 6 gradations.

We recommend that the trench excavation along the proposed underground utilities invert be inspected by a CT geotechnical engineer or qualified representative. This is to confirm that the encountered subsoils are consistent with those encountered in the test borings and that the exposed materials are capable of supporting the proposed underground utilities.

5.2 Open-Cut Installation Methods

The sides of the temporary excavations for underground utilities installation should be adequately sloped to provide stable sides and safe working conditions. If the proposed underground utilities alignment requires working in close proximity to existing underground utilities or other structures, this may not be possible. Where sloped excavations will not be used, the excavation must be properly braced against lateral movements. In any case, applicable OSHA safety standards must be followed. It is the responsibility of the installation contractor to develop appropriate installation methods and equipment prior to commencement of work, and to obtain the services of a geotechnical engineer to design or approve sloped or benched excavations and/or lateral bracing systems as required by OSHA criteria. While not anticipated, any excavations greater than 20 feet deep should be evaluated by a registered professional engineer.

If the excavation is to be performed with sloped banks, adequate stable slopes must be provided. Based on the borings drilled for this investigation, soils encountered in trench excavations may include one or more of the following:

- OSHA Type A soils (cohesive soils with unconfined compressive strengths of 3,000 pounds per square foot (psf) or greater),
- OSHA Type B soils (cohesive soils with unconfined compressive strengths greater than 1,000 psf but less than 3,000 psf), and
- OSHA Type C soils (granular soils and fill materials).

For temporary excavations in Type A, B and C soils, side slopes must be no steeper than ¾ horizontal to 1 vertical (¾H:1V), 1H:1V, and 1½H:1V, respectively. For situations where a higher strength soil is underlain by a lower strength soil and the excavation extends into the lower strength soil (including excavation through cohesive soils that are underlain by granular soils or bedrock), the slope of the entire excavation is governed by that required for the lower strength soil. In all cases, flatter slopes may be required if lower strength soils or adverse seepage conditions are encountered during construction.

For permanent excavations and slopes, we recommend that grades be no steeper than 3H:1V without a more extensive geotechnical evaluation of the proposed construction plans and site conditions.

5.3 Braced Excavations

Braced excavations constructed using soldier piles with wood lagging or sheetpiling may be considered in areas of restricted access or proximity to structures. The method employed will depend on the construction sequencing, required access size and area, and economic considerations.

All braced excavations should be designed to resist lateral earth pressures. Based on the encountered predominantly cohesive soil profile, a total (wet) unit weight of 130 pounds per cubic foot (pcf) should be utilized for developing lateral soil pressures. A coefficient of active lateral earth pressure (k_a) of 0.35 may be used for analysis of cantilevered sheetpiling or similar systems that allow slight movement or yielding in the soil. However, higher lateral earth pressures may be associated with braced excavations that restrain movement and prevent development of "active" soil conditions. The actual design of the shaft or braced excavation will depend on the size and configuration of the opening, as well as the bracing system as selected by the contractor.

Additionally, lateral loading due to hydrostatic pressures below the design groundwater depth should be included in design of below-grade walls. Depending on the design methodology, total lateral pressures would be the resultant of the hydrostatic pressures in combination with submerged (or “effective”) unit weights of the soil. An effective unit weight of 70 pcf should be used for lateral earth pressure design below the design groundwater depth.

It should be noted that the above k-parameters may be used for general design of excavation support systems associated with the project. However, certain types of braced excavations may account for method-specific earth pressure distributions, for which the above parameters should be reviewed and utilized in the proper context of the design method/system.

A passive earth pressure coefficient (k_p) of 3.0 may be utilized for the portion of temporary walls (e.g., sheet pile walls) that is below the excavation bottom. In the case of permanent structures, a k_p value of 3.0 should only be utilized below the frost depth of 3½ feet below toe grades. It should be noted that some wall movement or horizontal displacement is typically needed to mobilize the full passive pressure of the soil.

It should also be noted that the earth pressure coefficients in the preceding paragraphs are based on a level backfill condition behind the retaining wall. In areas where appreciable sloping materials are present behind the top of the wall, surcharge loading or equivalent higher earth pressure coefficients should be evaluated, based on the sloping material, backfill slope, and proximity to the wall. In general, 50 percent of the vertical surcharge load should be used for lateral loading in the design of the wall.

5.4 Construction (General)

Construction traffic and excavated material stockpiles should be kept away from the excavation a minimum distance equal to the full depth of the excavation. In all cases, pertinent OSHA requirements must be followed, and adequate protection for workers must be provided.

Where existing buildings or structures, including underground utilities, are located within a distance from the excavation equal to approximately twice its depth, an adequate system of sheet piling and/or lateral bracing may be required to prevent lateral movements that could cause settlement. Any retaining system proposed by the contractor should be reviewed by a registered professional engineer prior to approval for installation and use.

It is also suggested that a condition survey (i.e., preconstruction documentation) of any existing structures and transportation infrastructure located in the vicinity of the proposed underground utilities alignment be completed. For general below-grade underground utilities installation, we recommend the condition survey extend a distance from the proposed installation extents equal to the depth of the excavation, but not less than 50 feet. The condition survey should be extended to 100 feet from the underground utilities alignment in areas where driving of sheetpiling or H-piling, or compaction of granular material will be performed for braced excavations. The condition survey should identify existing cracks and other forms of distress to the structures before the start of construction operations. This procedure will be helpful to evaluate possible effects the construction operations may have on nearby structures and to mitigate potential disputes with property owners.

The construction excavation should not be left open any longer than necessary. As soon as a section of the underground utilities is completed, the area should be backfilled to final grade. After the specified bedding material has been provided below and around the pipe, backfill material placed above the pipes should be compacted sufficiently to achieve stable backfill and avoid undesirable settlements.

