Geotechnical Engineering Report

Sub-District H Water Main Extension Project – Phase 1

Orlando Drive, Enzweiler Road, Barrs Branch Road, and Rifle Range Road
Alexandria, Campbell County, Kentucky
Project No. N1095342
May 21, 2010 (revised)
January 18, 2010 (original)

Prepared for:

Northern Kentucky Water District
Erlanger, Kentucky

Prepared by:

HCN
A Terracon COMPANY
Cincinnati, Ohio

May 21, 2010 (revised)
January 18, 2010 (original)

Northern Kentucky Water District
2835 Crescent Springs Road
P.O. Box 18640
Erlanger, Kentucky 41018

Attn: Mr. John Scheben
TEL: 859-426-2717
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Re: Geotechnical Engineering Report
Proposed Sub-District H Water Main Extension Project – Phase 1
Orlando Drive, Enzweiler Road, Barrs Branch Road, and Rifle Range Road
Aelxandria, Campbell County, Kentucky
HCN/Terracon Project Number: N1095342

Dear Mr. Scheben:

H.C. Nutting, A Terracon Company (HCN) has completed the geotechnical engineering services for the above referenced project. This study was performed in general accordance with our proposal number PN1090210, dated March 10, 2009. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork during the installation of water main along with slope stability considerations in the areas of instability. This report has been prepared as requested by NKWD and Viox & Viox to more specifically address the geotechnical aspects along the waterline alignment for incorporation onto the project plans.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report, or if we may be of further service, please contact us.

Sincerely,
H.C. Nutting, a Terracon Company

Bobby Daita, P.E.
Senior Staff Engineer

Jess A. Schroeder, P.E.
Senior Principal - Office Manager

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EXECUTIVE SUMMARY

This summary should be used in conjunction with the entire report for design purposes. It should be recognized that details were not included or fully developed in this section, and the report must be read in its entirety for a comprehensive understanding of the items contained herein. The section titled **GENERAL COMMENTS** should be read for an understanding of the report limitations.

A geotechnical study was performed for the phase 1 portion of the proposed sub-district H water main extension project in Campbell County, Kentucky. The project involves installation of an 8-inch water main along Orlando Drive, Enzweiler Road, Rifle Range Road, and Barrs Branch Road in Alexandria, Campbell County, Kentucky. Based on a review of provided plan and profile drawings the proposed water main invert elevations are generally about 4 to 10 feet below existing site grade, with the typical depth being about 4 to 6 feet.

Based on the results of the test borings and the anticipated water main subgrade elevations, we anticipate that trench excavations in the area of the test boring locations will typically consist of medium stiff to hard natural cohesive residual soils and weathered shale bedrock with limestone. We anticipate excavations could likely be completed using conventional trench box support or conventional trench box support incorporated with laid-back slopes (open-cut and cover). All temporary cut slopes required for water main installation should be made in accordance with OSHA Safety Regulations.

In general, the placement of the water main, hydrants, and valves within the soil profile will not add significant load on the underlying bearing material. However, it is important to have uniform and proper support, and to maintain proper line and grade of the pipe to prevent the pipe from becoming over-stressed in hoop compression or bending. Any soft to medium stiff soils encountered at pipe subgrade elevation may need undercutting to expose suitable stiff to very stiff bearing materials. Based on review of the project plans, the use of pipe restraints and thrust blocks along portions of the alignment is proposed.

It is our understanding that open-cut techniques are preferred; however, directional drilling construction techniques may be implemented for installation of water main across the creek near Rifle Range Road. The nearest test boring (RR-1) indicated very stiff clay at pipe invert but weathered bedrock at slightly greater depth.

Close monitoring of the construction operations discussed herein will be critical in achieving the design subgrade support. We recommend that HCN/Terracon be retained to perform construction testing and inspection for this project.

GEOTECHNICAL ENGINEERING REPORT
SUB-DISTRICT H WATER MAIN EXTENSION PROJECT- PHASE 1
ORLANDO DRIVE AND ENZWEILER, RIFLE RANGE, AND BARRS BRANCH ROADS
ALEXANDRIA, CAMPBELL COUNTY, KENTUCKY
HCN/TERRACON PROJECT NO. N1095342
MAY 21, 2010 (REVISED)
JANUARY 18, 2010 (ORIGINAL)

1.0 INTRODUCTION

A geotechnical engineering report has been completed for the Phase 1 portion of the proposed Sub-District H Water Main Extension project in Alexandria, Campbell County, Kentucky (Figure 1A to 1C). A total of sixteen borings including two borings each along Enzweiler Road and Orlando Drive (designated as EZ-1, EZ-2, OR-1, and OR-2), five borings along Barrs Branch Road (designated as BB-1 to BB-5), and seven borings along Rifle Range Road (designated as RR-1 to RR-7) were drilled to approximate depths of 7.5 to 9 feet below existing grades. Logs of the borings along with site vicinity maps, boring location plans are included in Appendix A of this report.

The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- subsurface soil conditions
- groundwater conditions
- earthwork recommendations
- slope stability considerations
- pipe subgrade recommendations

2.0 PROJECT INFORMATION

The Northern Kentucky Water District (NKWD) is planning to extend the public water system into various unserved areas of Campbell County. The project is divided into four different phases (Phase 1 to Phase 4) and will involve installation of approximately 66,985 lineal feet of new 6, 8, and 12-inch water mains. Phase 1 of the project involves 8-inch water main installation along Orlando Drive, Enzweiler Road, Rifle Range Road, and Barrs Branch Road in Alexandria, Campbell County, Kentucky. The project length along Enzweiler Road is 1,270 feet, along Orlando Drive is 750 feet, along Rifle Range Road is 3,300 feet and along Barrs Branch Road is 2,675 feet. The water main alignment is generally along the edge of the pavement within its right-of-way. All four roadways within Phase 1 have rolling terrain with Rifle Range Road showing the most significant grade changes along the roadway. The water main alignment within phase 1 has one major creek crossing (along Rifle Range Road near Sta. 3+00) and three ditch crossings - one along Rifle Range Road near Sta. 24+50 and two along Barrs Branch Road near Sta. 8+50 and Sta. 22+00. Based on the profile drawings provided by Viox & Viox, the invert elevation of the water main will be 3 to 7 feet below existing grade along Rifle Range Road, Enzweiler Road and

Orlando Drive. Along Barrs Branch Road, the water main invert elevation varies between 4 and 10 feet below existing grade.

The existing grades along Enzweiler Road generally increase from south to north (Sta. 0+00 to Sta. 13+36) and vary approximately between El. 793 feet and El. 900 feet. Along Orlando Drive, existing grades increase from east to west and vary approximately between El. 825 and El. 860 feet. The existing grades along Barrs Branch Road decrease from north to south and vary approximately between El. 697 and El. 645 feet. Rifle Range Road has a rolling terrain with the existing grades varying approximately between El. 591 and El. 512 feet.

3.0 SUBSURFACE CONDITIONS

3.1 Typical Profile

The surficial material at test borings consisted of topsoil, gravel, asphalt pavement with or without granular base or natural cohesive soils. Topsoil with thickness varying between 4 and 5 inches was encountered at three test borings (OR-1, RR-5, and RR-6). Asphalt pavement with thickness varying between 7 and 11 inches was encountered at nine test borings (BB-2, BB-3, BB-4, BB-5, RR-1, RR-2, RR-3, RR-4, and RR-7). Granular base with thickness varying between 3 and 5 inches was encountered beneath the asphalt pavement at RR-4 and RR-7. Underlying these surficial materials were natural cohesive soils of residual origin and shale and limestone bedrock. Exceptions were existing fill soils that were encountered immediately below the pavement at three test borings (BB-3, RR-1, and RR-3). Natural cohesive soils were encountered at surface at three test borings (EZ-1, EZ2, and BB-1). The following table summarizes the encountered subsurface conditions:

Description	Approximate Depth to Bottom of Stratum (feet)	Material Encountered	Consistency/Density
Existing Fill[1]	2.5 to 5	Fat Clay, Lean Clay	Stiff to Very Stiff
Natural Cohesive Soils	2.5 to 9	Silty Clay, Lean Clay, Fat Clay	Soft to Hard
Bedrock[2]	Bottom of Boring	Weathered Brown Shale with Limestone	Soft (rock hardness)

1. Existing fill extended to a depth of 2.5 to 5 ft. at three referenced borings. It appears that the existing fill was placed with some compactive effort. However, we have not reviewed any records showing its placement as structural fill. Bedrock was encountered below overburden soils at nine test borings (EZ-2, OR-2, BB-2, BB-4, BB-5, RR-3, RR-4, RR-6, and RR-7). Based on the elevation at which bedrock was encountered, a review of published literature suggests that Ordivician Age bedrock along Barrs Branch Road and Rifle Range Road belong to the Latonia formation under the Kope group and that along Enzweiler Road and Orlando Drive belong to the McMillan formation under Maysville group. Bedrock belonging to Kope formation is generally shale rich and that belonging to Maysville formation is limestone rich.

Conditions encountered at each boring location are indicated on the individual boring logs. Stratification boundaries on the boring logs represent the approximate location of changes in soil types; the transition between materials may be gradual. Details for each of the borings can be found on the boring logs in Appendix A of this report.

3.2 Groundwater

Groundwater conditions were noted during and after drilling operations at each of the test boring locations. No groundwater or "dry" conditions were reported during and after drilling operations at each of the test boring locations. A "dry" condition is reported when no water is observed in the borehole or on the sampling tools. Boreholes were backfilled immediately upon completion and patched at the roadway surface for safety reasons. Therefore, long-term groundwater conditions at the site were not obtained.

Perched water may be encountered at shallow depths within the existing fill, at the fill/natural soil interface or near the soil/bedrock interface.

Groundwater level fluctuations occur due to seasonal variations in the amount of rainfall, runoff and other factors not evident at the time the borings were performed. Therefore, groundwater levels during construction or later may be higher or lower than the levels indicated on the boring logs. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

4.0 RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION

4.1 Geotechnical Considerations

Based on the provided water main alignment plans prepared by Viox & Viox, the proposed water main inverts are generally about 3 to 10 feet below existing site grades along the various roads planned within Phase 1. The proposed water main alignment has one creek crossing within phase 1 near Sta. 3+00 along Rifle Range Road. It is our understanding that open-cut methods are

preferred; however, directional drilling construction techniques may be implemented for installation of water main near the creek crossing.

Based on the results of the test borings and the anticipated water main subgrade elevations, we anticipate that trench excavations in the area of the test boring locations will typically consist of medium stiff to hard natural cohesive residual soils. Weathered shale and limestone bedrock may be encountered at pipe subgrade elevation at some locations. Based on the project plans, the use of pipe restraints and thrust blocks along portions of the alignment is proposed. The use of thrust blocks/restraints are typically shown where horizontal and/or vertical grade changes cannot be accommodated by the inherent flex of the waterline. Recommendations for the use of thrust blocks/restraints or lowering the waterline into bedrock where stability is a concern has been provided for evaluation by the waterline designer and NKWD. Additional details regarding general water main construction are provided in the following sections, followed by a station-by-station overview of our recommendations.

4.2 Construction Assessment

We anticipate excavations could likely be completed using conventional trench box support or conventional trench box support incorporated with laid-back slopes (open-cut and cover). Open-cut and cover techniques (with/without trench box support) can be considered, provided that precautions are taken to protect any existing utilities, structures, roadways, or creeks within the construction area. The following table shows the proposed invert elevations and anticipated bearing materials at the soil test boring locations.

Boring Number	Approx. Ground Elevation (ft.)	Approx. Invert Depth (ft.)	Anticipated Material @ Pipe Invert (approx.)	Estimated Depth to Bedrock (ft.)
Orlando Drive				
OR-1	855	5	Lean Clay	>9
OR-2	830	5	Lean Clay	7.5
Enzweiler Road				
EZ-1	786	6	Fat Clay	>9
EZ-2	819	5	Weathered Shale & Limestone	2.5
Barrs Branch Road				
BB-1	690	6	Fat Clay	>9
BB-2	680	7	Weathered Shale & Limestone	5
BB-3	675	4.5	Fat Clay	>9
BB-4	656	5	Fat Clay (Residuum)	7.5
BB-5	652	5	Lean Clay/Silty Clay (Residuum)	7.5
Rifle Range Road				
RR-1	497	6	Fat Clay	8.5

Boring Number	Approx. Ground Elevation (ft.)	Approx. Invert Depth (ft.)	Anticipated Material @ Pipe Invert (approx.)	Estimated Depth to Bedrock (ft.)
RR-2	507	4.5	Lean Clay	>9
RR-3	527	4	Fat Clay	7.5
RR-4	567	4.5	Fat Clay	5
RR-5	591	4.5	Lean Clay	>9
RR-6	592	4.5	Lean Clay (Residuum)	7.5
RR-7	545	5.5	Lean Clay (Residuum)	7.5

Notes: 1. Residuum can contain hard limestone fragments and layers.
2. Bedrock below about elevation 650 (+/-) ft. typically contains less than 20% limestone (Kope). Above this elevation, the limestone content increases to as much as about 50%.

