



Pipeline Design for Installation by Horizontal Directional Drilling

Task Committee on Pipeline Design for Installation
by Horizontal Directional Drilling



Edited by
Eric R. Skonberg, P.E.
Tennyson M. Muindi, P.E.



Pipeline Design for Installation by Horizontal Directional Drilling

Other Titles of Interest

Horizontal Auger Boring Projects: Second Edition, prepared by Horizontal Auger Boring Task Force of the Trenchless Installation of Pipelines Committee (ASCE/UESI 2017). MOP 106, Second Edition, presents current practices for the planning, design, and construction of pipelines using horizontal auger boring methods. (ISBN 978-0-7844-1458-3)

Pilot Tube and Other Guided Boring Methods, prepared by the Task Committee on Pilot Tube and Other Guided Boring Methods of the Committee on Trenchless Installation of Pipelines (ASCE/UESI 2017). MOP 133 provides a detailed description of the pilot tube and guided boring methods with chapters on project planning, site and geotechnical assessment, shaft design, pipe characteristics and design, contract documents, and construction aspects. (ISBN 978-0-7844-1474-3)

Direct Steerable Pipe Thrusting, prepared by the Task Committee on Direct Steerable Pipe Thrusting (ASCE/UESI 2023). MOP 155 details how engineers and construction professionals can utilize the Direct Steerable Pipe Thrusting (DSPT) method to design and install pipelines. (ISBN 978-0-7844-1610-5)

Pipe Ramming: Second Edition, prepared by the Pipe Ramming Task Force of the Trenchless Installation of Pipelines Committee; edited by Glenn M. Boyce (ASCE/UESI 2020). MOP 115, Second edition, describes current pipe ramming practices in design and construction of pipelines under roads, railroads, streets, and other constructed and natural structures and obstacles including information on culvert replacements, pipe crushing, slick bores, pipe extraction, and assists with horizontal directional drilling projects. (ISBN 978-0-7844-1560-3)

Sustainable Design of Pipelines: Guidelines for Achieving Advanced Functionality, prepared by the Task Committee on the Sustainable Design of Pipelines of the Pipeline Location and Installation Committee; edited by Walt Schwarz, Patrick White, and Mark S. Mihm (ASCE/UESI 2022). MOP 151 details the sustainable design and construction of pipelines and presents methods, practices, and decisions that influence and guide sustainable planning, design, construction, and operation, including the Envision infrastructure sustainability rating system. (ISBN 978-0-7844-1597-9)

Pipeline Design for Installation by Horizontal Directional Drilling

Third Edition

Edited by
Eric R. Skonberg, P.E.
Tennyson M. Muindi, P.E.

Prepared by
Task Committee on Pipeline Design for Installation by Horizontal
Directional Drilling of the Trenchless Installation of Pipelines
Committee of the Pipelines Division of the Utility Engineering and
Surveying Institute of the American Society of Civil Engineers



UTILITY ENGINEERING
& SURVEYING
INSTITUTE

Published by the American Society of Civil Engineers

Cataloging-in-Publication Data on file with the Library of Congress

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia 20191-4382
asce.org/bookstore | ascelibrary.org | amplify.org

Any statements expressed in these materials are those of the individual authors and do not necessarily represent the views of ASCE, which takes no responsibility for any statement made herein. No reference made in this publication to any specific method, product, process, or service constitutes or implies an endorsement, recommendation, or warranty thereof by ASCE. The materials are for general information only and do not represent a standard of ASCE, nor are they intended as a reference in purchase specifications, contracts, regulations, statutes, or any other legal document. ASCE makes no representation or warranty of any kind, whether express or implied, concerning the accuracy, completeness, suitability, or utility of any information, apparatus, product, or process discussed in this publication, and assumes no liability therefor. The information contained in these materials should not be used without first securing competent advice with respect to its suitability for any general or specific application. Anyone utilizing such information assumes all liability arising from such use, including but not limited to infringement of any patent or patents.