Where underground utilities will be installed beneath pavement areas, future structure areas, or future pavement areas, the backfill material should be placed in uniform layers not more than 8 inches thick and compacted to 100 percent of the maximum dry density as determined by ASTM D 698 (Standard Proctor). Backfill

placed in pavement areas should consist of dense-graded aggregate, such as ODOT Item 304 material. In order to achieve the desired compaction, the backfill material should be within 3 percent of the optimum moisture content. Alternatively, flowable controlled-density fill could be used to backfill the excavated trenches.

We emphasize the need for placing the fill in lifts and compacting each lift to the specified density, especially where the trench will be directly beneath roadway pavement. The installation contractor should not be allowed to push or end-dump several feet of backfill into the trench as a single layer or lift, because the lower portion of a thick lift will not achieve proper densification from compaction equipment operating at the surface of that lift. If backfill is not properly placed and compacted, undesirable trench backfill settlement may occur.

if high groundwater levels are present at the time of construction, vibratory compaction may be detrimental to the prepared subgrade. Therefore, compaction under "static" operation would be required. If issues with controlling groundwater are encountered, it may be necessary to augment sump-and-pump operations with one or more wellpoints to facilitate construction dewatering. In the event excessive seepage is encountered during construction, CT may be notified to evaluate whether other dewatering methods are required.

It is recommended that all earthwork and site preparation activities be conducted under adequate specifications and properly monitored in the field by a CT geotechnical engineer or qualified representative.

5.5 Construction Dewatering

Based on the soil characteristics and groundwater conditions encountered in the borings, it is our opinion that the static, long-term groundwater table will be generally encountered at or above the planned excavation depth based on our observations from the groundwater monitoring wells. **We must stress that excavation along the whole section of the proposed watermain alignment might experience unstable trench bottom. To prevent this situation, a sufficient dewatering system must be designed and implemented in the subject areas**. The water level must be lowered at least to the depth of two feet below the trench bottom to allow workability. Sometimes, due to a large water influx from rain or snow (depending on the permeability characteristics of the soils) this operation might be very difficult. If that is the case, a different method of trench bottom stabilization must be considered such as undercutting and replacement with 12-inch or more (depends of the severity of the situation) thick layer of coarse aggregate (#1's and #2's) wrapped in Geofabric or Geogrid (full overlap on the top). The depth of the undercut will be determined to allow installation of sufficient thickness of the coarse stone aggregate (pillow) and placement of the designed pipe stone bedding.

However, groundwater elevations can fluctuate with seasonal and climatic influences. In particular, "perched" groundwater may be encountered within, the pavement base materials, fill materials as well as the granular soils.. Therefore, the groundwater conditions may vary at different times of the year from those encountered during this exploration.

If excavations below the groundwater table are required (e.g., site utilities, foundations, etc.), or if seasonally elevated groundwater conditions are prevalent at the time of construction, diligent dewatering using point wells will be required for groundwater management during construction. In the event excessive seepage is encountered during construction, CT may be notified to evaluate whether other dewatering methods are required. Installation of the proposed site utilities is expected to require excavation below the "normal" groundwater level and groundwater seepage into excavations should be anticipated.

5.6 Flexible (Asphalt) Pavement

Based on the results of the plasticity and gradation testing for the upper profile cohesive subgrade soil samples, we recommend a subgrade CBR value of 5 percent for the Group A-6a or better soils. This CBR value is based on subgrade compacted to at least 100 percent of the maximum dry density as determined by ASTM D 698 (Standard Proctor) or verified as stable through proof rolling.

It should be noted that we are not privy to the design traffic loads or intended design life. The subgrade support recommendations indicated herein should be reviewed by the site engineer in conjunction with the design traffic criteria to determine the required pavement sections. In any case, we recommend the light-duty pavement cross-section consist of at least 3 inches of asphalt underlain by 6 inches of aggregate base for even the lightest-duty pavements based on our experience regarding environmental exposure and reasonable serviceability. For the same reason, we recommend the heavy-duty pavement cross-section consist of at least 4 inches of asphalt underlain by 8 inches of aggregate base.

All paving operations should conform to the State of Ohio Department of Transportation (ODOT) specifications. The pavement and subgrade preparation procedures outlined in this report should result in a reasonably workable and satisfactory pavement. It should be recognized, however, that all flexible pavements need repairs or overlays from time to time as a result of progressive yielding under repeated traffic loads for a prolonged period of time, as well as exposure to freeze-thaw conditions.

5.7 Pavement Drainage

Based on the poorly-drained nature of the silty and clayey subgrade soils at the site, it is anticipated that surface water infiltration may collect in the aggregate base course. Without adequate drainage, water will remain in the base for extended periods of time, creating localized wet, soft pockets. The presence of these pockets will increase the likelihood that pavement distress (cracking, potholes, etc.) will develop. Drainage features may include grading the subgrade surface to slope downward to the outside edge of pavements and/or providing longitudinal edge drains connected to storm sewers or other outlets. A system of “finger drains” could also be installed near catch basins within the pavement areas to collect surface water, thus reducing the potential for freeze-thaw effects on the pavement.

6.0 QUALIFICATION OF RECOMMENDATIONS

Our evaluation of geotechnical-related pavement subgrade and underground utilities installation and support conditions has been based on the data obtained during our field investigation and our understanding of the furnished site and project information. general subsurface conditions were based on interpretation of the subsurface data at specific boring locations. Regardless of the thoroughness of a subsurface investigation, there is the possibility that conditions between borings will differ from those at the boring locations, that conditions are not as anticipated by the designers, or that the construction process has altered the soil conditions. This is especially true for previously developed sites. Therefore, experienced geotechnical engineers should observe earthwork and foundation construction to confirm that the conditions anticipated in design are noted. Otherwise, CT assumes no responsibility for construction compliance with the design concepts, specifications, or recommendations.

The design recommendations in this report have been developed on the basis of the previously described project characteristics and subsurface conditions. If project criteria or locations change, a qualified geotechnical engineer should be permitted to determine whether the recommendations must be modified. The findings of such a review will be presented in a supplemental report.