In general, the placement of the water main, hydrants, and valves within the soil profile will not add significant load on the underlying bearing material. However, it is important to have uniform and proper support, and to maintain proper line and grade of the pipe to prevent the pipe from becoming over-stressed in hoop compression or bending. Based on the proposed invert elevations and subsurface conditions encountered at the test borings, we anticipate the bearing material at invert elevations should generally consist of stiff to very stiff cohesive soils and/or weathered shale and limestone bedrock. Any soft to medium stiff soils encountered at pipe subgrade elevation may need undercutting to expose suitable stiff to very stiff bearing materials. The undercut area may be brought up to design bearing levels with engineered fill as discussed in the Bedding and Backfill section of this report. For uniform support, the water main should be bedded on a minimum of 3 inches of appropriate granular (sand) material. The contractor should adhere to all installation specifications provided by the water main manufacturer. Thrust blocks and pipe restraints should also be provided along the water main alignment in accordance with manufacturer's specifications.

4.3 Trench Excavations

All temporary cut slopes required for water main installation should be made in accordance with OSHA Safety Regulations. It is anticipated that the depths of excavation will range between about 3 and 10 feet below existing grades. We anticipate that trench boxes or other types of temporary shoring will be utilized within the existing roadway and in close proximity to existing physical features.

Where sufficient space is available, the excavation slope can be laid back, in accordance with OSHA criteria. Slope stability analyses were not conducted here and are beyond the scope of work. However, according to OSHA, stiff to very stiff cohesive soils, such as those typically encountered at the test boring locations classify as Type B soil, which requires a 1H:1V slope or flatter (for excavations less than 20 feet deep). Where medium stiff to soft cohesive soils are encountered, or where seepage is encountered, all soils should classify as OSHA Type C soils, requiring a 1.5H:1V slope or flatter. Excavations within weathered shale bedrock could be

performed at 0.75H:1V side slopes or flatter. It is recommended that temporary excavation slopes be examined periodically to evaluate any potential destabilizing effects.

Trench excavations are not anticipated to be deeper than about 10 feet below existing grade. It is our opinion that the overburden soils/weathered shale bedrock encountered in the test borings can typically be excavated using conventional rubber tired backhoes and trackhoes. If excavations penetrate into bedrock, especially above about elevation 650 ft., the rock formation could include hard limestone layers in perhaps 30 to 50% (+/-)% of the mass. Below elevation 650 ft. (+/-), the rock formation still contains limestone, but at a comparatively lesser degree. No rock coring was performed as part of this study. The weathered bedrock typically breaks along the natural horizontal bedding planes. Excavation of narrow trenches in the shale and limestone can be difficult. A rock trencher or line drilling may be used to define the edge of the trench, with the rock being excavated with a large hydraulic hoe. Breaking with percussion tools will likely be advantageous to excavate some zones of limestone. The Contractor's "responsible person" should also establish a minimum lateral distance from the crest of the slope or excavation for all spoil piles and vehicles. Likewise, the contractor's "responsible person" should establish protective measures for exposed slope faces.

We recommend that the engineering specifications state that the contractor will be responsible for the temporary shoring, bracing, and sheeting design, if required, and the protection of roadways, utilities, and any other structures. We recommend that a pre-condition survey of all-adjacent structures and roadways be performed prior to the start of construction.

If utility trenches are backfilled with relatively clean granular material, they should be capped with at least 18 inches of cohesive fill in non-pavement areas to reduce the infiltration and conveyance of surface water through the trench backfill.

Unless visually apparent, the location of private underground utilities and other manmade physical features cannot be easily identified during our site reconnaissance. Oftentimes, the subsurface soils adjacent to these underground features, whether in-use or abandoned, may not represent the subsurface conditions encountered in the soil test borings. Unless notified in advance, identifying and/or locating the presence of underground manmade features such as leach fields, septic systems, irrigation piping, drainage tile, vaults, privies, cisterns, wells, shelters, private utilities, etc. is beyond our scope of services. Interviewing individual home and property owners for the purposes of identifying/locating known underground physical features is also outside the range of our site reconnaissance activities.

These manmade features are often used to collect, store, and/or provide an avenue for transporting water/ liquid waste. Similarly, underground utilities bedded in granular soils and utility trenches that may be inadequately backfilled tend to "hold" water. As a result, the soils in the area of the underground features tend to be saturated or near saturation, resulting in "weakening" of the soil structure and increased susceptibility to failure if exposed and/or disturbed. Due to the proposed construction being within a developed area where manmade disturbances are likely, we

recommend that the contractor carefully evaluate their excavation methods so that properly laid back slopes or sheeting/shoring/trench boxes can be readily utilized during construction. Additionally, if any suspicious surficial features (i.e., depressions, mounds, etc.) and/or seepage within the excavation are observed, further excavation should stop and the owner and geotechnical engineer should be notified.

4.4 Undercut and Replacement

The bottom of the excavations for the water main pipes and valves/hydrants must be stable so that no excessive settlement will occur. In some of the proposed pipe subgrade areas where soft to medium stiff soils may be encountered or if excessive water seepage is encountered during excavation, the on-site cohesive fill or natural soil is highly susceptible to strength loss when wet and disturbed. Therefore, a limited undercut and replacement could be required (or other stabilizing measures) to be determined at the time of construction.

4.5 Bedding and Backfill

It is recommended that pipe bedding material be used and consist of a "shaped" surface of well-graded sand and/or gravel (with a maximum size less than 1 inch) with no more than 10 percent passing the No. 200 sieve. This granular material should not be less than 3 inches in thickness below the bottom of the pipe and should extend to a height of at least 12 inches above the top of the pipe. This material should be placed in 4 to 6 inch thick lifts and be uniformly compacted to at least 95 percent (in non-pavement areas) of the Standard Proctor maximum dry density (ASTM D 698) at 2 percent below to 3 percent above of the optimum moisture content. Some pipe manufacturers provide backfill requirements pertaining to their particular brand or type of pipe. If this is the case for this project, the manufacturer's specifications could be adopted. If the manufacturer's specifications vary significantly from those provided herein, HCN/Terracon should be contacted to evaluate the appropriateness of the compaction specifications.

The remaining backfill above the granular zone previously described, can consist of on-site cohesive soils or high quality granular material unless specified otherwise. Excavated overburden soils from the water main alignment areas appear to be suitable for reuse as trench backfill, though likely wet of optimum. Some moisture adjustment may be necessary to achieve specified compaction. Material classifying as fat clay, such as the cohesive material encountered in majority of the test borings, should be placed wet of optimum to reduce swell potential. The trench backfill above the bedding fill should be in compliance with Northern Kentucky Water District and KTC 2004 specifications if within the roadway right-of-way (low strength mortar). Any proposed backfill material (on-site or imported) should be properly tested to determine its optimum moisture content and moisture-density characteristics and pre-approved before use. All backfill material should be free of organics, topsoil, debris and other deleterious substances. Maximum solid particle size (rock fragments, etc.) should be less than about 4 inches. The following table provides property requirements for structural fill:

Fill Type [1]	USCS Classification	Acceptable Location for Placement
Lean clay	CL (LL<40)	All locations and elevations
Fat clay [2]	CH (LL >50)	In non-structural fill areas
Well graded granular	GW [3]	All locations and elevations
On-site soils	Varies	The on-site soils, including the existing uncontrolled fill material, typically appear suitable for use as fill; however, if they do not meet the low volume change zone criteria, they should not be utilized within 2 feet of finished grade beneath pavement areas. Appropriate moisture conditioning may be needed.

1. New structural fill should consist of approved materials that are free of organic matter and debris. Frozen material should not be used, and fill should not be placed on a frozen subgrade. A sample of each material type should be submitted to the geotechnical engineer for evaluation.

2. Delineation of fat clays should be performed in the field by a qualified geotechnical engineer or their representative. Generally it is preferred not to use high plasticity clay within the structural fill areas, within 2 ft. of pavement subgrade.

3. Similar to KTC DGA stone or crushed limestone aggregate or granular material such as sand, gravel or crushed stone containing less than 8% low plasticity fines.

Compaction Requirements for Backfill

Fill Lift Thickness	8-inches or less in loose thickness 6-inches or less if hand compaction equipment used
Compaction Requirements [1] (Pavement Areas)	Top 12" beneath pavement areas, 100% of the materials maximum Standard Proctor dry density (ASTM D 698); structural fill beneath the top 12" should be compacted to at least 98% of the materials maximum Standard Proctor dry density (ASTM D 698)
Compaction Requirements (Landscape Areas)	95% of maximum Standard Proctor dry density (ASTM D 698) provided long-term plans do not include a structure in these areas

Moisture Content - Cohesive Soil (Low Plasticity)	Within ±3% of optimum moisture content (OMC) as determined by the standard Proctor test at the time of placement and compaction
Moisture Content - Granular Material	Within ±2% of OMC

1. Should the results of the in-place density tests indicate the specified moisture or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified moisture and compaction requirements are achieved.

2. Specifically, moisture levels should be maintained low enough to allow for satisfactory compaction to be achieved without the cohesionless fill material pumping when proofrolled.

3. All materials to be used as structural fill should be tested in the laboratory to determine their suitability and compaction characteristics.

Flowable concrete fill (low strength mortar) should be used within roadway easements to reduce construction time and minimize the risk of future trench settlement. It is our experience that reduced labor costs associated with flowable concrete backfill make the use of this material an attractive alternative. Flowable concrete is a semi-rigid backfill, typically stronger than the soil that was removed. The flowable concrete fill should not be placed in more than 36-inch lifts.

4.6 Drainage and Groundwater Considerations

Water should not be allowed to collect in the bottom of excavation or on prepared subgrades of the construction area. Undercut or excavated areas should be sloped toward one corner to facilitate removal of any collected rainwater, groundwater, or surface runoff.

Based on the predominately cohesive soil types and observed groundwater conditions during drilling, we do not anticipate significant seepage within the excavations. Any encountered water can most likely be removed with typical sump and pump methods. The presence and handling of groundwater should be further evaluated at the time of construction.

4.7 Slope Stability Considerations

Based on the relatively very stiff to hard cohesive overburden soils and relatively shallow brown shale bedrock, deep-seated (global) slope failure does not appear to be a concern (although detailed slope stability analyses were not performed). Note that there were some areas along Rifle Range Road (vicinity of Sta. 16+00) where the asphalt pavement had been patched on the downhill traffic lane. We are not aware of the cause for these repairs, but they could be the result of slope creep. The proposed water line will be on the opposite (upslope) side of the road.

4.8 Creek Crossing

The proposed water main alignment crosses an existing creek along Rifle Range Road near Sta. 3+00. Due to the open nature of the area, we anticipate that water main installation in the area of the existing creek can be accomplished with open-cut methods. Trench excavations should be performed as discussed previously. Excavation in both overburden soil and bedrock should be anticipated. Due to the multiple pipe bends anticipated in the area of the creek crossing, we further recommend that pipe restraints and/or thrust blocks be utilized in the area of the creek crossing.

Dewatering techniques, such as a cofferdam or sandbags, will likely be required to create a "dry" environment during excavation and subgrade preparation at the creek crossing. Water should be maintained a minimum of 2 feet below the excavation subgrade elevation during pipe installation and fill placement. The contractor should be required to submit their dewatering plan to the NKWD for review prior to implementation.

It is our understanding that while open-cut methods are considered feasible and preferable, directional drilling construction techniques may be implemented for installation of the water main across the creek. The horizontal directional drilling (HDD) method is a process of boring a pilot hole with a drill head suitable for the soil conditions. Once the initial pilot hole is complete, a reamer, slightly larger than the pilot hole is attached to the drill stem and pulled back. The reamer enlarges the borehole to accommodate the pipe that is then pulled into place.

Control of tunnel alignment and elevation is typically more easily achieved in uniform material. Based on test boring RR-1 and other test borings drilled along Rifle Range Road, we anticipate that the encountered materials will generally consist of very stiff clays, although weathered shale and limestone occurs at relatively shallow depth in some areas. Based on the elevation at which bedrock was encountered along Rifle Range Road, published literature suggests that bedrock belongs to the Latonia Formation under the Kope group which is rich in shale. The contractor selected to perform the HDD should have equipment and proof of experience appropriate for such construction. The contractor should have experience with similar soil geology and installation type (size and length) for the project.

4.9 Thrust Block and Restrained Joints Recommendations

Thrust block or restrained joints are used to resist thrust forces that occur in waterlines when the pipeline changes directions, changes sizes, or stops. A thrust block may be constructed between the fitting and the undisturbed side or bottom of the trench. The base of the thrust block is designed to support the anticipated thrust loads by providing a bearing area through which the thrust forces can be transferred to the soil without exceeding the bearing capacity of the soil.

An alternative method of providing thrust restraint is the use of restrained joints. A restrained joint is a special type of push-on or mechanical joint that is designed to provide longitudinal restraint. Restrained joint systems function in a manner similar to thrust blocks; as the reaction of the entire

restrained unit of piping with the soil balances the thrust forces. The objective in designing a restrained joint thrust restraint system is to determine the length of pipe that must be restrained on each side of the focus of a thrust force. This will be a function of the pipe size, the internal pressure, depth of cover, the characteristics of the soil surrounding the pipe, and whether the pipe is polyethylene encased.

The provided plans depicting the water main alignment shows several bends where thrust blocks are anticipated. Based on the invert elevations of the water main pipeline, existing fill and natural cohesive soils and/or weathered shale bedrock are anticipated in the vicinity of the thrust blocks. Two areas of instability were identified in this study where long-term creep of the slopes is likely. Consideration should be given to using restrained joints from station 45+00 to 55+00 where the slope instability was observed.