ASCE and American Society of Civil Engineers—Registered in US Patent and Trademark Office.

Photocopies and permissions. Permission to photocopy or reproduce material from ASCE publications can be requested by sending an email to permissions@asce.org or by locating a title in the ASCE Library (<https://ascelibrary.org>) and using the “Permissions” link.

Errata: Errata, if any, can be found at <https://dx.doi.org/10.1061/9780784485712>.

Copyright © 2024 by the American Society of Civil Engineers.
All Rights Reserved.

ISBN 978-0-7844-1624-2 (soft cover)
ISBN 978-0-7844-8571-2 (PDF)
ISBN 978-0-7844-8572-9 (ePub)

Manufactured in the United States of America.
28 27 26 25 24 1 2 3 4 5

Cover photo credit: J. D. Hair & Associates, Inc.

MANUALS AND REPORTS ON ENGINEERING PRACTICE

(As developed by the ASCE Technical Procedures Committee, July 1930, and revised March 1935, February 1962, and April 1982)

A manual or report in this series consists of an orderly presentation of facts on a particular subject, supplemented by an analysis of limitations and applications of these facts. It contains information useful to the average engineer in his or her everyday work, rather than findings that may be useful only occasionally or rarely. It is not in any sense a “standard,” however, nor is it so elementary or so conclusive as to provide a “rule of thumb” for nonengineers.

Furthermore, material in this series, in distinction from a paper (which expresses only one person’s observations or opinions), is the work of a committee or group selected to assemble and express information on a specific topic. As often as practicable, the committee is under the direction of one or more of the Technical Divisions and Councils, and the product evolved has been subjected to review by the Executive Committee of the Division or Council. As a step in the process of this review, proposed manuscripts are often brought before the members of the Technical Divisions and Councils for comment, which may serve as the basis for improvement. When published, each manual shows the names of the committees by which it was compiled and indicates clearly the several processes through which it has passed in review, so that its merit may be definitely understood.

In February 1962 (and revised in April 1982), the Board of Direction voted to establish a series titled “Manuals and Reports on Engineering Practice,” to include the manuals published and authorized to date, future Manuals of Professional Practice, and Reports on Engineering Practice. All such manual or report material of the Society would have been refereed in a manner approved by the Board Committee on Publications and would be bound, with applicable discussion, in books similar to past manuals. Numbering would be consecutive and would be a continuation of present manual numbers. In some cases of joint committee reports, bypassing of journal publications may be authorized.

A list of available Manuals of Practice can be found at <https://ascelibrary.org/page/books/s-mop>.