The nature and extent of variations between the borings may not become evident until the course of construction. If such variations are encountered, it will be necessary to reevaluate the recommendations of this report after on-site observations of the conditions.

Our professional services have been performed, our findings derived, and our recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices. This warranty is in lieu of all other warranties either expressed or implied. CT is not responsible for the conclusions, opinions, or recommendations of others based on this data.

Plates

Plate 1.0 Site Location Map
Plate 2.0 Test Boring Location Plan

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Site Location Map

City of Willoughby
Willoughby, Ohio

Willoughby-Eastlake WPCC
Watermain Improvements

DRAWN:	RK 1/8/24
REVISED:	---
Project No.:	23004301
Drawing No.:	Plate 1.0

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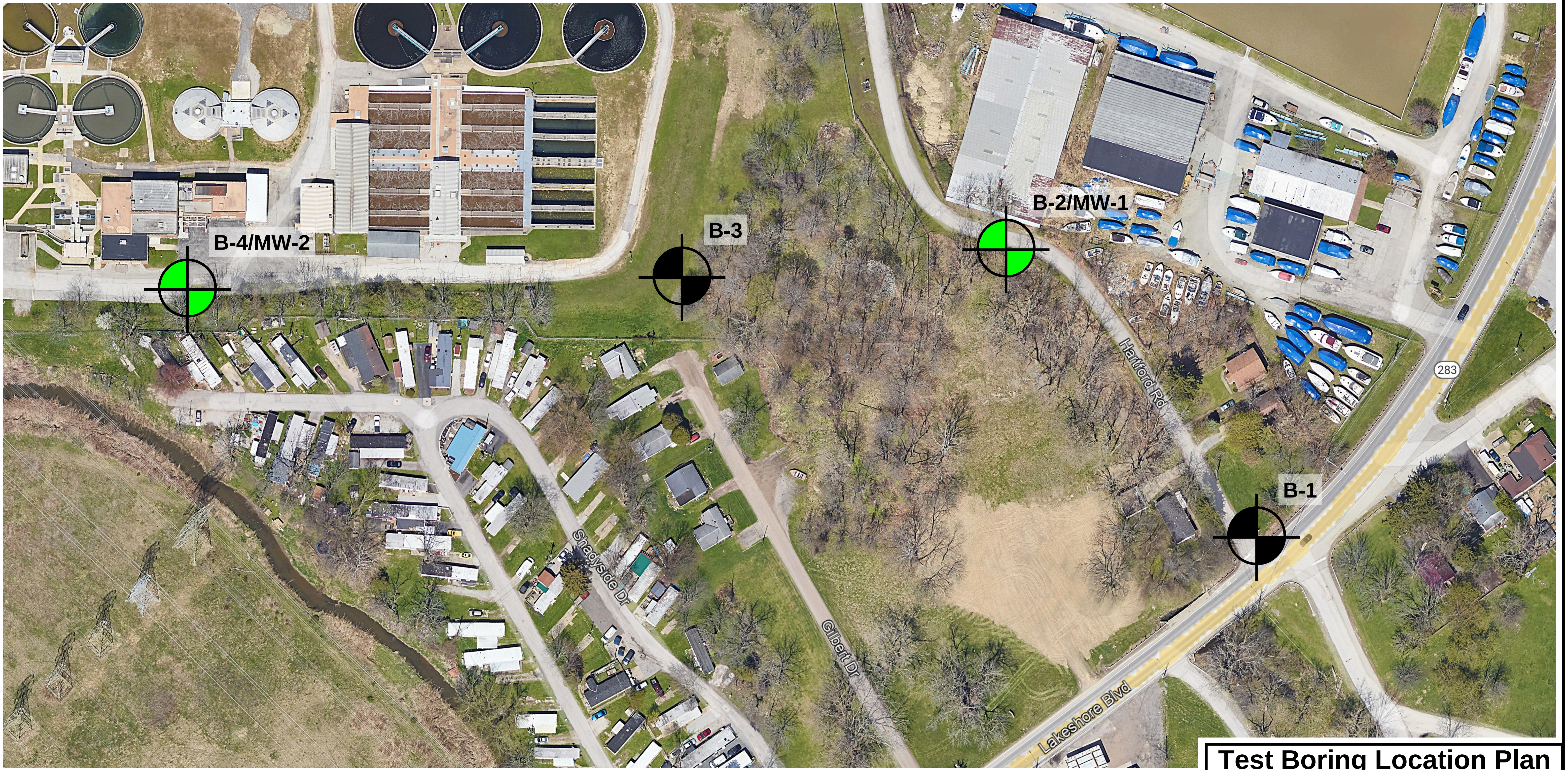
Notes: Aerial Basemap obtained From Google Earth and dated 4/28/2022.



Test Boring Location Plan

City of Willoughby
Willoughby, Ohio

Willoughby-Eastlake WPCC
Watermain Improvements

DRAWN:	RK 1/8/24
REVISED:	---
Project No.:	23004301
Drawing No.:	Plate 2.0

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Legend:

B-1 Approximate Test Boring Location

B-2/MW-1 Approximate Boring and Monitoring Well Location

0' 100' 200'

N

Notes: Aerial Basemap obtained From Google Earth and dated 04/27/2022

APPENDIX A

Logs of Test Borings

CT Consultants, Inc.
1915 N 12th Street
Toledo Ohio 43604
Telephone: (419)324-2222

BORING NUMBER B-1

CLIENT Cities of Willoughby-Eastlake
PROJECT NAME WPCC Watermain Project
PROJECT NUMBER 23004301
PROJECT LOCATION Willoughby and Eastlake, OH
DRILLING CONTRACTOR CT Consultants Inc. JP DC
RIG NO. 550
GROUND ELEVATION 583 ft
DRILLING METHOD 3-1/4 in. HSA
GROUND WATER LEVELS:
DATE STARTED 10/23/23 **COMPLETED** 10/23/23
AT TIME OF DRILLING 8.0 ft / Elev 575.0 ft
LOGGED BY KKC **CHECKED BY** RK
AT END OF DRILLING 8.0 ft / Elev 575.0 ft
NOTES
0hrs AFTER DRILLING Backfilled w/Cuttings and Bentonite Chips