The following soil parameters can be used in sizing the thrust blocks and restrained joints:

Material	Angle of Internal Friction (ϕ)	Total Unit Weight (γ, pcf)	K_o (At-rest)	K_p (Passive)
Stiff to Very Stiff Existing Fill	23°	120	0.61	2.28
Stiff to Very Stiff Natural Cohesive Soil	26 °	125	0.56	2.56
Weathered Shale Bedrock	36 °	135	0.41	3.85

The following allowable bearing capacities can be used in sizing the thrust block for downward directed thrust:

Bearing Material	Allowable Bearing Capacity
New Engineered Granular Fill (placed over stiff to very stiff natural soils)	3,000 psf
Stiff to Very Stiff Natural Cohesive soils	3,000 psf
Weathered Shale Bedrock	8,000 psf

The following table summarizes the recommended coefficient of friction values for the interface of thrust block concrete and in-situ soil. These are ultimate values (no safety factors applied).

Interface Material	Coefficient of Friction
Stiff to Very Stiff Existing Fill	0.30
Stiff to Very Stiff Natural Cohesive soils	0.35
Weathered Shale Bedrock	0.50

It is recommended that the trench backfill in the areas of thrust blocks and restrained joints consist of compacted granular backfill or flowable concrete fill.

4.10 Overview of Geotechnical Recommendations

The following table is being provided for use by the NKWD and the waterline designer to aid in waterline design, and development of the project plans. The table generally outlines our recommendations along the alignment in consideration of the geotechnical aspects outlined above and based on review of the plan and profile information provided to us. The actual design of the waterline and design methodology is the responsibility of the designer. We have not considered flowrates, pressures, valve/hydrant placement, etc., along the waterline, which may require the further use of thrust blocks/restraints, grade change, waterline relocation, in addition to the recommendations provided below. We request the opportunity to review such changes and/or meet with the NKWD/designer to discuss any of our recommendations, as deemed necessary. It should be further acknowledged that our test borings provide limited, widely-spaced information and that "ground truth" is only obtained in the field during construction at the time of excavation. Adjustments in the field at the time of construction based on actual field conditions should be anticipated. Additional exploration and/or long-term monitoring may be required.

Alignment	Approximate Station	Applicable Test Boring(s)	Geotechnical Consideration(s)	Remarks[3]
Rifle Range Road	0+00 to 1+00	RR-1[1]	None anticipated	Road crossing
	1+00 to 4+00	RR-1	None anticipated	Thrust blocks/restraints; Creek crossing; dewatering required
	4+00 to 11+75	RR-2 & 3	None anticipated	Within road
	11+75 to 12+50	RR-3	None anticipated	Thrust blocks/restraints: Pipe bend
	12+50 to 24+00	RR-3, 4, & 5	None anticipated[2]	Within road
	24+00 to 25+50	RR-5[1]	None anticipated	Thrust blocks/restraints; Bend in alignment (off road to avoid culvert)
	25+50 to 33+36	RR-6 & 7	None anticipated	Within road
Enzweiler Road	0+00 to 13+36	EZ-1 & 2	None anticipated	Bedrock excavation near EZ-2

Alignment	Approximate Station	Applicable Test Boring(s)	Geotechnical Consideration(s)	Remarks[3]
Orlando Drive	0+00 to 1+75	OR-1	None anticipated	(none)
	1+75 to 3+75	OR-1[1]	None anticipated	Within road
	3+75 to 7+10	OR-2	None anticipated	(none)
Barrs Branch Road	0+00 to 3+75	BB-1	None anticipated	(none)
	3+75 to 5+00	BB-1[1]	None anticipated	Thrust blocks/restraints; Bend in alignment
	5+00 to 9+00	BB-2[1]	None anticipated	Possible rock excavation
	9+00 to 9+50	BB-2	None anticipated	Thrust blocks/restraints; Bend in alignment
	9+50 to 26+76	BB-3, 4, & 5	None anticipated	(none)

(1) Boring drilled outside of station range.
(2) Considers waterline alignment on upslope side of road.
(3) Thrust block/restraint use based on project plans.

5.0 GENERAL COMMENTS

Terracon should be retained to review the final design plans and specifications so comments can be made regarding interpretation and implementation of our geotechnical recommendations in the design and specifications. Terracon also should be retained to provide observation and testing services during grading, excavation, foundation construction and other earth-related construction phases of the project.

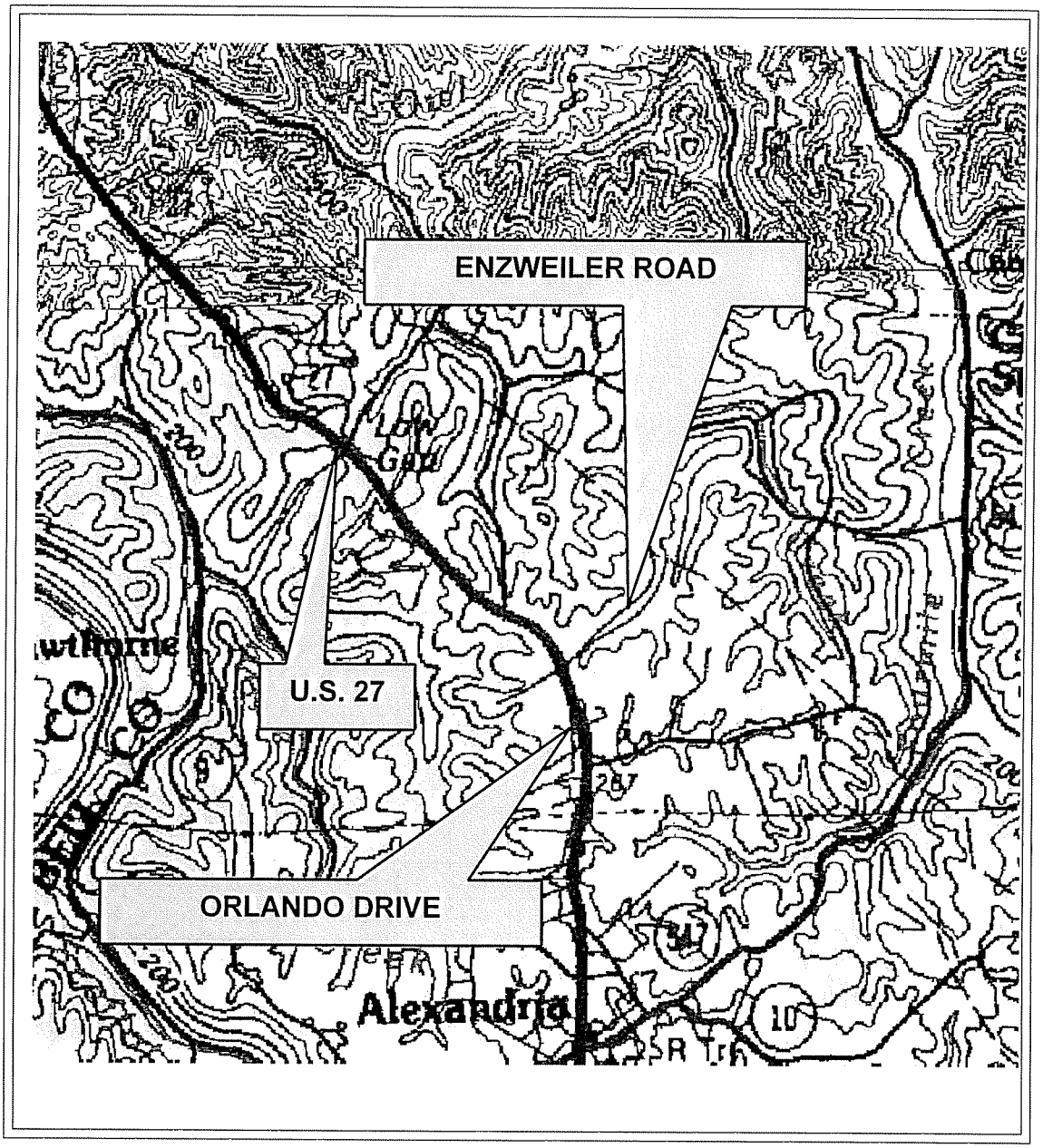
The analysis and recommendations presented in this report are based upon the data obtained from the borings performed at the indicated locations and from other information discussed in this report. This report does not reflect variations that may occur between borings, across the site, or due to the modifying effects of weather. The nature and extent of such variations may not become evident until during or after construction. If variations appear, we should be immediately notified so that further evaluation and supplemental recommendations can be provided.

The scope of services for this project does not include either specifically or by implication any environmental or biological (e.g., mold, fungi, bacteria) assessment of the site or identification or prevention of pollutants, hazardous materials or conditions. If the owner is concerned about the potential for such contamination or pollution, other studies should be undertaken.

This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either express or implied, are intended or made. Site safety, excavation support, and dewatering requirements are the responsibility of others. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions and recommendations contained in this report shall not be considered valid unless Terracon reviews the changes and either verifies or modifies the conclusions of this report in writing.

APPENDIX A
FIELD EXPLORATION

UNITED STATES – DEPARTMENT OF THE INTERIOR – GEOLOGICAL SURVEY



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1 .5 0 KILOMETERS 1 2

1000 0 METERS 1000 2000

1 .5 0 1

MILES

1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

CONTOUR INTERVAL FEET FEET

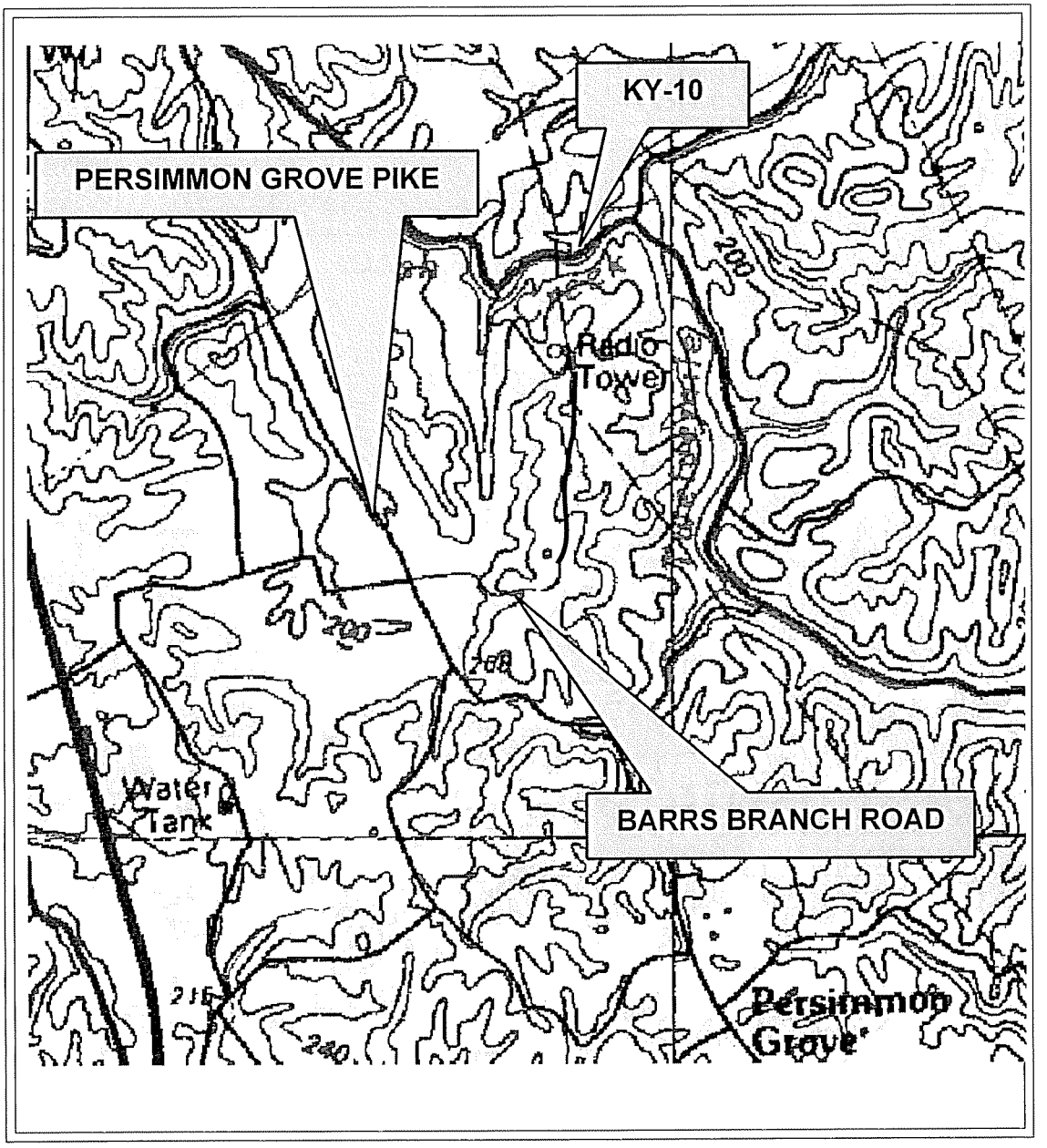
NATIONAL GEODETIC VERTICAL DATUM OF 1929

MAP OF ALEXANDRIA, KENTUCKY 1983

7.5 MINUTE SERIES (TOPOGRAPHIC)

Project Mngr: AJM	Project No: N1095342	Consulting Engineers and Scientists	SITE VICINITY MAP	FIG. No.
Drawn By: DRK	Scale: AS SHOWN	611 LUNKEN PARK DRIVE CINCINNATI, OHIO 45226	SUBDISTRICT H WATER MAIN EXTENSION – PHASE 1	1A
Checked By: AJM	File No: FIGURE 1A	PH. (513) 321-5816 FAX. (513) 321-4540	NORTHERN KENTUCKY WATER DISTRICT	
Approved By: JAS	Date: 1/7/2010		ENZWEILER ROAD AND ORLANDO DRIVE	
			ALEXANDRIA, CAMPBELL COUNTY KENTUCKY	

