Geotechnical Baseline Reports for HDD: *When, Why, and How*

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1. INTRODUCTION

As HDD installations get longer, larger, and increasingly complicated, the cost and risk of these installations also increases. The intent of the Geotechnical Baseline Report is to identify project-specific risk and balance the risk between the Contractor performing the work and the Owner. The goal of a well-written GBR is to establish measurable baseline statements describing ground conditions and behaviors in advance of bidding and construction. As shown on the following figure, the opportunity to minimize risk is greatest earlier in the project, whereas the cost associated with change is greatest later in the project cycle.

Risk Management over the Course of a Project

The purpose of the baseline statements is two-fold: during the bid process the baseline statements allow the Contractors a common basis of interpretation for their bid and during construction the baseline statements provide a contractual mechanism to evaluate potential differing site condition claims. In principal, if the subsurface conditions and ground behaviors encountered during construction are consistent with the baselines, the Contractor "owns" the condition. If specific subsurface conditions or ground behaviors exceed the baselines, and the Contractors' means and methods, schedule, or material costs are impacted, additional compensation from the Owner may be warranted.

More and more frequently Owners are requesting Geotechnical Baseline Reports (GBR's) for Horizontal Directional Drill (HDD) projects. However, ASCE's Geotechnical Baseline Reports for Construction was written specifically for the tunneling industry and does not address ground conditions and behaviors that influence HDD construction. As such, challenges arise for Owners and Design Engineers when adapting the ASCE guidelines to HDD projects. Owners and Design Engineers must evaluate the ground conditions for an HDD project and develop baseline statements that are project-specific, are realistic and measurable, capture the ground conditions that impact project cost and risk, and influence project success.

Other challenges with baseline reports for HDD projects come from Owners that are unfamiliar with the purpose, process, contracting implications, and cost of a well-written GBR. Often Owners see the GBR as a report that relieves the Owner of risk; this is not the intent. A well-written GBR is a report that is written by the Design Engineer with input, collaboration, and consensus from the Owner and that ultimately becomes part of the Contract documents.

The following section will address the challenges of writing baseline statements for HDD projects, the ground conditions and behaviors to baseline, how to craft measurable baseline statements, and suggestions on how to convey this information to a Contractor pool that may be unfamiliar with the GBR concept. Example baseline (both well and poorly written) statements from previous projects are presented.

> *"The opportunity to minimize risk is greatest earlier in the project."*

2. CHALLENGES OF WRITING A GBR FOR HDD PROJECTS

The GBR must not conflict with other sources of geotechnical data, and typically takes precedence over all other geotechnical-related documents, including data reports and design memoranda. This should be clearly expressed within the Contract Documents. For the baseline statements to be effective, they need to be specific to the construction process (HDD) and must be measurable during construction. Some additional challenges of writing GBRs for HDD projects are summarized below:

Owners that are unfamiliar with the contractual importance of GBRs:

Owners often incorrectly assume that the purpose of the GBR is to eliminate their risk. As noted, the purpose of the

GBR is not to relieve the Owner of risk, but rather to balance this risk between the Contractor and Owner. Where overly conservative or broad baselines are applied, the bid prices can be expected to increase, but the potential for claims will decrease. To accurately represent the Owner's desired risk and budget profile, the Owner's representatives should be involved during the baseline selection process and drafting of the baseline statements.

Contractors that are unfamiliar with the contractual importance of GBRs:

In many cases, small to medium-sized HDD contractors may not be familiar with the purpose, or the contractual implications of the GBR. Unless clearly presented, the GBR may be mistaken for a generic geotechnical report used to present data (e.g. a "test boring report"). A project which seeks to use a GBR should incorporate a pre-bid conference allowing review and explanation of the document and drilling subcontractors should be required to attend. Where appropriate, a pre-contract meeting may be warranted to further discuss the baselines and the expectations for measuring the baselines.