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	PL / MC / LL; SPT N VALUE
583	0	TOPSOIL - 8 Inches (0.7')						
		Moist Medium Dense Brown/Gray COARSE and FINE SAND (A-3a), Some Clay, Little Silt, Trace Gravel (3.0')	SS 1	100	14-10-12 (22)	NP		MC 15
580		Moist Very Soft Gray/Brown SILT and CLAY, Some Sand, Trace Wood A-6a (8)	SS 2	100	0-0-0 (0)	0.50		MC 34
	5	@6': Brown (8.0')	SS 3	100	0-0-1 (1)	0.50		MC 33
575		Wet Loose Brown COARSE and FINE SAND (A-3a), Little Silt, Trace Clay, Trace Gravel (12.0')	SS 4	100	1-3-2 (5)	NP		MC 16
	10							
570		Moist Medium Dense Brown COARSE and FINE SAND (A-3a) , Little Silt, Trace Clay, Trace Gravel (15.0')	SS 5	100	4-13-15 (28)	NP		MC 17
	15	Bottom of hole at 15.0 feet.						

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Telephone: (419)324-2222

BORING NUMBER B-2

CLIENT Cities of Willoughby-Eastlake
PROJECT NAME WPCC Watermain Project
PROJECT NUMBER 23004301
PROJECT LOCATION Willoughby and Eastlake, OH
DRILLING CONTRACTOR CT Consultants Inc. JP DC
RIG NO. 550
GROUND ELEVATION 581 ft
DRILLING METHOD 3-1/4 in. HSA
GROUND WATER LEVELS:
DATE STARTED 10/23/23 **COMPLETED** 10/23/23
▽ **AT TIME OF DRILLING** 4.0 ft / Elev 577.0 ft
LOGGED BY KKC **CHECKED BY** RK
▼ **AT END OF DRILLING** 4.0 ft / Elev 577.0 ft
NOTES A monitoring well was installed at 15.0 feet.
0hrs AFTER DRILLING Backfilled w/Cuttings, Well Sand, and Bentonite C

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	MC (PL 20 40 60 80 LL)	SPT N VALUE (20 40 60 80)
581	0	TOPSOIL - 7 Inches (0.6')							
580		FILL - Moist Medium Dense Dark Gray COARSE and FINE SAND (A-3a), Some Clay, Little Silt, Trace Gravel (3.0')	SS 1	100	6-6-6 (12)	NP		20	▲
		FILL - Wet Loose Dark Gray COARSE and FINE SAND (A-3a), Some Silt, Little Clay, Trace Gravel, Trace Asphalt Fragments ▼ (6.0')	SS 2	100	6-3-2 (5)	NP		13	▲
575	5	FILL - Wet Very Dense Dark Gray COARSE and FINE SAND (A-3a), Some Clay, Little Silt, Trace Gravel, Trace Asphalt Fragments (9.0')	SS 3	100	50/4"	NP		21	>>▲
	10	Moist Very Loose Black/Gray COARSE and FINE SAND (A-3a), Some Clay, Little Silt, Trace Gravel, Trace Organics (Possible Fill) (12.0')	SS 4	100	0-1-1 (2)	NP		39	▲
570		Moist Very Stiff Gray SILT and CLAY (A-6a), Little Sand, Trace Gravel (15.0')	SS 5	100	8-9-10 (19)	>4.5		12	▲
	15	Bottom of hole at 15.0 feet.							

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BORING NUMBER B-3

CLIENT Cities of Willoughby-Eastlake
PROJECT NAME WPCC Watermain Project
PROJECT NUMBER 23004301
PROJECT LOCATION Willoughby and Eastlake, OH
DRILLING CONTRACTOR CT Consultants Inc. JP DC
RIG NO. 550
GROUND ELEVATION 582 ft
DRILLING METHOD 3-1/4 in. HSA
GROUND WATER LEVELS:
DATE STARTED 10/23/23 **COMPLETED** 10/23/23
AT TIME OF DRILLING None
LOGGED BY KKC **CHECKED BY** RK
AT END OF DRILLING None
NOTES
0hrs AFTER DRILLING Backfilled w/Cuttings and Bentonite Chips

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	PL / MC / LL (20 40 60 80); ▲ SPT N VALUE ▲ (20 40 60 80)
	0	TOPSOIL - 8 Inches 0.7'						
580		Moist Very Stiff Brown/Gray SILT and CLAY (A-6a), Some Sand, Trace Gravel, Trace Iron Oxide Stain Seam 3.0'	SS 1	100	9-7-9 (16)	>4.5		19
	5	Moist Very Loose Brown COARSE and FINE SAND (A-3a), Some Silt, Litlte Clay 6.0'	SS 2	100	2-1-2 (3)	NP		27
575		Moist Soft Brown SILT and CLAY, Some Sand A-6a (9)	SS 3	100	2-2-2 (4)	0.50		36
	10	@8': Very Soft, Brown/Gray 11.0'	SS 4	100	0-0-0 (0)	0.50		40
570	15	Moist Very Stiff Gray SILT and CLAY (A-6a), Little Sand, Trace Gravel 15.0'	SS 5	100	9-14-16 (30)	>4.5		10
		Bottom of hole at 15.0 feet.						