UNITED STATES – DEPARTMENT OF THE INTERIOR – GEOLOGICAL SURVEY



SCALE 1:24 000

1 .5 0 KILOMETERS 1 2

1000 0 METERS 1000 2000

1 .5 0 1

MILES

1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

CONTOUR INTERVAL FEET FEET

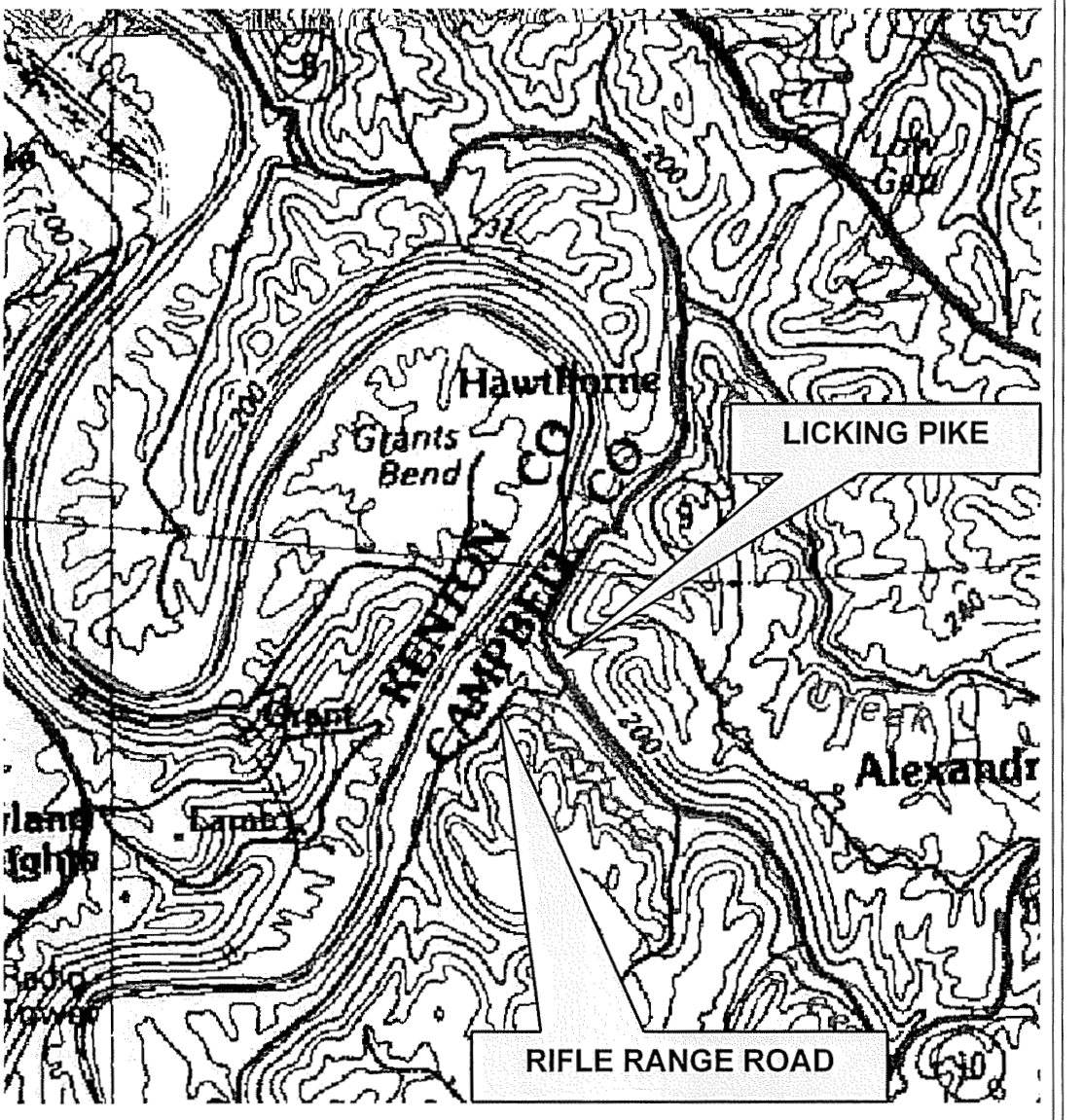
NATIONAL GEODETIC VERTICAL DATUM OF 1929

MAP OF ALEXANDRIA, KENTUCKY 1983

7.5 MINUTE SERIES (TOPOGRAPHIC)

Project Mngr: AJM	Project No: N1095342	Consulting Engineers and Scientists	SITE VICINITY MAP	FIG. No.
Drawn By: DRK	Scale: AS SHOWN	611 LUNKEN PARK DRIVE CINCINNATI, OHIO 45226	SUBDISTRICT H WATER MAIN EXTENSION – PHASE 1	1B
Checked By: AJM	File No: FIGURE 1B	PH. (513) 321-5816 FAX. (513) 321-4540	NORTHERN KENTUCKY WATER DISTRICT	
Approved By: JAS	Date: 1/7/2010		BARRS BRANCH ROAD	
			ALEXANDRIA, CAMPBELL COUNTY KENTUCKY	

UNITED STATES – DEPARTMENT OF THE INTERIOR – GEOLOGICAL SURVEY



SCALE 1:24 000

1 .5 0 KILOMETERS 1 2

1000 0 METERS 1000 2000

1 .5 0 1

MILES

1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000

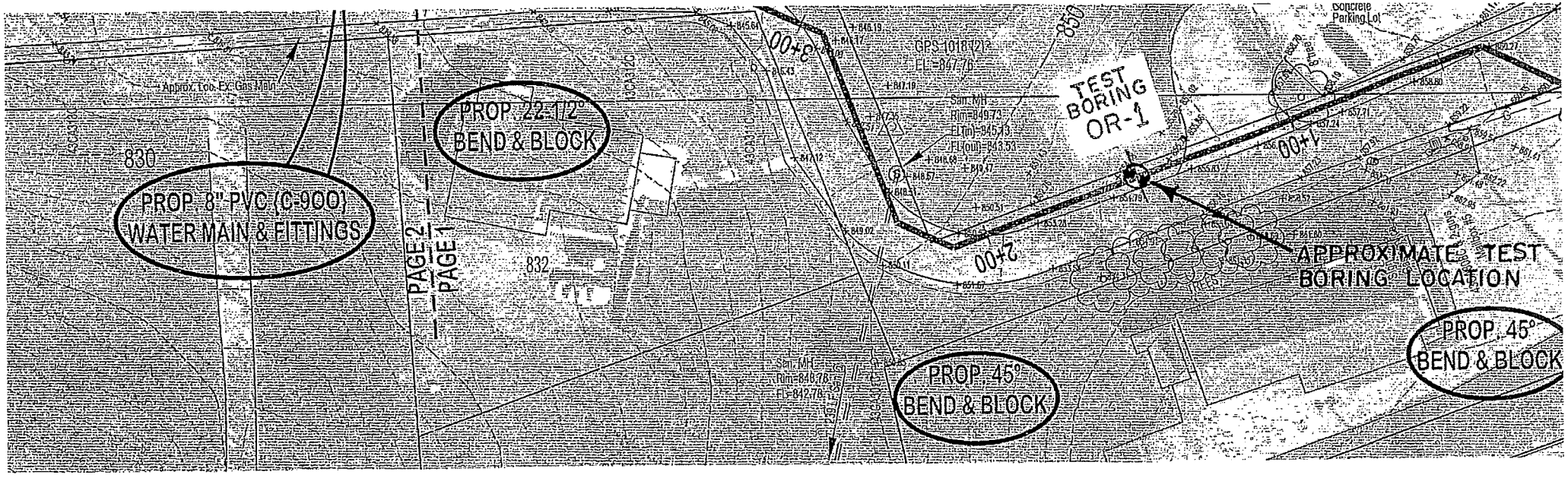
CONTOUR INTERVAL FEET FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