Baselines for HDD projects can be challenging to measure during construction:

Baselines that cannot be effectively measured may result in confusion and unnecessary conflict. Unlike large diameter tunneling, the HDD construction process typically does not allow direct inspection of the subsurface conditions encountered. Therefore, the Owner needs to provide full-time oversight of the HDD activities, which should be completed by field personnel experienced in HDD drilling and reaming methods. Ideally the field staff should also be familiar with the purpose and content of the GBR. In some cases, secondary subsurface explorations such as supplemental sampling and testing may be required to accurately document the conditions encountered.

Owners often desire a "turn-key" GBR:

Each GBR should be specifically written for the geologic setting, the project conditions, and in concert with the Owner's risk profile. Engineers should use caution if approached by an Owner that only desires to review the GBR with the Final Design Package. Because GBRs are part of the Contract Documents and are typically higher in the contractual hierarchy than other geotechnical documents, Owners should assemble a GBR team that includes legal professionals familiar with trenchless construction. Early engagement between the Owner, legal counsel, and the trenchless engineer will ensure that the Owner is aware of the legal ramifications of the GBR and that the baselines capture the trenchless risks for the project along with the Owner's desired risk profile. Owners should be actively involved in the GBR process from inception, through development of baseline statements, to supporting construction monitoring of conditions.

3. WHAT TO BASELINE?

The baseline report must be specific to the subsurface conditions and potential risk specific to the project. The risks may be identified based on previous drilling in the project vicinity, project-specific explorations and laboratory test data, and engineering geologic judgement.

Potential conditions that may warrant baselines for soil, bedrock, and groundwater are summarized in Tables 1 through 3, below. It should be noted that these are not considered comprehensive lists.

4. WHAT NOT TO BASELINE

In general, the following items are not baselined:

- Performance rates, such as drilling and reaming rates;
- Drill fluid components;
- Equipment size and capacity;
- Presence or length of conductor casings (this should be required as part of the design if needed);
- Drill tool types and drilling methods;
- Construction schedule;
- Direction of HDD construction; and
- Number and location of inadvertent fluid returns

5. HOW TO CONVEY BASELINE CONDITIONS

To better define baseline conditions, and to reduce complexity, the geologic units may be grouped into engineering units exhibiting similar behavior or responding similarly to HDD construction methods. Geologic units are often based on divisions of geologic time and on general geologic processes. Engineering units are based on how the ground (soil or bedrock) is anticipated to behave during construction. Ground that is expected to behave in a similar way may be grouped together into a single engineering unit. An example of an engineering unit comprised of soil and bedrock is provided below.

Rarely do the ground conditions along an HDD drill path remain constant for the entirety of the alignment. There are several ways to convey the variability of

Table 1 – Potential Sources of HDD Risk – Soil

Geotechnical Condition	Potential Risk
Gradation	Encountering unanticipated soil gradations (i.e. gravel instead of silt) may result in reduced penetration rates, require tool replacement, and require additional drill fluid additives.
Density and strength	Encountering unanticipated soil density and strength may impact penetration rates, steering accuracy, and the pressure confining capability, which is related to risk of inadvertent drill fluid returns ("frac-out").
Frequency of cobbles and boulders	Cobbles and boulders may become obstructions during drilling and reaming, which may redirect the drill string, impact line and grade control, and necessitate tooling changes.
Soil Abrasivity	Encountering abrasive soils will increase tool wear, which may impact the rate of penetration and increase costs associated with tool rehabilitation and replacement.
Swelling Clays	Swelling clays may restrict borehole annulus, increasing annular pressure and risk of frac-out. They may also result in increased costs associated with larger reamer diameter, additional drill fluid additives required to stabilize swelling behavior, and time spent swabbing the borehole.
Stickiness	Encountering soils with high stickiness may result in clogged tooling (i.e. drill fluid jets and pressure probes) requiring drill string retraction and reducing penetration rate.