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BORING NUMBER B-4

CLIENT Cities of Willoughby-Eastlake
PROJECT NAME WPCC Watermain Project
PROJECT NUMBER 23004301
PROJECT LOCATION Willoughby and Eastlake, OH
DRILLING CONTRACTOR CT Consultants Inc. JP DC
RIG NO. 550
GROUND ELEVATION 579 ft
DRILLING METHOD 3-1/4 in. HSA
GROUND WATER LEVELS:
DATE STARTED 10/23/23 **COMPLETED** 10/23/23
∇ **AT TIME OF DRILLING** 9.0 ft / Elev 570.0 ft
LOGGED BY KKC **CHECKED BY** RK
▼ **AT END OF DRILLING** 9.0 ft / Elev 570.0 ft
NOTES A monitoring well was installed at 15.0 feet.
0hrs AFTER DRILLING Backfilled w/Cuttings, Well Sand, and Bentonite C

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	MC (%)	SPT N VALUE
	0	TOPSOIL - 6 Inches (0.5')							
		Moist Medium Stiff Brown SILT and CLAY (A-6a), Some Sand	SS 1	100	1-3-3 (6)	2.00		27	6
575	5	@3.5': Very Soft (6.0')	SS 2	100	0-0-2 (2)	2.00		28	2
		Wet Loose Brown COARSE and FINE SAND (A-3a), Some Silt, Little Clay, Trace Organics (9.0')	SS 3	100	1-2-3 (5)	NP		27	5
570	10	Wet Medium Dense Brown COARSE and FINE SAND (A-3a), Some Silt, Little Clay, Trace Gravel (13.0')	SS 4	100	4-6-5 (11)	NP		17	11
565	15	Moist Hard Brown/Gray SILT and CLAY (A-6a), Some Sand, Trace Gravel (18.5')	SS 5	100	8-16-16 (32)	3.00		10	32
560	20	Moist Very Hard Gray SILT and CLAY (A-6a), Little Sand, Trace Gravel (20.0')	SS 6	100	11-20-30 (50)	>4.5		11	50

Bottom of hole at 20.0 feet.

APPENDIX B

Legend Key

LEGEND KEY

Unified Soil Classification System Soil Symbols

GW - WELL GRADED GRAVEL Includes Gravel-Sand mixtures, little or no fines.	GP - POORLY GRADED GRAVEL Includes Gravel-Sand mixtures, little or no fines.	GM - SILTY GRAVEL Includes Gravel-Sand-Silt mixtures.	GC - CLAYEY GRAVEL Includes Gravel-Sand-Clay mixtures.
SW - WELL GRADED SAND Includes Gravelly Sands, little or no fines.	SP - POORLY GRADED SAND Includes Gravelly Sands, little or no fines.	SM - SILTY SAND Includes Sand-Silt mixtures.	SC - CLAYEY SAND Includes Sand-Clay mixtures.
ML - SILT Includes Silt with Sand and Sandy Silt.	CL - LEAN CLAY Includes Sandy Lean Clay and Lean Clay with Sand and Gravel.	MH - ELASTIC SILT Includes Sandy Elastic Silt and Elastic Silt with Sand.	CH - FAT CLAY Includes Sandy Fat Clay and Fat Clay with Sand.
CL-ML - SILTY CLAY Includes Clayey Silt of low plasticity.	OL - ORGANIC SILT and ORGANIC CLAY of low plasticity.	OH - ORGANIC SILT and ORGANIC CLAY of medium to high plasticity.	Pt - PEAT Includes humus, swamp and other soils with high organic content.
FILL MATERIAL - Includes controlled and non-controlled soil and non-soil materials.	TOPSOIL	ASPHALT - Bituminous Asphalt	CONCRETE - Includes broken concrete rubble.

Sample Symbols

SS - Split Spoon	ST - Shelby Tube	RC - Rock Core	GS - Geoprobe Sleeve
	AU - Auger Cuttings	GB - Grab	

Notes:

1. Exploratory borings and auger probes were drilled on October 23, 2023, using 3¼-inch diameter hollow-stem augers. Ground water monitoring wells were installed in Borings B-2 and B-4.

2. These logs are subject to the limitations, conclusions, and recommendations in the report and should not be interpreted separate from the report.

3. The borings were located in the field by CT in accordance with the Proposed Boring Location Plan, attached to the proposal.

4. Ground Surface Elevations were depicted from field survey data and are reported to the nearest foot.

5. Unconfined Compressive Strength (tsf):
   NP = Non Plastic

APPENDIX C

Tabulation of Laboratory Test Data

LEADING THROUGH
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SUMMARY OF LABORATORY RESULTS

CLIENT Cities of Willoughby-Eastlake **PROJECT NAME** WPCC Watermain Project

PROJECT NUMBER 23004301 **PROJECT LOCATION** Willoughby and Eastlake, OH

Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	Maximum Size (mm)	%<#200 Sieve	Class-ification	Water Content (%)	Dry Density (pcf)	Satur-ation (%)	Void Ratio
B-1	1.0							15.0			
B-1	3.5	32	21	11	4.75	76	CL	34.2			
B-1	6.0							33.3			
B-1	8.5							16.2			
B-1	13.5							16.6			
B-2	1.0							20.1			
B-2	3.5							13.3			
B-2	6.0							20.5			
B-2	8.5							38.7			
B-2	13.5							12.3			
B-3	1.0							18.8			
B-3	3.5							27.4			
B-3	6.0							35.8			
B-3	8.5	35	23	12	2	74	CL	40.3			
B-3	13.5							10.4			
B-4	1.0							26.6			
B-4	3.5							27.7			
B-4	6.0							27.2			
B-4	8.5							17.3			
B-4	13.5							10.2			
B-4	18.5							10.7			