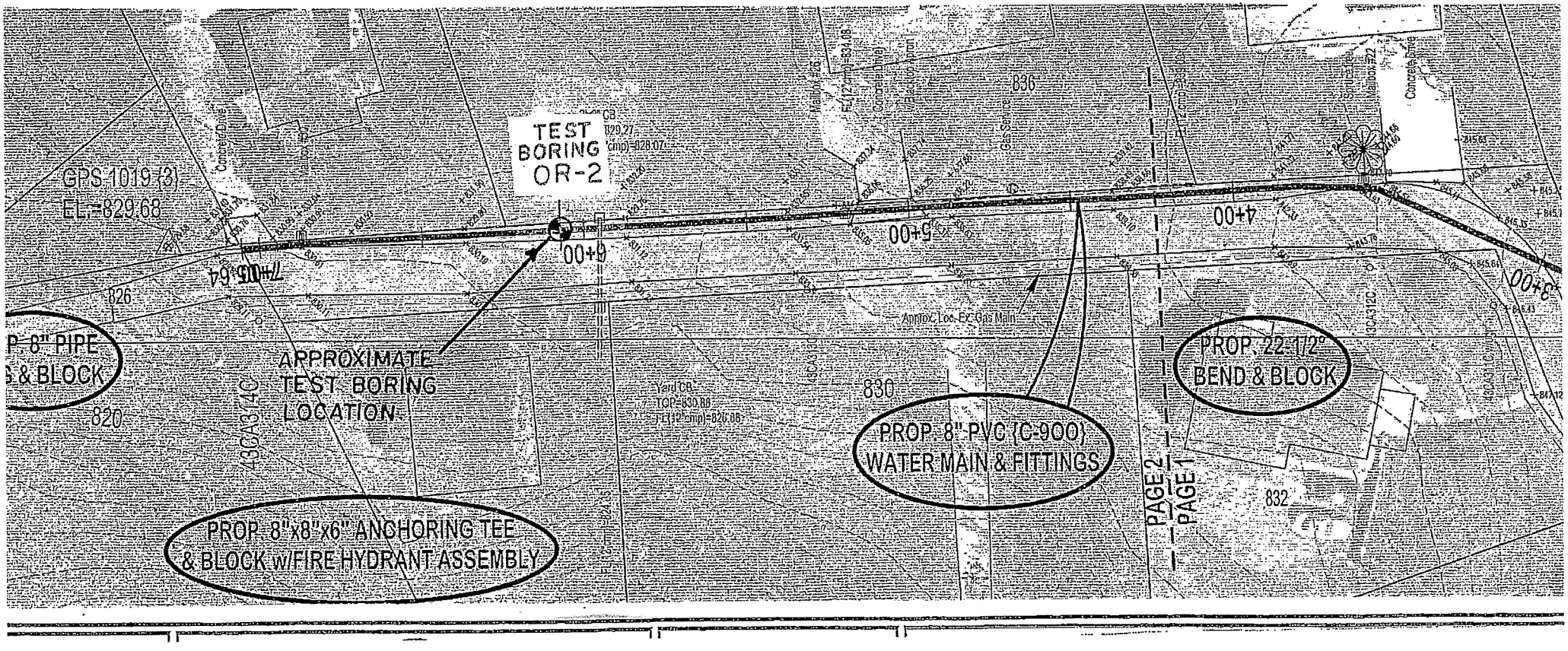
MAP OF ALEXANDRIA, KENTUCKY 1983

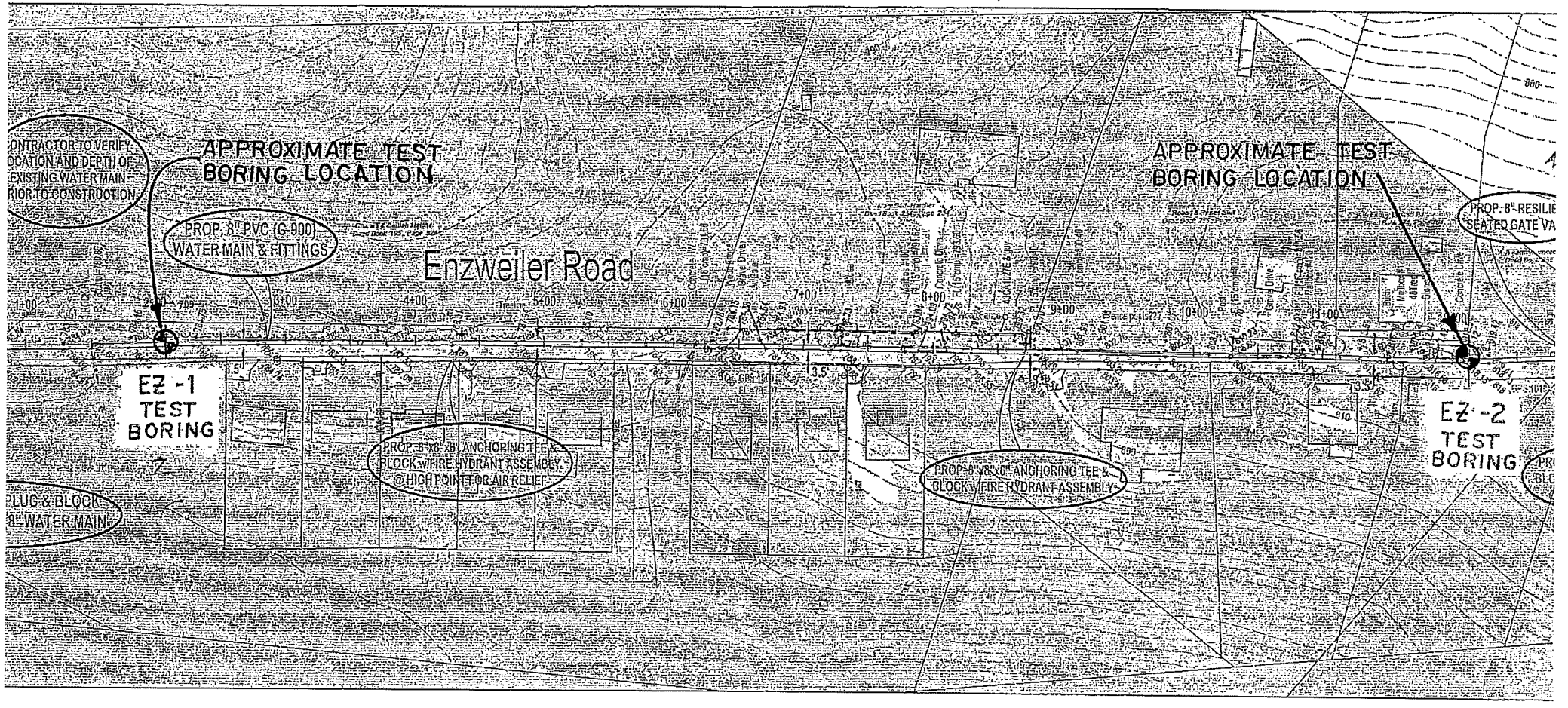
7.5 MINUTE SERIES (TOPOGRAPHIC)

Project Mngr: AJM	Project No. N1095342	Consulting Engineers and Scientists	SITE VICINITY MAP	FIG. No.
Drawn By: DRK	Scale: AS SHOWN	611 LUNKEN PARK DRIVE CINCINNATI, OHIO 45226	SUBDISTRICT H WATER MAIN EXTENSION – PHASE 1	1C
Checked By: AJM	File No. FIGURE 1C	PH. (513) 321-5816 FAX. (513) 321-4540	NORTHERN KENTUCKY WATER DISTRICT	
Approved By: JAS	Date: 1/7/2010		RIFLE RANGE ROAD	
			ALEXANDRIA, CAMPBELL COUNTY KENTUCKY	



ORLANDO DRIVE




APPROXIMATE TEST BORING LOCATION
PROP. 8" PVC (C-900) WATER MAIN & FITTINGS
Enzweiler Road
APPROXIMATE TEST BORING LOCATION
EZ-1 TEST BORING
EZ-2 TEST BORING
PROP. 8"x8"x8" ANCHORING TEE & BLOCK w/FIRE HYDRANT ASSEMBLY @HIGH POINT FOR AIR RELIEF
PROP. 8"x8"x8" ANCHORING TEE & BLOCK w/FIRE HYDRANT ASSEMBLY
PROP. 8" RESILIE SEATED GATE VA
CONTRACTOR TO VERIFY LOCATION AND DEPTH OF EXISTING WATER MAIN PRIOR TO CONSTRUCTION
PLUG & BLOCK 8" WATER MAIN
4+00
5+00
6+00
7+00
8+00
9+00
10+00
11+00


. 8" DUCTILE IRON WATER MAIN
LASS 50 w/BLUE POLYWRAP
BB-2
BB-3
Barn
7+00
8+00
9+00
10+00
11+00
12+00
13+00
14+00
15+00
16+00
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670
680
690
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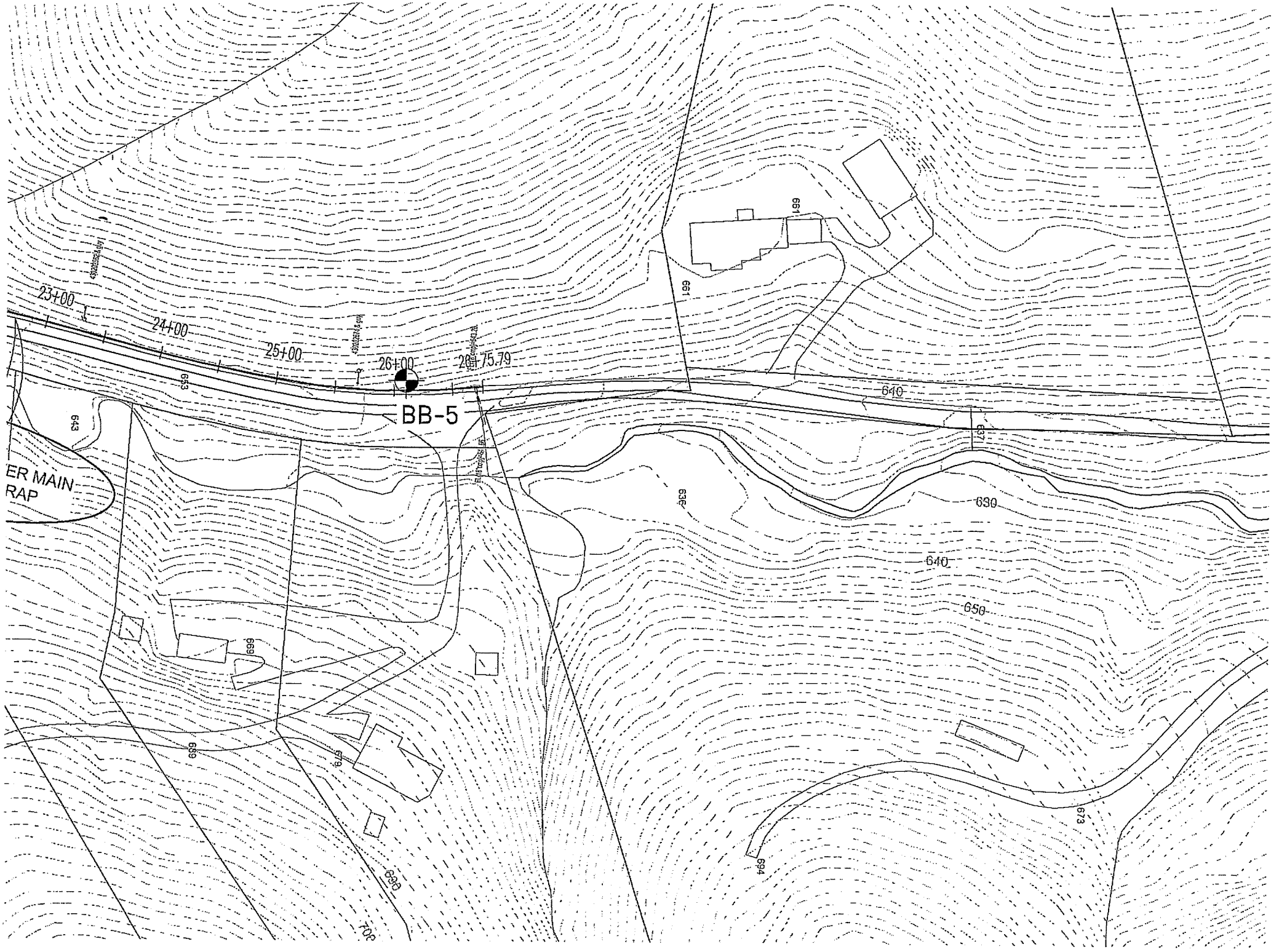
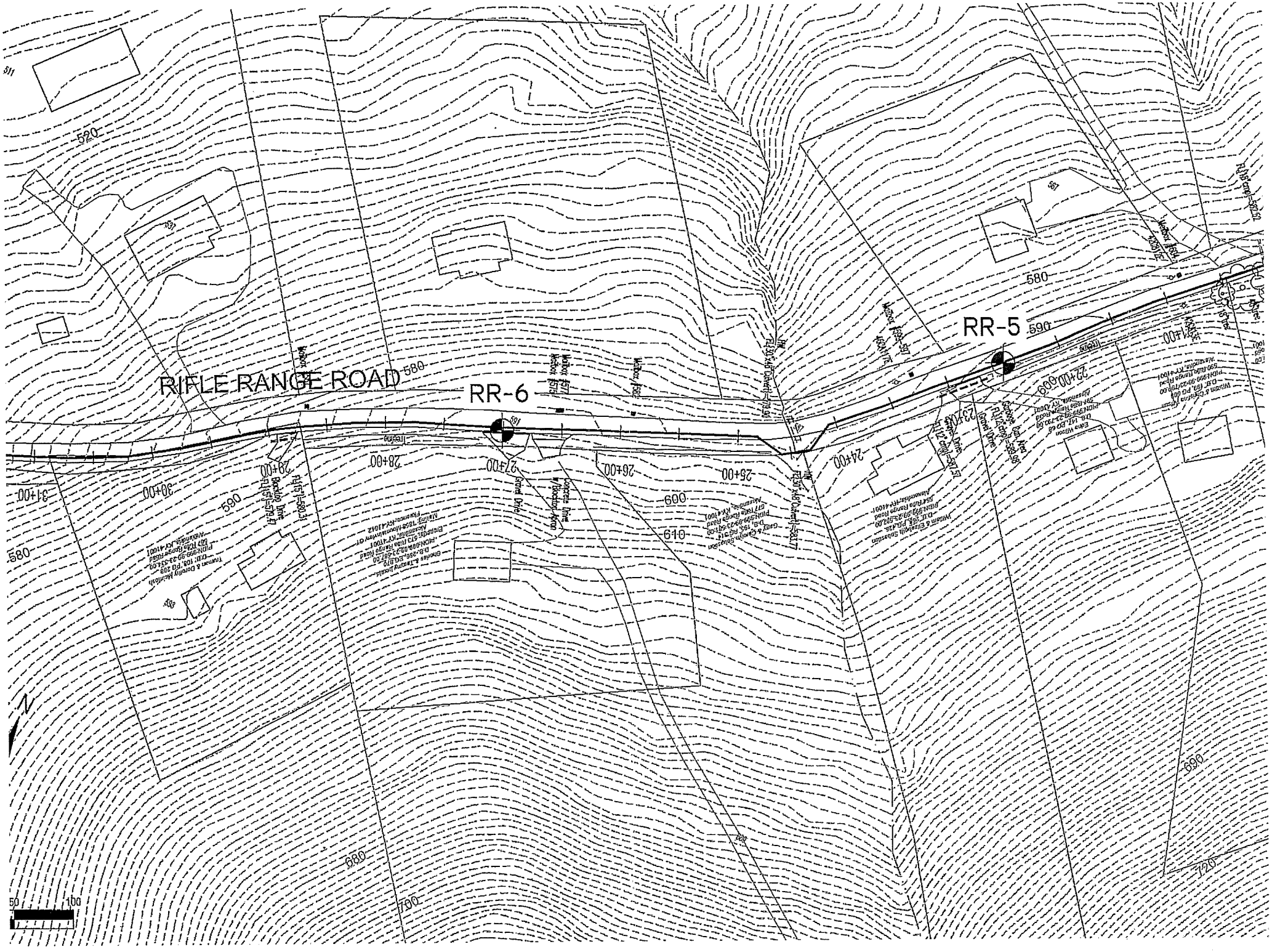
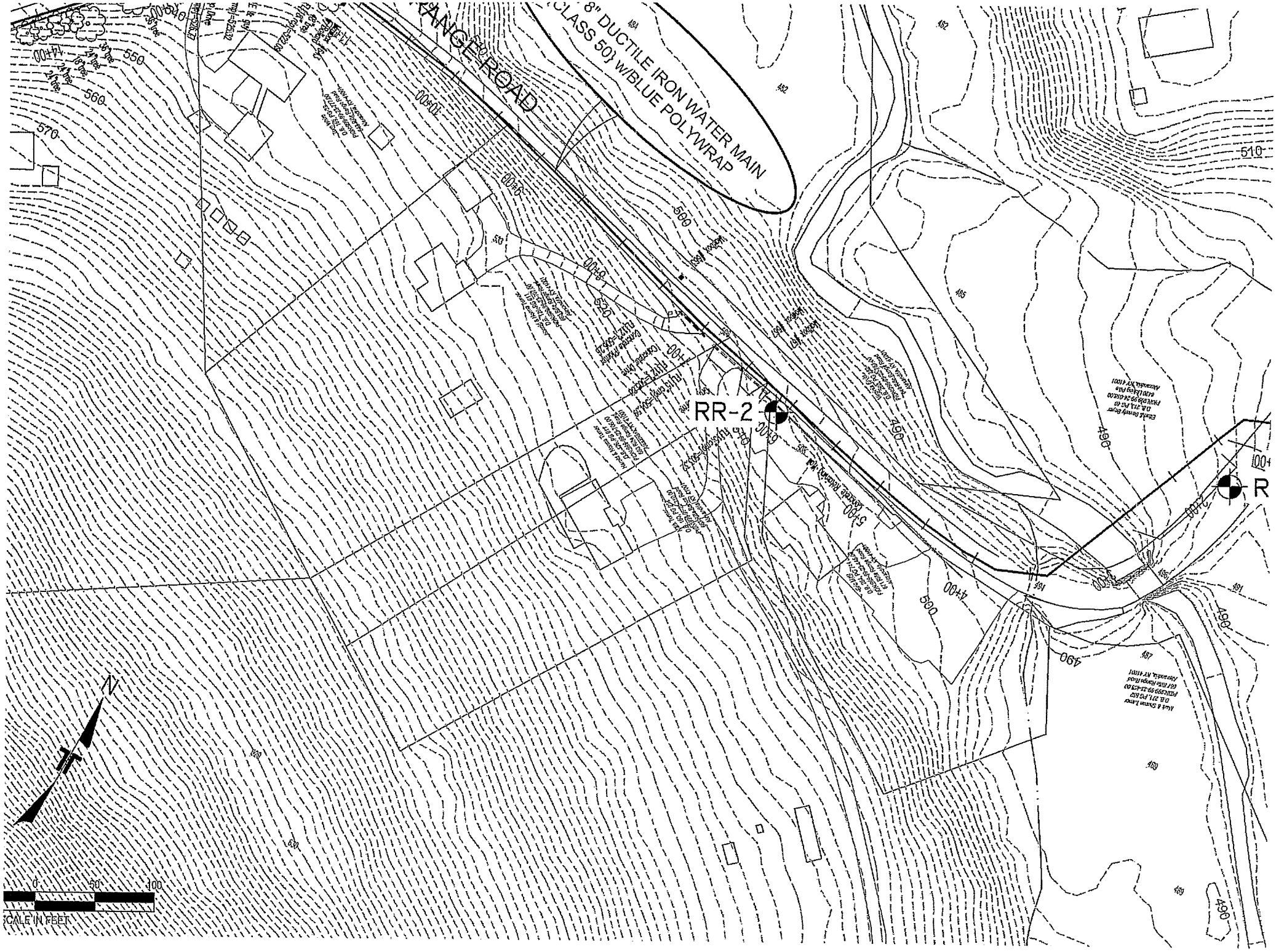
720
730
735
739
748
753
760
765
767