Table 2 – Potential Sources of HDD Risk – Bedrock

Geotechnical Condition	Potential Risk
Top of Bedrock	Encountering unanticipated bedrock may require retooling and may dramatically impact penetration rates and project costs. A variable top of bedrock may require modification of drill path to avoid unnecessary drill rod and tool stress. Variability in the bedrock surface elevation can impact the ability to achieve the desired penetration angle of the pilot hole and to effectively seat conductor casings.
Bedrock Weathering	Encountering weathered bedrock may adversely impact line and grade control and may increase tool wear.
Bedrock Strength	Encountering high-strength bedrock will reduce impact penetration rate and may exacerbate abrasive conditions.
Bedrock Abrasivity	Encountering abrasive bedrock will increase tool wear, which will impact the rate of penetration and increase costs associated with tool rehabilitation and replacement.
Rock Quality Designation (RQD)	Encountering low RQD (high natural fracture density) material may increase tool wear and the potential for drill fluid loss.
Fracture Characteristics	The orientation and aperture of fractures may adversely impact pilot hole steering, alter the behavior of reamers, and increase the potential for drill fluid loss.
Faults, Shears	Fault and shear zones may adversely impact pilot hole steering, behavior of reamers, and increase the potential for drill fluid loss.

Table 3 – Potential Sources of HDD Risk – Groundwater

Groundwater Condition	Potential Risk
Elevated groundwater pressures	Encountering elevated groundwater pressures (i.e. artesian conditions) may result in borehole collapse and drill fluid dilution.
Lack of groundwater	Lack of groundwater may result in loss of drilling fluid to the formation and require additional drilling fluid.
Unanticipated groundwater chemistry	Man-made and natural contaminants (i.e. hydrocarbon and saltwater) can adversely impact drill fluid behavior.

the ground conditions along the drill path to the Contractor. It is especially important to convey the changing ground conditions to the Contractor if the variability between ground conditions is distinct, the risks associated with the various ground conditions are different, and the changing ground conditions impact construction. The anticipated variability of anticipated ground conditions along the HDD alignment can be conveyed to the Contractor graphically (i.e. with a figure), in text, or in a table. The following table (Figure 3) is an example of one way to convey the changing ground conditions and where each unit will be encountered along the drill path. In this project the ground conditions were grouped into engineering units based on anticipated construction behavior.

Note that the example above establishes a reasonable degree of accuracy. This will vary by project depending on the degree of certainty associated with the geologic interpretation.

In many cases, baselines are shown in bold to distinguish them from general discussion and commentary. This helps to avoid conflict regarding what is and is not technically a baseline.

4.1.2 Unit 2- Hard Clay

Unit 2 consists of hard, high plasticity clay and weathered shale. This unit can be excavated with a bladed drill bit. This unit will exhibit swelling characteristics, will require special drilling mud additives to control the swelling ground during drilling and may require oversizing the maximum reamer diameter to accommodate the swelling soils.

For baseline purposes the Plasticity Index (PI) is 40, the percent fines is 95%, and the swell potential is very high.

Figure 2. Example of an Engineering Unit

For baseline purposes, the alignment will be drilling through the following:

Unit	Begin Station	End Station
Unit 1	**0+00**	**2+80**
Unit 2	**2+80**	**3+15**
Unit 3	**3+15**	**3+50**
Unit 4	**3+50**	**10+75**
Unit 3	**10+75**	**10+90**
Unit 2	**10+90**	**11+40**
Unit 1	**11+40**	**12+90**

***** Note: Stationing should be considered accurate +/- 25-feet***

Figure 3. Conveying Variability of Conditions Along an Alignment Using a Table

6. EXAMPLE BASELINE STATEMENTS

It is important to recognize that that the selection of baseline values need not be based strictly on data but may also incorporate local experience. This allows the author to accommodate data gaps and sampling limitations. Two examples are below:

Example baseline statement developed to address boulders:

"The HDD design borepath geometry is expected to encounter glacial till. Although not encountered by the project test borings, the glacial till deposits are known to contain boulders, which may impact HDD tooling requirements, line and grade of the bore, and penetration rates. ***For baselines purposes the contractor shall expect to encounter a total of 10 boulders during drilling and reaming, ranging in size from 12 inches to 5 feet, as measured along the pilot-hole axis.*** *Individual boulders shall be documented based on drilling behavior and shall be measured once per individual occurrence."*

Example baseline statement developed to expand on a limited rock strength data set:

"The HDD design borepath will encounter bedrock consisting of gneiss. Limited laboratory testing completed for the project resulted in unconfined compression strength values ranging from 8,000 to 20,000 psi. Local experience suggests that stronger bedrock may be present. ***For baseline purposes, the contractor shall expect***

to encounter gneissic bedrock having an average compressive strength of 18,000 psi, and a maximum compressive strength of 30,000 psi."

Baseline statements should be concise and precise. While many baseline values are based on laboratory test results, an effective baseline statement does not provide a wide range of possible values. For example, consider the following statement:

"Standard Penetration Test (SPT) values ranged from 0 blows per foot (bpf) to 50/4 inches bpf, with an average of 11 bpf. For baseline conditions, SPT values are expected to range from 0 bpf to refusal."

This statement does not provide the Contractor with definitive information. An improvement may be to baseline the durability of the unit (i.e. medium durability) or separate the single geologic unit into engineering units that can be baselined with a narrow range.

Additionally, baseline statements should not over-rely on statistical analysis of laboratory test results, but rather provide a narrow range of values or (preferably) a single value. The following table (Figure 4) is an example where simplification would be appropriate to convey a compressive baseline strength.

	Density pcf	Compressive Strength psi
Number of samples	12	12
Mean	139	3458
Median	138	3438
High	152	5839
Low	129	1497
Baseline Average	142	3438

Figure 4. Example of an Overly Statistical Baseline Table

1.1 Limitations

This GBR presents baselines with respect to certain subsurface conditions that are expected to be encountered during construction that may influence the contractor's rate of progress, tooling selection, tool wear, or approach to bidding the project. The GBR establishes a contractual basis for allocation of geotechnical risk during performance of the work; it does not define the single correct interpretation of geotechnical conditions. This baseline report represents the conditions the contractor should assume for bidding purposes and for which the contractor is responsible for during construction.

Figure 5. Example of a Limitations Clause

7. EXAMPLE GBR OUTLINE FOR HDD CONSTRUCTION

While every GBR will be project specific, there are commonalities to each report. Below is an example outline from a previous GBR.

1. Introduction
    1.1 Project Information
    1.2 Purpose and Organization
    1.3 Limitations
2. Project Overview
3. Geologic Data and Project Setting
    3.1 Data Sources
    3.2 Regional Setting and Geology
4. Ground Characterization and Groundwater Conditions
    4.1 Engineering Units
    4.2 Groundwater Conditions
    4.3 Engineering Units Along Alignment
5. Design and Construction Considerations

Similar to the recommendations in the ASCE guidelines for GBRs, it is important to clearly state the hierarchy of the GBR relative to the GDR and other Contract documents. Often it is also important that the limitations section does not attempt to unduly limit the scope of the GBR or caution the contractor from relying on the information in the GBR. An example limitations clause is provided below in Figure 5.

8. CONCLUSIONS

GBRs for Horizontal Directional Drilling projects should be project specific, concise, and clearly convey the key geotechnical risks that may impact HDD construction. Owners should be involved throughout the GBR process and fully understand the contractual obligations of their GBR. A well written GBR provides baseline statements that are understandable, measurable, and defendable.

9. REFERENCES

ASCE Geotechnical Baseline Reports for Construction: Suggested Guidelines, 2007, Edited by Randall J. Essex., 72 pp.

Tunnelingonline.com, What's the Deal with GBR's, Contributing Author, June 6, 2019

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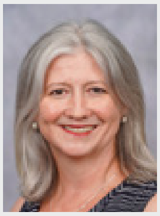

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