APPENDIX D

Laboratory Test Results

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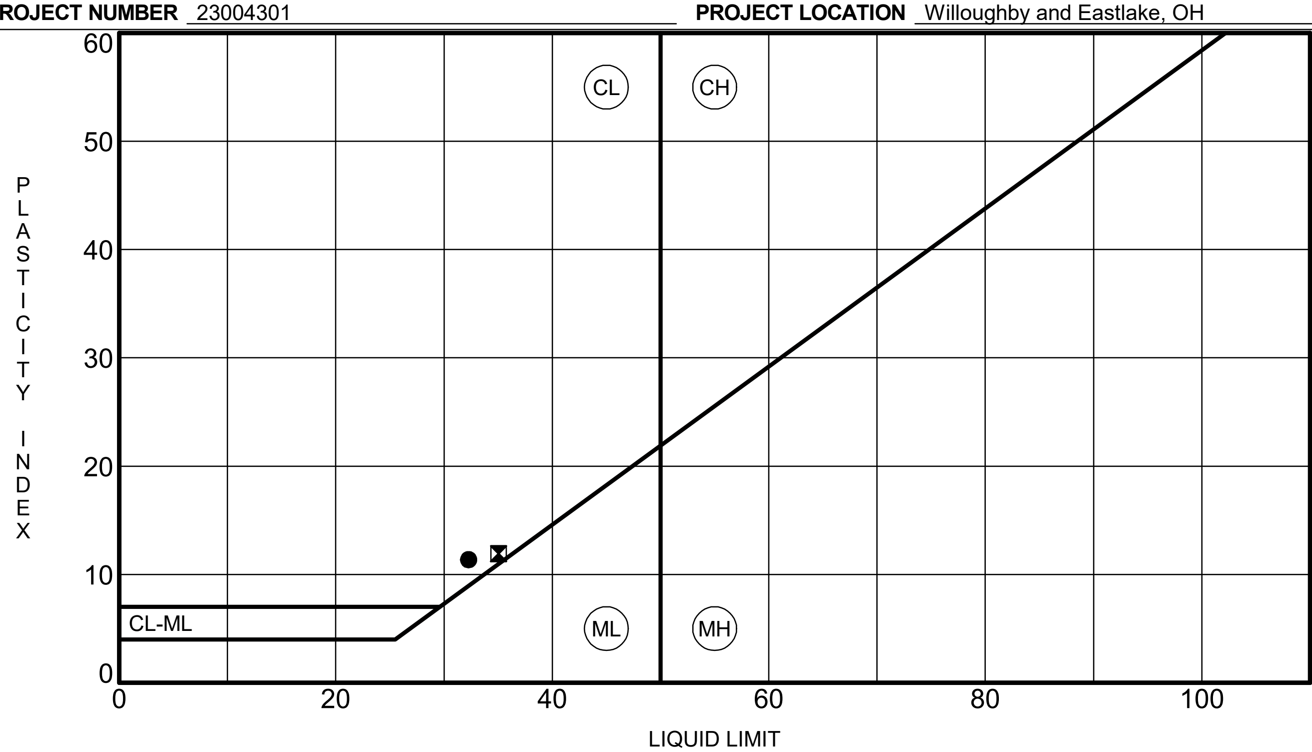
ATTERBERG LIMITS' RESULTS

CLIENT Cities of Willoughby-Eastlake
PROJECT NAME WPCC Watermain Project
PROJECT NUMBER 23004301
PROJECT LOCATION Willoughby and Eastlake, OH



	Specimen Identification		LL	PL	PI	Fines	Classification
●	**B-1**	**3.5**	**32**	**21**	**11**	**76**	**LEAN CLAY with SAND (CL)**
⊠	**B-3**	**8.5**	**35**	**23**	**12**	**74**	**LEAN CLAY with SAND (CL)**

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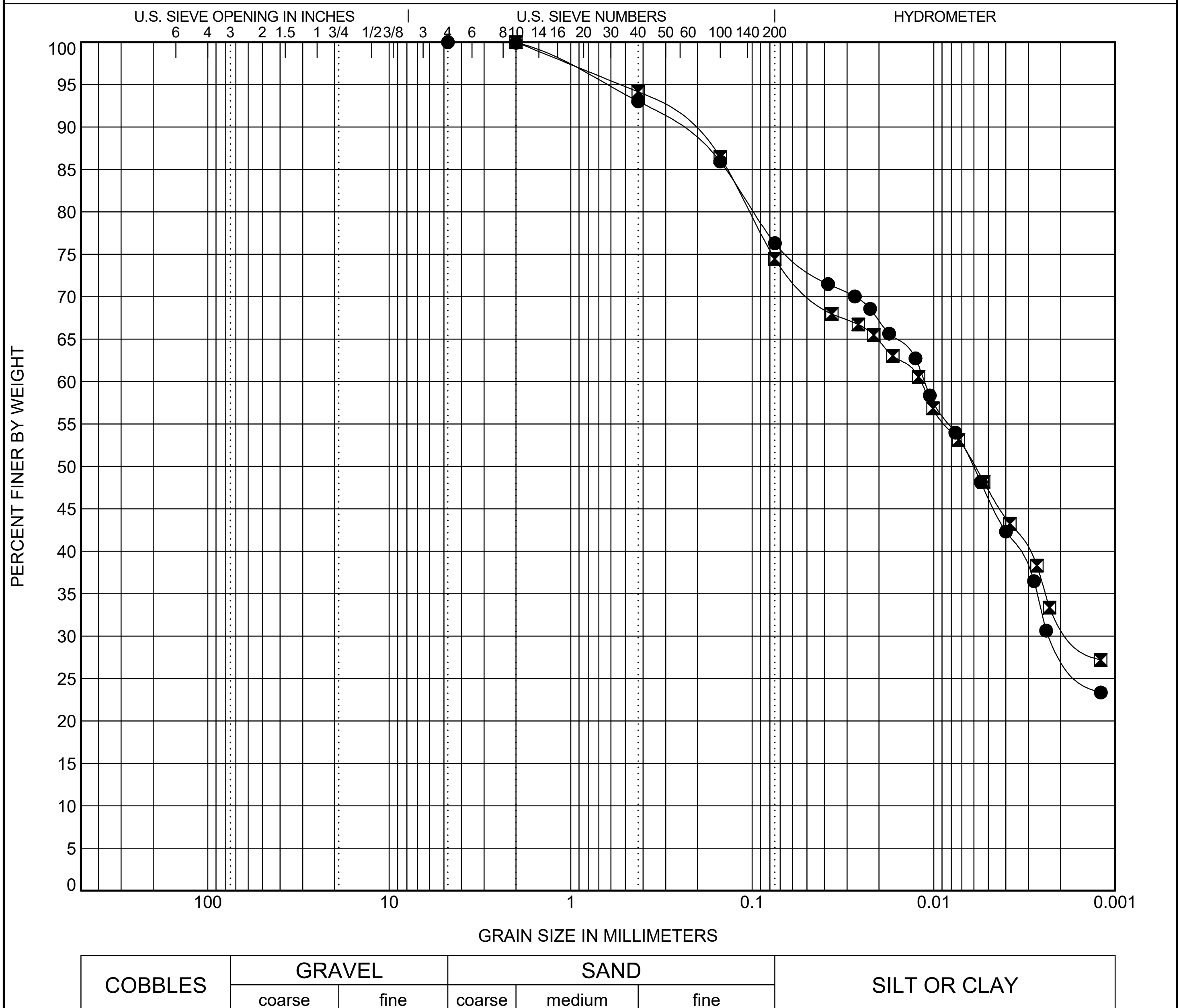
GRAIN SIZE DISTRIBUTION