23+00
24+00
25+00
26+00
BB-5
653
643
661
640
637
636
630
650
669
689
679
673
694
ER MAIN
RAP


RIFLE RANGE ROAD
RR-6
RR-5
580
590
600
610
680
690
700
720
21+00
22+00
23+00
24+00
26+00
27+00
28+00
29+00
30+00
31+00
50
100


8" DUCTILE IRON WATER MAIN
CLASS 50) W/BLUE POLYWRAP
RANGE ROAD
RR-2
N
0
50
100
SCALE IN FEET

LOG OF BORING NO. OR-1

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Site Plans (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 855 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.3 TOPSOIL 854.7									
	LEAN CLAY, little sand, brown, very stiff		CL	1	SS	100	5-4-6 (10)	18		7000*
			CL	2	SS	100	8-9-10 (19)	20		8000*
		5	CL	3	SS	100	2-4-5 (9)	21		6000*
	7.5 847.5									
	FAT CLAY, (LAKEBED), brown, trace		CH	4	SS	100	4-5-8 (13)	29		8000*
	9 gray, very stiff 846									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	N/E	WD	
WL	N/E	AB	
WL			

HCN A Terracon COMPANY

BORING STARTED	12-15-09
BORING COMPLETED	12-15-09
RIG 2295-Truck	FOREMAN JM
LOGGED DRK	JOB # N1095342

LOG OF BORING NO. OR-2

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Site Plans (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	Approx. Surface Elev.: 830 ft									
	1 GRAVEL 829			1	SS	67	11-8			
	FAT CLAY, trace silt, brown, trace gray, very stiff		CH	1A	SS	67	4	22		
			CH	2	SS	100	8-9-12 (21)			8000*
	5 825	5								
	LEAN CLAY, little silt, brown and gray, very stiff		CL	3	SS	100	4-6-6 (12)	20		8000*
	7.5 822.5									
	HIGHLY WEATHERED SHALE, brown, soft			4	SS	100	6-10-19 (29)			
	9 821									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

A Terracon COMPANY

BORING STARTED	12-15-09		
BORING COMPLETED	12-15-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

LOG OF BORING NO. EZ-1

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Site Plans (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	Approx. Surface Elev.: 786 ft									
	FAT CLAY, trace sand and limestone fragments, brown, very stiff		CH	1	SS	61	7-6-6 (12)	16		8000*
	2.5 783.5									
	FAT CLAY, trace root matter, brown, stiff		CH	2	SS	22	4-5-5 (10)	25		4000*
	5 781	5								
	FAT CLAY, trace sand and limestone fragments, brown, very stiff		CH	3	SS	67	2-5-5 (10)	36		6000*
			CH	4	SS	100	2-4-19 (23)			7000*
	9 777									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

HCN A Terracon COMPANY

BORING STARTED	12-14-09		
BORING COMPLETED	12-14-09		
RIG	D-50 Track	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

LOG OF BORING NO. EZ-2

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Site Plans (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	Approx. Surface Elev.: 819 ft									
	LEAN CLAY, trace root matter, brown, stiff		CL	1	SS	100	3-3-4 (7)	25		4000*
	2.5 816.5									
	LIMESTONE FRAGMENTS			2	SS	100	50/0.2			
	5 814	5								
	WEATHERED SHALE with **LIMESTONE FRAGMENTS**			3	SS	100	41-50/0.3			
	7.5 811.5									
	Auger Refusal Boring Completed @ 7.5 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▽
WL	▽ N/E	AB	▽
WL			

A Terracon COMPANY

BORING STARTED	12-14-09		
BORING COMPLETED	12-14-09		
RIG	D-50 Track	FOREMAN	AM
LOGGED	DRK	JOB #	N1095342

LOG OF BORING NO. BB-1

CLIENT: **Northern Kentucky Water District**

ELEVATION REFERENCE: **Interpolated from Site Plans (Approximate)**

SITE: **Alexandria, Kentucky**

PROJECT: **Subdistrict H Water Main Extension Project**

Boring Location: As Shown on Test Boring Location Plan

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	Approx. Surface Elev.: 690 ft									
	LEAN CLAY, little sand, trace root matter, dark brown trace gray, medium stiff		CL	1	SS	100	1-2-3 (5)	28		2000*
	2.5 687.5									
	FAT CLAY, trace sand, brown, very stiff		CH	2	SS	100	2-2-5 (7)	25		7000*
		5	CH	3	SS	100	3-5-5 (10)	22		8000*
			CH	4	SS	100	3-5-7 (12)			8000*
	9 681									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

A Terracon COMPANY

BORING STARTED	12-14-09		
BORING COMPLETED	12-14-09		
RIG	D-50 Track	FOREMAN	AM
LOGGED	DRK	JOB #	N1095342

LOG OF BORING NO. BB-2

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Site Plans (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	Approx. Surface Elev.: 680 ft									
	0.8 ASPHALT PAVEMENT 679.2									
	FAT CLAY, trace root matter, gray and brown, very stiff		CH	1	SS	72	2-3-5 (8)	25		7000*
	2.5 677.5									
	LEAN CLAY, little limestone fragments, brown and gray, stiff		CL	2	SS	61	7-12-29 (41)	20		3000*
	5 675	5								
	HIGHLY WEATHERED SHALE, trace limestone fragments, brown, soft			3	SS	94	9-10-19 (29)			
				4	SS	67	10-20-29 (49)			
	9 671									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

A Terracon COMPANY

BORING STARTED	12-15-09		
BORING COMPLETED	12-15-09		
RIG	D-50 Track	FOREMAN	AM
LOGGED	DRK	JOB #	N1095342

LOG OF BORING NO. BB-3

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Site Plans (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 675 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.9 ASPHALT PAVEMENT 674.1									
	2.5 **FILL**, fat clay, trace sand, brown and gray, very stiff 672.5			1	SS	100	3-4-4 (8)	29		6000*
	FAT CLAY, trace sand, brown, very stiff		CH	2	SS	33	4-5-8 (13)	24		8000*
	5 670	5								
	LEAN CLAY, trace sand and shale fragments, brown and gray, moist, hard (RESIDUUM)		CL	3	SS	100	6-15-12 (27)	20		9000*
	7.5 667.5									
	FAT CLAY, little limestone fragments, brown, very stiff		CH	4	SS	100	9-15-26 (41)			6000*
	9 666									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

HCN A Terracon COMPANY

BORING STARTED	12-15-09		
BORING COMPLETED	12-15-09		
RIG	D-50 Track	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

LOG OF BORING NO. BB-4

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Site Plans (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 656 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.8 ASPHALT PAVEMENT 655.2									
	LEAN CLAY, little silt, brown and gray, very stiff		CL	1	SS	100	5-5-7 (12)	20		
	2.5 653.5									
	FAT CLAY, trace shale framents, gray and brown, very stiff (RESIDUUM)		CH	2	SS	78	9-9-11 (20)	20		
		5	CH	3	SS	57	7-50/0.1	17		
	7.5 648.5									
	HIGHLY WEATHERED SHALE, trace limestone fragments, brown, soft			4	SS	83	19-15-20 (35)			
	9 647									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▽
WL	▽ N/E	AB	▽
WL			

HCN A Terracon COMPANY

BORING STARTED	12-15-09		
BORING COMPLETED	12-15-09		
RIG	D-50 Track	FOREMAN	AM
LOGGED	DRK	JOB #	N1095342

LOG OF BORING NO. BB-5

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Site Plans (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

GRAPHIC LOG	DESCRIPTION	DEPTH, ft	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf	
	Approx. Surface Elev.: 652 ft										
	0.8 ASPHALT PAVEMENT 651.2										
	FAT CLAY, brown, very stiff (RESIDUUM)		CH	1	SS	83	2-3-4 (7)	23		8000*	
	2.5 649.5										
	LEAN CLAY, trace shale fragments, brown, hard		CL	2	SS	61	8-10-31 (41)	21			LL = 42 PI = 19
	5 647	5									
	SILTY CLAY, trace shale fragments, brown, very stiff		CL ML	3	SS	89	9-9-16 (25)	19		8000*	
	7.5 644.5										
	COMPLETELY WEATHERED SHALE, brown, very soft			4	SS	100	7-12-21 (33)				
	9 643										
	Boring Completed at 9 ft.										

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

HCN A Terracon COMPANY

BORING STARTED	12-15-09		
BORING COMPLETED	12-15-09		
RIG	D-50 Track	FOREMAN	AM
LOGGED	DRK	JOB #	N1095342

LOG OF BORING NO. RR-1

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Site Plans (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	Approx. Surface Elev.: 497 ft									
	0.8 ASPHALT PAVEMENT 496.2									
	FILL, fat clay, trace sand, brown and gray, very stiff 2.5 494.5			1	SS	89	4-4-5 (9)	26		6000*
	FILL, lean clay, trace brick fragments, dark brown, stiff			2	SS	67	10-16-11 (27)	23		4000*
	5 492									
	FAT CLAY, some limestone fragments, trace sand, brown, medium stiff to very stiff	5	CH	3	SS	100	5-9-11 (20)	22		2000*
	8.9 488.1		CH	4	SS	72	12-16-50/0.4	19		7000*
	Boring Completed at 8.9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▽ N/E	AB	▼
WL			

HCN A Terracon COMPANY

BORING STARTED	12-15-09		
BORING COMPLETED	12-15-09		
RIG	D-50 Track	FOREMAN	AM
LOGGED	DRK	JOB #	N1095342

LOG OF BORING NO. RR-2

CLIENT: **Northern Kentucky Water District**

ELEVATION REFERENCE: **Interpolated from Site Plans (Approximate)**

SITE: **Alexandria, Kentucky**

PROJECT: **Subdistrict H Water Main Extension Project**

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 507 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf	
	0.6 ASPHALT PAVEMENT 506.4										
	LEAN CLAY, trace limestone fragments, brown, very stiff		CL	1	SS	56	9-16-25 (41)	21		8000*	
			CL	2	SS	0	14-8-10 (18)				
	5 502	5									
	FAT CLAY, trace shale and limestone fragments, brown, very stiff to hard		CH	3	SS	78	4-9-15 (24)	26		9000*	LL = 50 PI = 27
			CH	4	SS	100	5-9-14 (23)	20		8000*	
	9 498										
	Boring Completed at 9 ft.										