CONTENTS

CONTRIBUTORS.....xi

BLUE-RIBBON PANEL REVIEWERS xiii

ACKNOWLEDGMENTS xv

PREFACE xvii

1. INTRODUCTION 1

2. PREDESIGN SURVEYS 5

 2.1 Introduction..... 5

 2.2 Surface Survey..... 5

 2.3 Subsurface Investigation 8

 2.3.1 Utility Research..... 8

 2.3.2 Geotechnical Investigation..... 11

 References..... 14

3. DRILLED PATH DESIGN..... 15

 3.1 Introduction..... 15

 3.2 Penetration Angles 16

 3.3 Depth of Cover..... 18

 3.4 Elevations of Entry and Exit..... 19

 3.5 Radius of Curvature 19

 3.6 Directional Accuracy and Tolerances..... 20

 3.7 Pilot Hole Intersect Method 21

 3.8 Multiple-Line Installations..... 22

 3.9 Utility Casings..... 23

 3.10 Annular Seepage..... 23

 References..... 24

4. PIPE DESIGN 25

 4.1 Introduction..... 25

 4.2 Installation Loads 25

 4.2.1 Tension 26

 4.2.2 Bending 28

 4.2.3 External Pressure 28

 4.3 Operating Loads 29

 4.3.1 Internal Pressure 29

 4.3.2 Bending 29

 4.3.3 Thermal Expansion..... 30

 4.3.4 External Pressure 30

 4.4 Pipe Material 31

 4.5 Stresses in Steel Pipe..... 33

 4.5.1 Installation Stresses 33

 4.5.2 Operating Stresses 37

 4.6 Stresses in a High-Density Polyethylene Pipe and Fusible Polyvinyl Chloride Pipe..... 39

 4.6.1 Installation Stresses 39

 4.6.2 Post-installation Stresses..... 43

 4.7 Ductile Iron Pipe Design Considerations..... 45

 4.7.1 Installation Stresses 45

 4.7.2 External Loads..... 46

 4.8 Steel Pipe Corrosion Coating 46

 4.8.1 Field Joint Coatings 46

 4.8.2 Armoring Coatings..... 47

 References 47

5. CONSTRUCTION IMPACTS 51

 5.1 Introduction..... 51

 5.2 Workspace..... 51

 5.3 Drilling Fluid..... 53

 5.3.1 Consumption and Characteristics..... 53

 5.3.2 Containment and Recycling..... 54

 5.3.3 Inadvertent Drilling Fluid Returns 54

 5.3.4 Annular Seepage..... 57

 5.3.5 Structural Failure by Piping..... 58

 5.3.6 Drilling Fluid and Cuttings Disposal 59

 5.4 Surface Casing..... 59

 5.5 Breakover Bends 60

 5.6 Noise..... 62

 References 62

6. AS-BUILT DOCUMENTATION 63

 6.1 Introduction..... 63

 6.2 Construction Staking..... 63

6.3 Documentation of Actual Drilled Path End Points..... 63

6.4 Required Measurements prior to Commencing Drilling
Operations 64

6.5 Pilot-Hole As-Built Calculations 64

6.6 Pilot-Hole Survey Data 64

6.6.1 Surface-Monitoring System..... 64

6.6.2 Gyroscopic Steering Tool..... 67

6.6.3 Walkover System 67

6.7 Pilot-Hole As-Built Error Distribution..... 67

6.8 Pilot-Hole As-Built Drawing..... 68

6.9 Post-Installation Survey..... 68

References 69

GLOSSARY 71

INDEX 77

CONTRIBUTORS

Principal Authors

Eric Skonberg, P.E.,
Trenchless Engineering Corp., *MOP Task Committee Chair*

Luke Bever, P.E.,
J. D. Hair & Associates, Inc.

Maureen Carlin, Ph.D., P.E.,
Garver

Roz Javadizadeh,
Stantec

Michelle Macauley, P.E.,
Macauley Expert Services

Mark Miller, P.E.,
GeoEngineers, Inc.

Jim Williams, P.E.,
Brierley Associates

Webb Winston, P.E.,
Williams

ASCE UESI Committee on Trenchless Installation of Pipelines (TIPS)

Jon Robison, P.E., *Chair*
Jeff Boschert, P.E., *ExCom Liaison*

BLUE-RIBBON PANEL REVIEWERS

A thank you to the members of the Blue-Ribbon Review Committee who reviewed the finished document and provided their comments:

Tennyson Muindi, P.E.,
Delve Underground, *Chair*

Samuel Ariaratnam, Ph.D., P.E.,
Arizona State University

Andrew Sparks, P.E.,
Laney Directional Drilling

Mohammad Najafi, Ph.D., P.E.,
University of Texas at Arlington

ACKNOWLEDGMENTS

The American Society of Civil Engineers (ASCE) and the Utility Engineering & Surveying Institute (UESI) acknowledge the work of the Task Committee on Pipeline Design for Installation by Horizontal Directional Drilling. This group comprises individuals from many backgrounds, including design and consulting engineering, the construction industry, equipment manufacturing, pipeline owners, and academia.