CLIENT Cities of Willoughby-Eastlake
PROJECT NAME WPCC Watermain Project
PROJECT NUMBER 23004301
PROJECT LOCATION Willoughby and Eastlake, OH



	Specimen Identification		USCS Classification	LL	PL	PI	Cc	Cu
●	**B-1**	**3.5**	**LEAN CLAY with SAND (CL)**	**32**	**21**	**11**		
⊠	**B-3**	**8.5**	**LEAN CLAY with SAND (CL)**	**35**	**23**	**12**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**B-1**	**3.5**	**4.75**	**0.011**	**0.002**		**0.0**	**23.7**	**29.9**	**46.4**
⊠	**B-3**	**8.5**	**2**	**0.012**	**0.002**		**0.0**	**25.5**	**27.1**	**47.3**

APPENDIX E

Groundwater Monitoring Well Readings and Hydrographs

LEADING THROUGH
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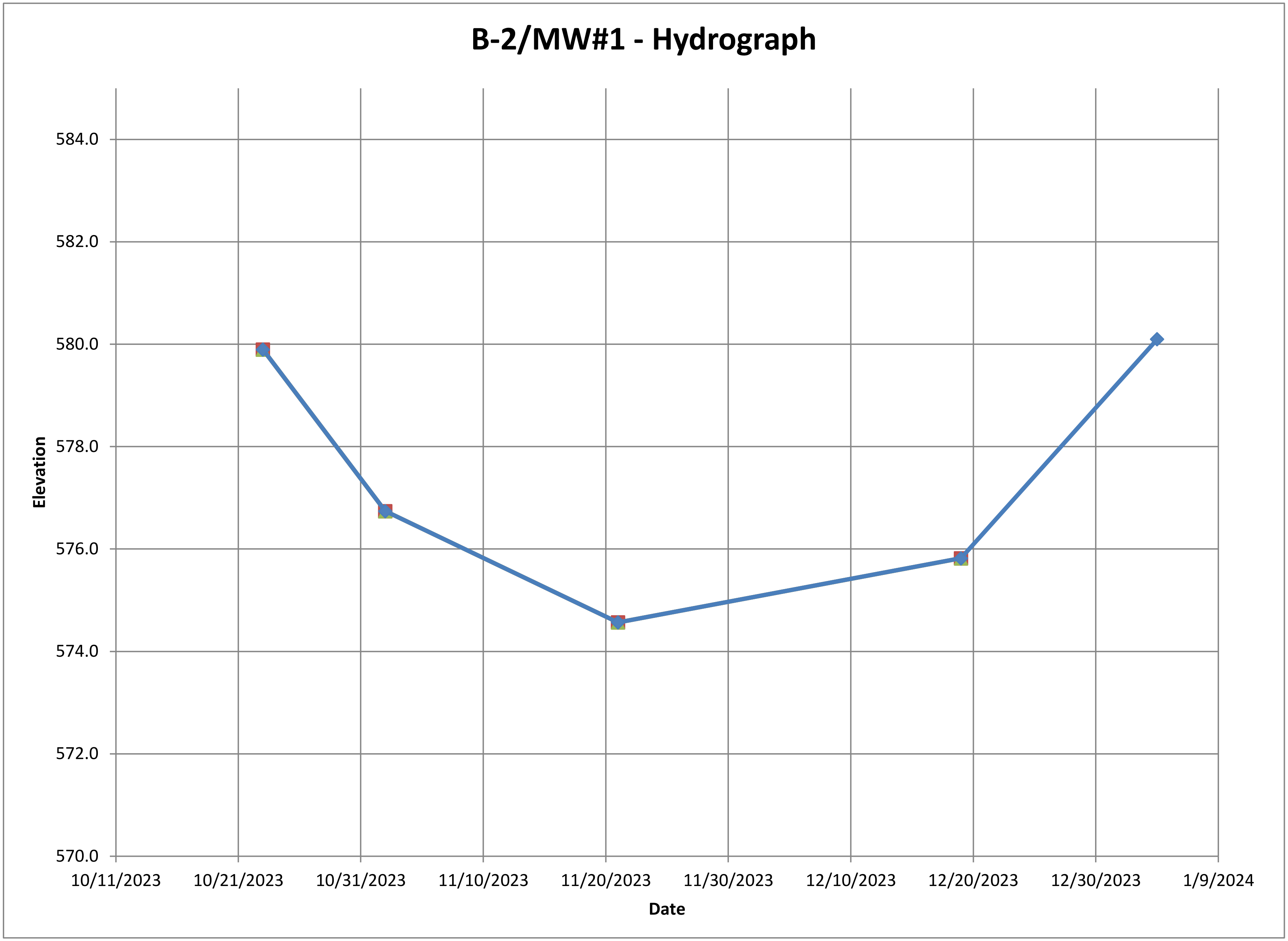
PROJECT: Willoughby/Eastlake WWTP