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

HCN A Terracon COMPANY

BORING STARTED	12-15-09		
BORING COMPLETED	12-15-09		
RIG	D-50 Track	FOREMAN	AM
LOGGED	DRK	JOB #	N1095342

LOG OF BORING NO. RR-3

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Site Plans (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 527 ft

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.7 ASPHALT PAVEMENT 526.3									
	FILL, lean clay, trace sand, dark gray and gray, stiff 2.5 524.5			1	SS	100	6-4-4 (8)	26		4000*
	FAT CLAY, trace silt and sand, brown, very stiff		CH	2	SS	67	4-5-5 (10)	24		7000*
	5 522	5								
	FAT CLAY, little limestone fragments, trace shale fragments, brown, very stiff		CH	3	SS	83	3-5-6 (11)	24		6000*
	7.5 519.5									
	HIGHLY WEATHERED SHALE, trace limestone fragments, brown, soft 9 518			4	SS	100	7-11-14 (25)			
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

A Terracon COMPANY

BORING STARTED	12-15-09		
BORING COMPLETED	12-15-09		
RIG	D-50 Track	FOREMAN	AM
LOGGED	DRK	JOB #	N1095342

LOG OF BORING NO. RR-4

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Site Plans (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

Approx. Surface Elev.: 567 ft

GRAPHIC LOG	DESCRIPTION		DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	0.6 ASPHALT PAVEMENT	566.4									
	1 GRANULAR BASE	566		CL	1	SS	67	7-11-8 (19)	20		7000*
	2.5 **LEAN CLAY**, little silt, trace limestone fragments, brown, very stiff	564.5		CH	2	SS	100	12-18-11 (29)	22		9000*
	FAT CLAY, little limestone fragments, brown, hard										
	5	562	5		3	SS	100	20-9-14 (23)	18		
	WEATHERED SHALE, brown, soft										
	9	558			4	SS	100	10-15-24 (39)			
	Boring Completed at 9 ft.										

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

A Terracon COMPANY

BORING STARTED	12-15-09		
BORING COMPLETED	12-15-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

LOG OF BORING NO. RR-5

CLIENT: **Northern Kentucky Water District**

ELEVATION REFERENCE: **Interpolated from Site Plans (Approximate)**

SITE: **Alexandria, Kentucky**

PROJECT: **Subdistrict H Water Main Extension Project**

Boring Location: As Shown on Test Boring Location Plan

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	Approx. Surface Elev.: 591 ft									
	0.4 TOPSOIL 590.6									
	LEAN CLAY, trace silt and sand, dark brown, very stiff		CL	1	SS	100	5-4-5 (9)	22		8000*
			CL	2	SS	100	10-11-12 (23)	24		8000*
	5 586	5								
	FAT CLAY, brown, trace gray, very stiff		CH	3	SS	100	3-3-5 (8)	25		7000*
			CH	4	SS	100	3-3-6 (9)	24		8000*
	9 582									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

HCN A Terracon COMPANY

BORING STARTED	12-15-09		
BORING COMPLETED	12-15-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

LOG OF BORING NO. RR-6

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Site Plans (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	Approx. Surface Elev.: 592 ft									
	0.3 TOPSOIL 591.7									
	LEAN CLAY, little silt, trace to little shale fragments (RESIDUUM), brown, very stiff to hard		CL	1	SS	100	11-5-6 (11)	18		8000*
			CL	2	SS	100	14-14-35 (49)	16		9000*
		5	CL	3	SS	100	10-11-15 (26)	18		9000*
	7.5 584.5									
	HIGHLY WEATHERED SHALE, brown, soft			4	SS	100	6-10-18 (28)			
	9 583									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

A Terracon COMPANY

BORING STARTED	12-15-09		
BORING COMPLETED	12-15-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

LOG OF BORING NO. RR-7

CLIENT: Northern Kentucky Water District

ELEVATION REFERENCE: Interpolated from Site Plans (Approximate)

SITE: Alexandria, Kentucky

PROJECT: Subdistrict H Water Main Extension Project

Boring Location: As Shown on Test Boring Location Plan

GRAPHIC LOG	DESCRIPTION	DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, %	SAMPLES BLOWS / 6in. (SPT - N)	TESTS WATER CONTENT, %	TESTS DRY UNIT WT pcf	TESTS UNCONFINED STRENGTH, psf
	Approx. Surface Elev.: 545 ft									
	0.7 ASPHALT PAVEMENT 544.3									
	0.9 GRANULAR BASE 544.1									
	LEAN CLAY, trace shale fragments (RESIDUUM), little silt, brown, very stiff		CL	1	SS	100	3-2-4 (6)	20		6000*
			CL	2	SS	100	6-8-10 (18)	20		8000*
		5	CL	3	SS	100	5-4-7 (11)	24		8000*
	7.5 537.5									
	WEATHERED SHALE, brown, soft			4	SS	100	13-16-27 (43)			
	9 536									
	Boring Completed at 9 ft.									

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ N/E	WD	▼
WL	▼ N/E	AB	▼
WL			

HCN A Terracon COMPANY

BORING STARTED	12-15-09		
BORING COMPLETED	12-15-09		
RIG	2295-Truck	FOREMAN	JM
LOGGED	DRK	JOB #	N1095342

Field Exploration Description

The boring locations were laid out on the site by HCN/Terracon personnel using water main alignment plans provided by Viox & Viox Inc., (dated 5/21/09 for Enzweiler Road and Orlando Drive, and undated for Rifle Range Road and Barrs Branch Road). Ground surface elevations at test boring locations were interpolated from the water main alignment plan drawings. The borings were drilled with track- and truck-mounted rotary drill rigs using continuous flight hollow-stem augers to advance the boreholes. Samples of the soil encountered in the borings were obtained using the split-barrel sampling procedures.

In the split barrel sampling procedure, the number of blows required to advance a standard 2 inch O.D. split barrel sampler the last 12 inches of the typical total 18 inch penetration by means of a rope and cathead manual safety hammer with a free fall of 30 inches, is the standard penetration resistance value (SPT-N). This value is used to estimate the in-situ relative density of cohesionless soils and consistency of cohesive soils.

An automatic SPT hammer was used to advance the split-barrel sampler in the borings performed on this site. A greater efficiency is typically achieved with the automatic hammer compared to the conventional safety hammer operated with a cathead and rope. Published correlations between the SPT values and soil properties are based on the lower efficiency cathead and rope method. This higher efficiency affects the standard penetration resistance blow count (N) value by increasing the penetration per hammer blow over what would obtained using the cathead and rope method. The effect of the automatic hammer's efficiency has been considered in the interpretation and analysis of the subsurface information for this report.

The samples were tagged for identification, sealed to reduce moisture loss, and taken to our laboratory for further examination, testing, and classification. Information provided on the boring logs attached to this report includes soil descriptions, consistency evaluations, boring depths, sampling intervals, and groundwater conditions. The borings were backfilled with auger cuttings prior to the drill crew leaving the site.

A field log of each boring was prepared by the drill crew. These logs included visual classifications of the materials encountered during drilling as well as the driller's interpretation of the subsurface conditions between samples. Final boring logs included with this report represent the engineer's review of obtained soil samples, driller's field logs and include modifications based on laboratory tests of the samples.

APPENDIX B

SUPPORTING INFORMATION

Laboratory Test Results
Northern Kentucky Water District ▪ Subdistrict H Water Main Extension Project
Alexandria, KY ▪ HCN Project No. N1095342

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TABLE I: CLASSIFICATION TEST DATA

Boring No.	Sample No. (SS)	Depth (Ft.)	U.S.C.S. Classification	Moisture Content (%)	Atterberg Limits		
					Liquid Limit (%)	Plastic Limit (%)	Plasticity Index
BB-1	1	0-1.5		28.4			
	2	2.5-4		25.1			
	3	5-6.5		22.3			
BB-2	1	1-2.5		24.9			
	2	2.5-4		20.4			
BB-3	1	1-2.5		28.6			
	2	2.5-4		24.3			
	3	5-6.5		20.2			
BB-4	1	1-2.5		20.3			
	2	2.5-4		19.6			
	3	5-6.5		17.2			
BB-5	1	1-2.5		22.8			
	2	2.5-4	CL	20.6	42	23	19
	3	5-6.5		18.9			
EZ-1	1	0-1.5		16.2			
	2	2.5-4		24.7			
	3	5-6.5		36.3			
EZ-2	1	0-1.5		24.5			
OR-1	1	0-1.5		17.6			
	2	2.5-4		20.3			
	3	5-6.5		20.9			
	4	7.5-9		29.2			
OR-2	2	2.5-4		21.6			
	3	5-6.5		19.6			

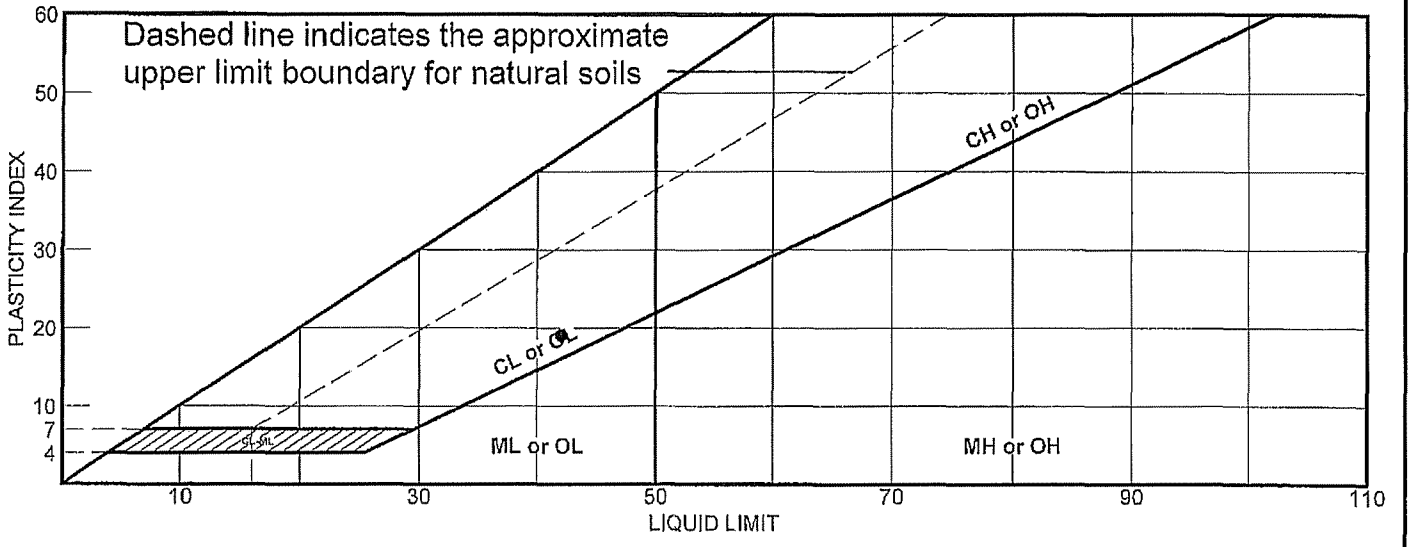
Laboratory Test Results
Northern Kentucky Water District ■ Subdistrict H Water Main Extension Project
Alexandria, KY ■ HCN Project No. N1095342

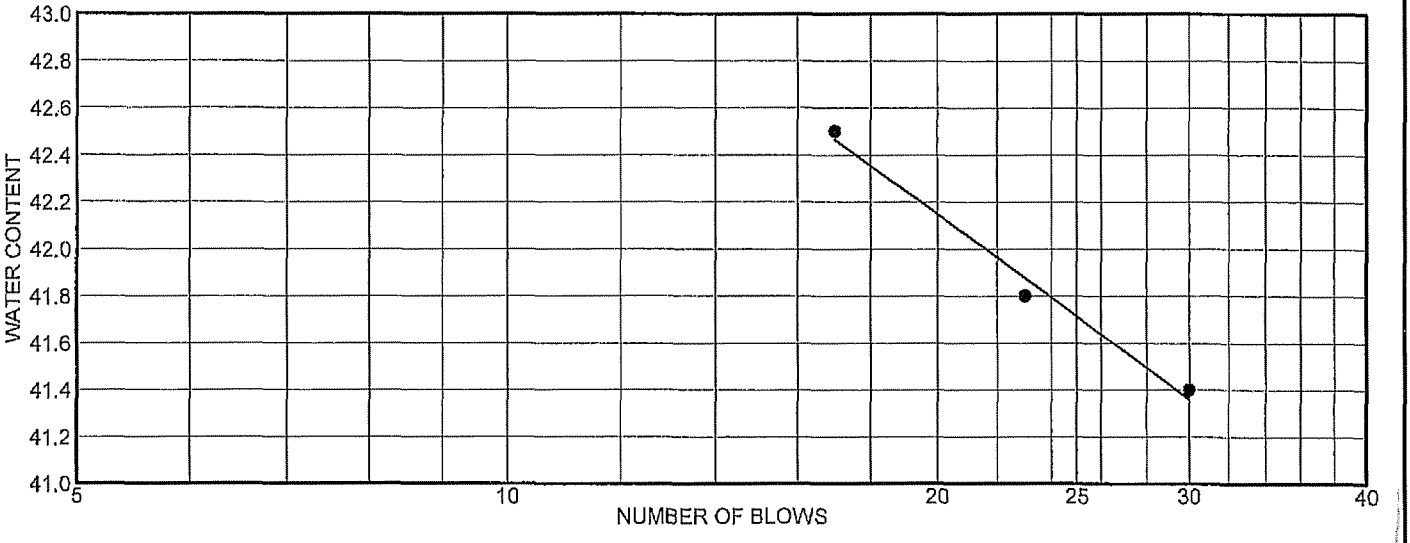
A Terracon COMPANY

TABLE I: CLASSIFICATION TEST DATA

Boring No.	Sample No. (SS)	Depth (Ft.)	U.S.C.S. Classification	Moisture Content (%)	Atterberg Limits		
					Liquid Limit (%)	Plastic Limit (%)	Plasticity Index
RR-1	1	1-2.5		25.7			
	2	2.5-4		22.8			
	3	5-6.5		21.7			
	4	7.5-9		18.8			
RR-2	1	1-2.5		21.4			
	3	5-6.5	CH	25.7	50	23	27
	4	7.5-9		20.0			
RR-3	1	1-2.5		25.6			
	2	2.5-4		23.6			
	3	5-6.5		23.8			
RR-4	1	1-2.5		19.9			
	2	2.5-4		21.6			
	3	5-6.5		17.8			
RR-5	1	0-1.5		21.8			
	2	2.5-4		23.9			
	3	5-6.5		25.2			
	4	7.5-9		23.6			
RR-6	1	0-1.5		17.5			
	2	2.5-4		16.1			
	3	5-6.5		18.1			
RR-7	1	0-1.5		20.4			
	2	2.5-4		20.0			
	3	5-6.5		24.0			