PREFACE

Horizontal directional drilling (HDD) is a surface-launched trenchless method for installing underground utilities and pipelines. Horizontal directional drilling has a storied history, existing in some form or fashion since the early 1970s. The HDD method initially gained prominence in the oil and gas industry for installing pipelines beneath waterways in remote locations, but refinements of the technology have allowed it to expand to a wide variety of markets and locations that include residential and urban areas. The tools and techniques initially used in the HDD process were an outgrowth of the oil well drilling industry but over time have evolved to become well established in their own right. These innovations were driven by the various markets for which HDD now serves.

Pipeline Design for Installation by Horizontal Directional Drilling. MOP 108, Third Edition, was prepared by the Horizontal Directional Drilling Design Guideline Task Committee as part of the broader Trenchless Installation of Pipelines (TIPS) Committee of ASCE. This manual is intended to assist engineers, contractors, and owners in understanding the HDD method, its various capabilities and limitations, and to help execute relevant trenchless projects in a safe and effective manner. The task committee acknowledges that HDD technology and its application continues to evolve and change, notwithstanding combining with other trenchless methods, to challenge contemporary understandings of HDD best practices and procedures.

Project planners shall consider the limitations of this manual, as no document can account for all project-specific constraints nor the evolution in practice borne out of the passage of time.

Contractors, owners, and engineers engaged in HDD design and construction shall possess competency in HDD practices and procedures. In the absence of such experience, contractors, owners, and engineers

should, at a minimum, seek additional guidance and/or subject matter expertise to avoid suboptimal outcomes and increased project risks.

The Horizontal Directional Drilling Design Guideline Task Committee would like to thank all contributors for their time and effort in advancing this publication to the third edition.

CHAPTER 1

INTRODUCTION

This Manual of Practice addresses the planning, design, and installation considerations for major pipeline or duct segments installed by horizontal directional drilling (HDD). Horizontal directional drilling is a trenchless installation method used to install pipes and pipelines and is accomplished using a specialized horizontal drilling rig with ancillary tools and equipment. It is separate from other installation methods such as microtunneling, auger boring, or pipe ramming, which are addressed in other Manuals of Practice.

Some of the potential benefits of utilizing HDD for a trenchless crossing include the following:

- No shafts are needed for installations. Shallow pits may be required.
- Relatively long lengths can be installed in a single installation.
- Curved alignments are possible.
- Minimum ground disturbances between entry and exit points.

Horizontal directional drilling is suitable in a variety of ground conditions and groundwater depths. Some of the limitations and risks of HDD include the following:

- Not applicable for all pipe materials.
- Some ground conditions (i.e., gravelly soils and cobbles) may present a higher risk.
- Inadvertent fluid returns could occur at unplanned locations.
- Creates a relatively large volume of fluid and spoils that require disposal.

For the purposes of this manual, major HDD installations are usually longer than 500 ft, greater than 4 in. in diameter, or have site constraints, complexities, or high-risk aspects (such as significant elevation differences between entry and exit or adjacent structures or utilities). The design practices described in this manual are not usually applicable to small-diameter or short trenchless segments of pipe, duct, or cable.

Horizontal directional drilling is a trenchless installation method that is typically a surface-to-surface installation method with similar elevations between tie-ins to adjacent pipeline segments. Construction is accomplished in three phases. The first phase consists of drilling a small-diameter pilot hole along a designed installation path, using steering and locating techniques to achieve the design. The second phase consists of enlarging the pilot hole through sequential reaming passes to a diameter suitable for installation of the pipe. The third phase consists of pulling the pipe through the enlarged borehole.

Since the previous edition of this manual, modifications, adaptations, and refinements to the HDD design and installation process have been developed. Key revisions and updates to this manual include

- Guidance for recommended number and depth of geotechnical borings for HDD design (Chapter 2, Section 2.3.2);
- Additional discussion on recommended depth of cover for HDD installations (Chapter 3, Section 3.3);
- New section discussing impacts of elevation differences on HDD design (Chapter 3, Section 3.4);
- New information for fusible polyvinyl chloride (FPVC) pipe (Chapter 3, Section 3.5, and Chapter 4);
- Additional discussion on HDD tolerances (Chapter 3, Section 3.6), the pilot hole intersect method (Section 3.7), and utility casings (Section 3.9);
- New sections on annular seepage (Chapter 3, Section 3.10, and Chapter 5, Section 5.3.4);
- New sections on surface casing (Chapter 5, Section 5.4), breakover bends (Chapter 5, Section 5.5), and noise (Chapter 5, Section 5.6);
- New discussion on pilot hole survey systems (Chapter 6, Section 6.6); and
- New recommendations for pilot hole as-builts (Chapter 6, Section 6.8) and the post-installation survey (Chapter 6, Section 6.9).