CT Project Number: 23004301

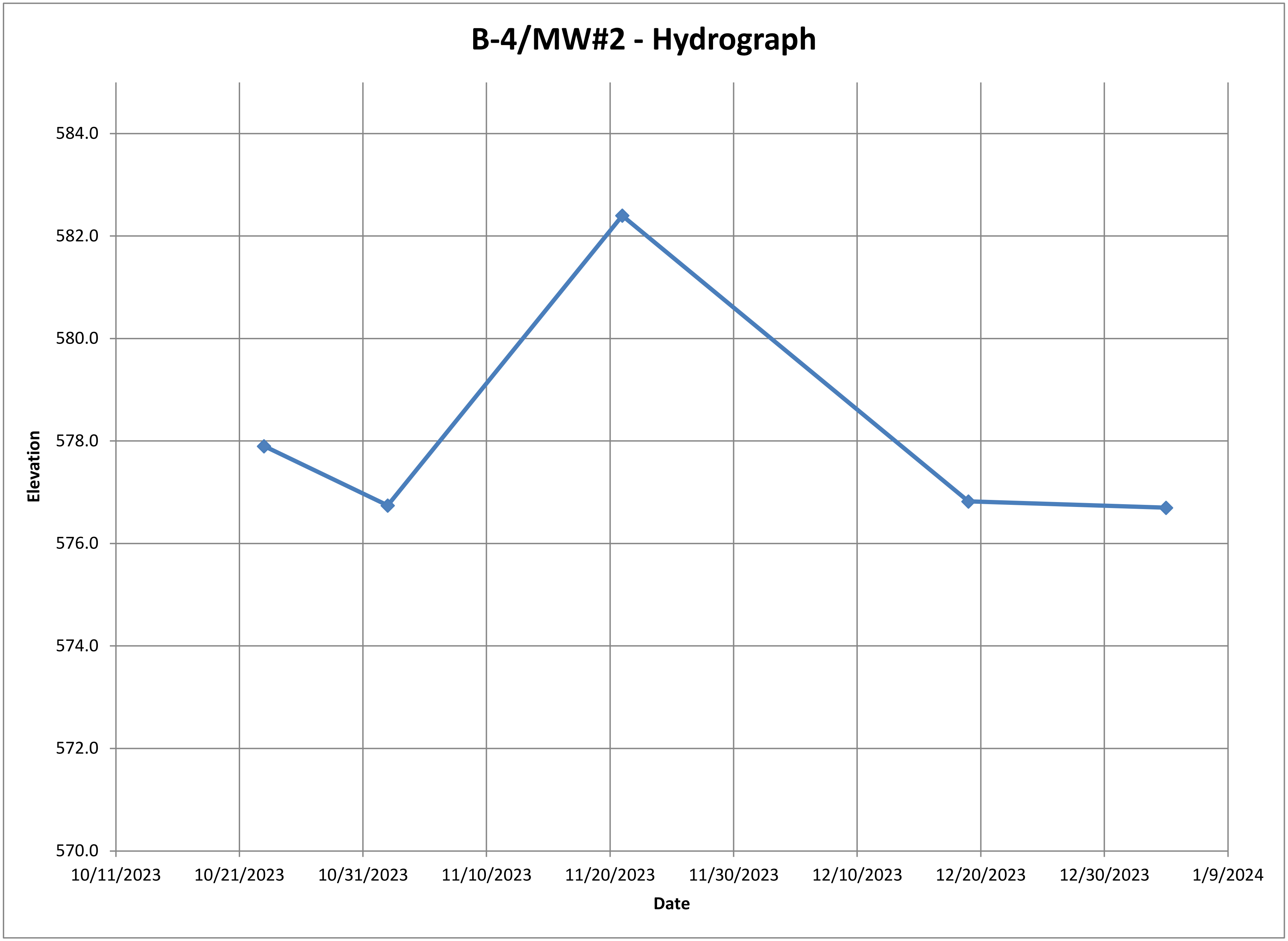
1. Elevations assumed to reference North American Vertical Datum of 1988 (NAVD88).
2. NE = not encountered.

Summary of Measured Water Level Readings

Boring Number	Ground Surface Elevation (feet)[1]	Elevation Referenced From	Depth to Groundwater[2] (feet)	Elevation of Groundwater at Time of Measurement (feet)[1]	Date Measured
B-2 / MW-1	581	Survey	1.1	579.9	10/23/2023
			4.3	576.7	11/2/2023
			6.4	574.6	11/21/2023
			5.2	575.8	12/19/2023
			0.9	580.1	1/4/2024
B-4 / MW-2	584	Survey	6.1	577.9	10/23/2023
			7.3	576.7	11/2/2023
			1.6	582.4	11/21/2023
			7.2	576.8	12/19/2023
			7.3	576.7	1/4/2024
B-1	583	Survey	8.0	576.0	10/23/2023
B-3	584	Survey	Not Encountered	Not Encountered	10/23/2023



B-2/MW#1 - Hydrograph
584.0
582.0
580.0
578.0
576.0
574.0
572.0
570.0
Elevation
10/11/2023
10/21/2023
10/31/2023
11/10/2023
11/20/2023
11/30/2023
12/10/2023
12/20/2023
12/30/2023
1/9/2024
Date


B-4/MW#2 - Hydrograph
Elevation
584.0
582.0
580.0
578.0
576.0
574.0
572.0
570.0
10/11/2023
10/21/2023
10/31/2023
11/10/2023
11/20/2023
11/30/2023
12/10/2023
12/20/2023
12/30/2023
1/9/2024
Date