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	LT BROWN AND GRAY LEAN CLAY	42	23	19			CL

Project No. N1095342 **Client:** NORTHERN KENTUCKY WATER DISTRICT

Project: SUBDISTRICT H WATER MAIN EXTENSION PROJECT
ALEXANDRIA, KY

● **Source:** BB-5 **Sample No.:** 2 **Elev./Depth:** 2.5-4'

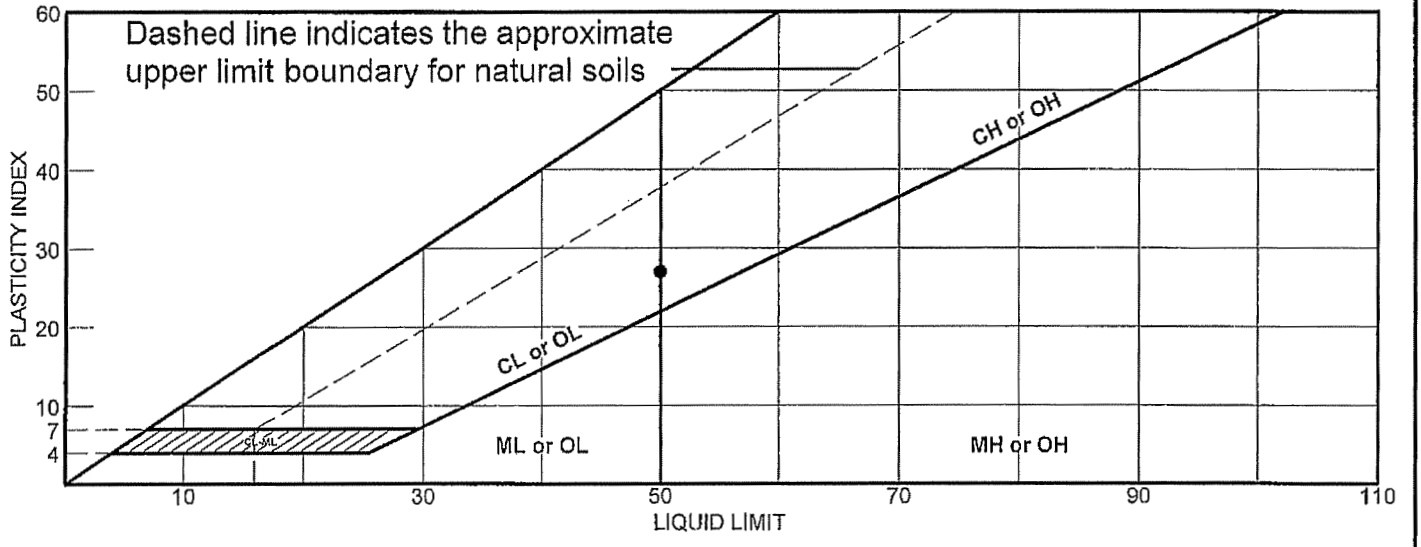
Remarks:
● WC=20.6%

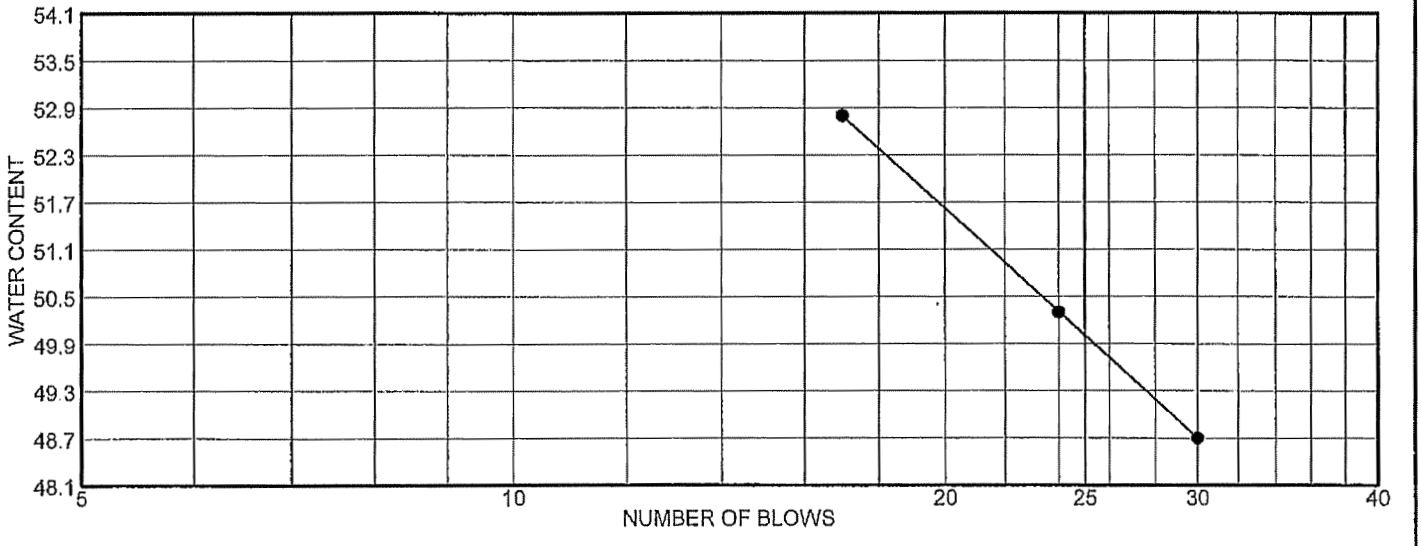
LIQUID AND PLASTIC LIMITS TEST REPORT

H. C. NUTTING COMPANY

Figure 9986

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	LT BROWN AND GRAY FAT CLAY	50	23	27			CH

Project No. N1095342 **Client:** NORTHERN KENTUCKY WATER DISTRICT

Project: SUBDISTRICT H WATER MAIN EXTENSION PROJECT

ALEXANDRIA, KY

● **Source:** RR-2 **Sample No.:** 3 **Elev./Depth:** 5-6.5

Remarks:

● WC=25.7%

LIQUID AND PLASTIC LIMITS TEST REPORT

H. C. NUTTING COMPANY

Figure 10002

Laboratory Testing

Selected soil samples were tested in the laboratory to measure natural water content and Atterberg Limits. A calibrated hand penetrometer was used to estimate the approximate unconfined compressive strength of some samples. The calibrated hand penetrometer has been correlated with unconfined compression tests and provides a better estimate of soil consistency than visual examination alone. The test results are provided on the boring logs included in Appendix A.

Descriptive classifications of the soils indicated on the boring logs are in accordance with the enclosed General Notes and the Unified Soil Classification System. Also shown are estimated Unified Soil Classification Symbols. A brief description of this classification system is attached to this report. All classification was by visual manual procedures. Selected samples were further classified using the results of Atterberg limit testing. The Atterberg limit test results are also provided on the boring logs.

APPENDIX C
SUPPORTING DOCUMENTS

GENERAL NOTES

DRILLING & SAMPLING SYMBOLS:

SS:	Split Spoon – 1-3/8" I.D., 2" O.D., unless otherwise noted	HS:	Hollow Stem Auger
ST:	Thin-Walled Tube - 2" O.D., unless otherwise noted	PA:	Power Auger
RS:	Ring Sampler - 2.42" I.D., 3" O.D., unless otherwise noted	HA:	Hand Auger
DB:	Diamond Bit Coring - 4", N, B	RB:	Rock Bit
BS:	Bulk Sample or Auger Sample	WB:	Wash Boring or Mud Rotary

The number of blows required to advance a standard 2-inch O.D. split-spoon sampler (SS) the last 12 inches of the total 18-inch penetration with a 140-pound hammer falling 30 inches is considered the "Standard Penetration" or "N-value".

WATER LEVEL MEASUREMENT SYMBOLS:

WL:	Water Level	WS:	While Sampling	N/E:	Not Encountered
WCI:	Wet Cave in	WD:	While Drilling		
DCI:	Dry Cave in	BCR:	Before Casing Removal		
AB:	After Boring	ACR:	After Casing Removal		

Water levels indicated on the boring logs are the levels measured in the borings at the times indicated. Groundwater levels at other times and other locations across the site could vary. In pervious soils, the indicated levels may reflect the location of groundwater. In low permeability soils, the accurate determination of groundwater levels may not be possible with only short-term observations.

DESCRIPTIVE SOIL CLASSIFICATION: Soil classification is based on the Unified Classification System. Coarse Grained Soils have more than 50% of their dry weight retained on a #200 sieve; their principal descriptors are: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are principally described as clays if they are plastic, and silts if they are slightly plastic or non-plastic. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size. In addition to gradation, coarse-grained soils are defined on the basis of their in-place relative density and fine-grained soils on the basis of their consistency.

CONSISTENCY OF FINE-GRAINED SOILS

Unconfined Compressive Strength, Qu, psf	Standard Penetration or N-value (SS) Blows/Ft.	Consistency
< 500	<2	Very Soft
500 – 1,000	2-3	Soft
1,001 – 2,000	4-6	Medium Stiff
2,001 – 4,000	7-12	Stiff
4,001 – 8,000	13-26	Very Stiff
8,000+	26+	Hard

RELATIVE DENSITY OF COARSE-GRAINED SOILS

Standard Penetration or N-value (SS) Blows/Ft.	Ring Sampler (RS) Blows/Ft.	Relative Density
0 – 3	0-6	Very Loose
4 – 9	7-18	Loose
10 – 29	19-58	Medium Dense
30 – 49	59-98	Dense
50+	99+	Very Dense

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term(s) of other Constituents	Percent of Dry Weight
Trace	< 15
With	15 -- 29
Modifier	> 30

GRAIN SIZE TERMINOLOGY

Major Component of Sample	Particle Size
Boulders	Over 12 in. (300mm)
Cobbles	12 in. to 3 in. (300mm to 75 mm)
Gravel	3 in. to #4 sieve (75mm to 4.75 mm)
Sand	#4 to #200 sieve (4.75mm to 0.075mm)
Silt or Clay	Passing #200 Sieve (0.075mm)

RELATIVE PROPORTIONS OF FINES

Descriptive Term(s) of other Constituents	Percent of Dry Weight
Trace	< 5
With	5 – 12
Modifiers	> 12

PLASTICITY DESCRIPTION

Term	Plasticity Index
Non-plastic	0
Low	1-10
Medium	11-30
High	30+

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]					Soil Classification	
					Group Symbol	Group Name [B]
Coarse Grained Soils: More than 50% retained on No. 200 sieve	**Gravels:** More than 50% of coarse fraction retained on No. 4 sieve	**Clean Gravels:** Less than 5% fines [C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$ [E]		GW	Well-graded gravel [F]
			$Cu < 4$ and/or $1 > Cc > 3$ [E]		GP	Poorly graded gravel [F]
		Gravels with Fines: More than 12% fines [C]	Fines classify as ML or MH		GM	Silty gravel [F,G,H]
			Fines classify as CL or CH		GC	Clayey gravel [F,G,H]
	Sands: 50% or more of coarse fraction passes No. 4 sieve	**Clean Sands:** Less than 5% fines [D]	$Cu \geq 6$ and $1 \leq Cc \leq 3$ [E]		SW	Well-graded sand [I]
			$Cu < 6$ and/or $1 > Cc > 3$ [E]		SP	Poorly graded sand [I]
		Sands with Fines: More than 12% fines [D]	Fines classify as ML or MH		SM	Silty sand [G,H,I]
			Fines Classify as CL or CH		SC	Clayey sand [G,H,I]
Fine-Grained Soils: 50% or more passes the No. 200 sieve	**Silts and Clays:** Liquid limit less than 50	**Inorganic:**	PI > 7 and plots on or above "A" line [J]		CL	Lean clay [K,L,M]
			PI < 4 or plots below "A" line [J]		ML	Silt [K,L,M]
		Organic:	Liquid limit - oven dried	< 0.75	OL	Organic clay [K,L,M,N]
			Liquid limit - not dried			Organic silt [K,L,M,O]
	Silts and Clays: Liquid limit 50 or more	**Inorganic:**	PI plots on or above "A" line		CH	Fat clay [K,L,M]
			PI plots below "A" line		MH	Elastic Silt [K,L,M]
		Organic:	Liquid limit - oven dried	< 0.75	OH	Organic clay [K,L,M,P]
			Liquid limit - not dried			Organic silt [K,L,M,Q]
Highly organic soils:	Primarily organic matter, dark in color, and organic odor				PT	Peat

[A] Based on the material passing the 3-in. (75-mm) sieve

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay

[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥ 15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.

[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ≥ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.