This manual has been prepared to serve as a guide for design engineers, contractors, owners, and permitting agencies. The authors presume that the user has some knowledge of the HDD installation process and pipeline design methods. However, HDD engineering is a specialized field, and engineers with geotechnical and HDD design experience should be engaged throughout the stages of planning, design, and construction.

Other sources of information and design methods should be consulted for guidance on designing the pipeline to satisfy hydraulics, permitting, safety, and service and regulatory requirements. This manual is not a general design handbook for pipelines, and it is not meant to replace sound engineering judgment.

CHAPTER 2

PREDESIGN SURVEYS

2.1 INTRODUCTION

A successful horizontal directional drilling (HDD) project requires thorough surface and subsurface investigations and utility data prior to construction. Trenchless installation methods require the design engineer to provide the contractor with sufficient information to reasonably anticipate the obstacles and challenges that may be encountered for the contractor to best determine how to plan and execute drilling operations. During the design phase, surface and subsurface investigation information assists in determining the suitability of utility installation by the HDD process. In addition, some projects may require or benefit from additional considerations for environmental and socioeconomic factors in determining final design.

This chapter describes data that need to be gathered and presented to enhance the prospects for a successful HDD installation. Obtaining and providing accurate surface and subsurface information results in fewer installation problems and change orders during the work.

2.2 SURFACE SURVEY

Once HDD is selected as the installation method, a surface survey should be performed. Prior to conducting the actual survey, the design engineer should investigate the site to determine the limits of workspace available for equipment staging and setup, pipe layout and welding/fusion, and areas of potential impact such as adjacent utilities or structures. The survey should be performed in an area sufficient in size to accommodate

equipment setup, truck access, and supply storage locations. Typical staging areas required for HDD construction projects are discussed in Chapter 5.

The survey should be conducted along the proposed drill path centerline for a width of approximately 100 ft. Each HDD project has specific staging requirements that should be identified by the design engineer prior to initiating the field survey.

Information to be gathered during the survey should include, but not be limited to, the following:

- Existing grade elevation data referenced to a public datum if practical;
- Surface features such as roadways, sidewalks, utility poles, overhead power lines, and fire hydrants;
- Ledge or rock outcrops;
- Existing boring/test pit locations;
- Waterways;
- Potentially delineated wetlands;
- Culverts;
- Visible subsurface utility landmarks, such as manholes or valve boxes;
- Structures such as buildings, towers, retaining walls, piers, or bridges adjacent to the proposed drill path;
- Structures, obstructions, or objects that may interfere with magnetic guidance systems;
- Historical use of land identifying potential hazards/contamination areas;
- Indigenous areas; and
- Environmental considerations with regard to endangered and protected species.

A plan view of a finished survey for a major HDD river crossing is shown in [Figure 2-1](#). Contours are useful because HDD activities on the surface are limited to entry and exit point work areas. Contours are particularly integral to a proper design when annular pressure and hydraulic fracture calculations are required as the depth of cover. This especially applies to ampacity calculations for high-voltage cables, which require elevation data along the alignment. It is important to note that HDD crossings designed with significant elevation differences between entry and exit present unique challenges to HDD construction, and therefore, the ground surface elevations should be readily apparent in the design drawing. Controlled aerial photographs, if recently taken, are commonly used and can eliminate the need for surveying many surface features.

Waterway crossings may also require a hydrographic survey and/or bathymetric survey. The hydrographic survey should include tidal ranges and edges of waterways. It should be conducted along the proposed drill

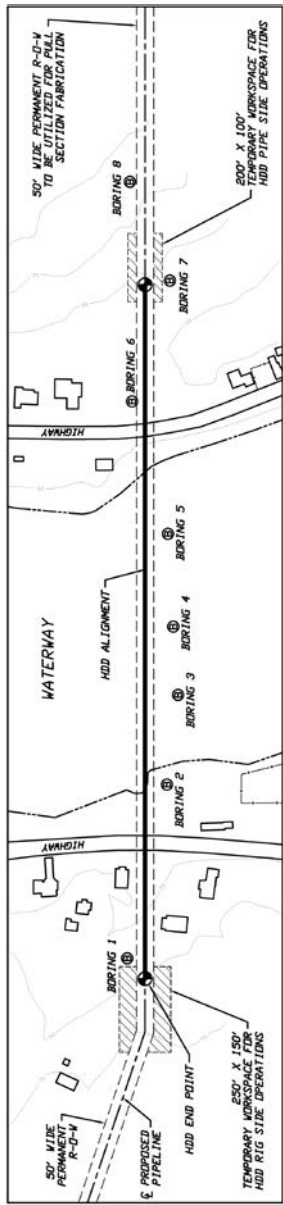


Figure 2-1. Survey of a major HDD river crossing.

path and include appropriate data upstream and downstream of the path. As with the surface survey, bottom contours are imperative, particularly when dramatic variations in bathymetric elevations are anticipated. Most drilled paths are designed well below a waterway bottom, and even small variations in elevation may affect design particularly to longer and more complex crossings.

2.3 SUBSURFACE INVESTIGATION

Once the surface survey data have been obtained, an evaluation of subsurface features can be initiated. Subsurface feature concerns that may affect HDD design and therefore should be investigated include the presence of existing utilities, adjacent structure foundations or other human-engineered obstructions, and geotechnical and hazardous material conditions along the proposed HDD alignment.

2.3.1 Utility Research

Utility survey information is important to the planning and execution of the HDD project. Unlike conventional open-cut installations, HDD projects require the contractor to install the utility line *in the blind*. Unable to see possible obstructions, the contractor should be given as complete and accurate a record of potential conflicts and utility clearances as may be obtained by reasonable and diligent inquiry. Guidance with respect to subsurface utility research may be found in CI/ASCE 38-02 ([ASCE 2002](#)).

The designer should also be aware of code requirements related to the degree of utility research required. For example, Section 434.13.5(a) of ASME B31.4-2009 ([ASME 2010](#), p. 49) requires the crossing plan and profile drawings to include all “pipelines, utilities, cables, and structures that cross the drill path, are parallel to and within 100 ft (30 m) of the drill path, and that are within 100 ft (30 m) of the drilling operation, including mud pits and bore pits.” Alternate codes may not contain such specific details. The designer should research utility location and depiction requirements on a project-specific basis prior to the initiation of the process.

The first step in obtaining subsurface utility information is accomplished during the surface survey by locating visible subsurface utility landmarks. Knowing where valve boxes, manholes, and other structures are located provides a starting point for utility research. The design engineer should exercise due diligence not only in identifying what utilities are located along the proposed HDD path, but also in determining their horizontal and vertical positions, especially if the existing utility was installed via HDD construction.

A critical method of obtaining utility data is to contact the local *One Call* locating service. This service can be reached by dialing 8-1-1 from anywhere in the United States and is a somewhat easy and straightforward way to identify and locate utilities that are members of the *One Call* network. In areas where *One Call* assistance is not provided during the design phase of work, municipalities and private utility companies should be contacted to obtain the required information. Additional research is often necessary, however, because not all utilities belong to the *One Call* Network and *One Call* Locates are not always clear with respect to depth. This is particularly true in the case of utilities installed by HDD. Postconstruction locating methods are often not effective because of the significant depth of HDD installations.

Obtaining as-built record drawings for the project vicinity gives the design engineer location information and identify many, if not all, of the utility lines that could be encountered. However, because of the possibility of inaccurate information, relying solely on record drawings may not be sufficient for construction. Because of the potential impact on construction and damage to utility lines if HDD operations interfere an existing utility, the contractor must conduct additional investigations before beginning work to verify utility line locations where they are at risk of damage by new construction activities. This may include private utility locators using one of the investigation methods described subsequently.

In general, if the HDD alignment is expected to pass within 10 ft of an existing utility, physically confirming the location prior to initiating HDD operations if possible is prudent. Utilities located more than 10 ft away may also require physical locating depending on specific requirements of the utility owner or the presence of unusual ground conditions along the proposed HDD alignment near the existing utility. Methods of confirming subsurface utility locations include

- Pipe locators,
- Ground-penetrating radar,
- Probing,
- Manual excavation,
- Vacuum excavation, and
- Seismic survey.

2.3.1.1 Pipe Locators. Utility lines can have both horizontal and vertical locations identified by means of surface-applied pipe locators. Pipe locators can be instruments that simply detect underground lines by means of a magnetic field application similar to a metal locator. More sophisticated locators require imposing an electric current on the utility line. Applied current travels along the utility and is detected and traced with the pipe locator. Nonmetallic pipe such as polyvinyl chloride or high-density

polyethylene that has not been installed with a tracing wire cannot be detected with a pipe locator. Some underground utility lines such as electric and cable television lines can produce a detectable signal as long as current is flowing through them. Pipe locators are usually less accurate with depth but can be extremely accurate in locating utilities buried less than 12 ft deep, depending on conditions.

2.3.1.2 Ground-Penetrating Radar. Ground-penetrating radar (GPR) utilizes radio waves to detect underground lines and surfaces. When an object is detected, the radio waves reflect back to the receiver that records the information. The data are downloaded to a computer, and a profile of the utility and geologic information is plotted for interpretation. Subsurface obstructions such as rock and groundwater surfaces are also detected by GPR and can result in misinterpretation of the gathered data. Because interpretation of the data is a critical element in GPR surveys, this method should be performed by a qualified professional and used in conjunction with other subsurface survey methods to improve the accuracy of the information. GPR is most useful at depths of less than 20 ft when the density of the object or utility in question contrasts greatly with the surrounding ground. GPR is also highly dependent on soil type and moisture content. GPR is more effective in dry sands than in wet soils and does not work well in clay soils and soils that are contaminated with salt, or in identifying pipe made of clay.

2.3.1.3 Vacuum Excavation. Nondestructive vacuum excavation is used to physically remove soil and expose the utility lines being investigated. Unlike test pits, which are completed by means of excavation equipment such as a backhoe, vacuum excavation removes the soils by means of high-pressure air or water jetting. This method reduces the risk of damage to existing utility lines. The water or air loosens the soil, which, in turn, is vacuumed into a truck for replacement upon completion of the survey. Vacuum excavation allows for a physical identification of horizontal and vertical alignments of utility lines and pipe materials and provides the designer with information concerning soil types and water table levels. Conventional vacuum excavation is limited to depths of approximately 20 ft and is most effective in unsaturated, medium-density, gravel size or smaller granular soils. Excavation holes must be large enough to allow for a visual inspection of the uncovered utility lines.

2.3.1.4 Seismic Surveys. Seismic surveys require that a small explosive charge or impact by means of sledgehammer be initiated and detected via a series of detectors or geophones spaced along the path of the utility line. A time recorder is used to record the time of origin of the wave and the time of arrival at each detector. Similar to GPR, the water table and type of subsurface material affect the data output; therefore, proper interpretation

of the data is critical, and greater density contrasts tend to yield more beneficial results. Seismic surveys are usually used in uncongested areas or locations where deep utility installations exist. Once the subsurface utility information is obtained, it should be correlated to determine possible conflicts and then included in the survey base drawings.

2.3.2 Geotechnical Investigation

A second phase of subsurface investigation for HDD projects is the determination of ground conditions. Once the proposed routing has been identified, a geotechnical investigation must be performed. Geotechnical investigations are critical to the success of construction operations imperative to managing risk appropriately. The geotechnical investigation should be tailored to suit the complexity of the installation being designed. Investigations for complex installations typically consist of two phases: a general geologic and historic desktop review and geotechnical borings.

A general geologic review involves examining existing geological and historical data to determine what conditions might be encountered in the vicinity of the installation. Existing data may be available from construction project records in the area of the HDD (e.g., buildings, piers, bridges, levees) and/or water well drilling logs, historic aerial photographs, and geologic maps. Previous geotechnical borings performed in the project vicinity should also be studied. Such an overall review provides information that may not be developed from a geotechnical survey consisting only of exploratory borings. It also allows the geotechnical survey to be tailored to the anticipated conditions at the site, thus enhancing the effectiveness of the survey.

A typical geotechnical survey consists of taking exploratory borings to observe subsurface ground behavior and to collect samples for classification and laboratory analysis. Methods utilized in the survey of underground utilities, as described previously, can also be incorporated into the geotechnical survey.

The number, location, and depth of exploratory borings should be determined taking into account site-specific conditions such as the geology of the area, availability of access, availability of existing data, cost, and so on. At a minimum, one boring each near the entry location and near the exit location should be completed, as well as along the proposed alignment at a minimum spacing of 300 to 500 ft, as access allows. Borings should be offset from the proposed bore profile centerline approximately 20 to 40 ft to reduce the possibility of drilling fluid inadvertently surfacing through the borings during HDD operations. The borings should penetrate to an elevation 20 to 30 ft below the depth of the proposed drill path to collect sufficient information to allow for design modifications and anticipated pilot-hole deviations during construction. Areas of geologic transition and/or significant contrast in physical ground properties can present

unique challenges to HDD construction and should be carefully scrutinized with a greater frequency of investigation.

Sampling interval and technique should be set to accurately describe subsurface material characteristics taking into account site-specific conditions. Typically, split spoon samples are taken in soil overburden at 5-ft depth intervals in accordance with ASTM D1586-11 ([ASTM 2011b](#)). The designer may desire more frequent intervals within the zone 10 ft above and 10 ft below the planned drill path. Where rock is encountered, it should be cored in accordance with ASTM D2113-08 ([ASTM 2008](#)), to the maximum depth of the boring. The following data should be developed from exploratory test borings:

- Standard classification of soils in accordance with ASTM D2487-10 ([ASTM 2011a](#));
- Particle size analysis, gradation and distribution;
- Standard penetration test values where applicable (usually unconsolidated ground);
- Cored samples of rock with lithologic description, rock quality designation, and percent recovery;
- Unconfined compressive strength for representative rock samples (frequency of testing should be proportionate to the degree of variation encountered in rock core samples);
- Unconsolidated-undrained triaxial shear strength;
- Mohs hardness for rock samples;
- Unit weight;
- Atterberg limits;
- Cohesion coefficient;
- Cerchar abrasivity for rock samples, as applicable;
- Swell testing;
- Soil friction angle; and
- Depth to water table.

Steps for abandoning exploratory borings based on local requirements must be undertaken. At a minimum, borings must be backfilled in a manner that will minimize the possibility of drilling fluid migration from the borehole during subsequent HDD operations. A mixture containing cementitious grout and a bentonite product to promote expansion is recommended. Cuttings from the drilling operation may be incorporated into the backfill mixture if considered beneficial. The upper 5 ft of land-based borings should be filled with the surrounding soil.

The results of the subsurface survey should be presented in the form of a geotechnical report containing generalized stratigraphy, groundwater conditions, engineering analysis, boring logs, test results, and a profile of the subsurface conditions. It is also useful to present exploratory boring logs on the drill path profile. An example of this is shown in [Figure 2-2](#).