Appendix C. Driven Pile Report Example

PLEASE NOTE

A sample foundations report is included here for reference. It is provided as an example of content, format, and organization representative of a typical Foundation Investigation and Recommendation Report for a driven pile foundation. As site conditions vary widely, the investigation means and methods, and report content (including recommendations), may differ for other projects. Note that the selection and inclusion of this report as a sample does not imply that it is guaranteed to be free of errors. Please contact the Foundations Unit with any questions when interpreting a geotechnical report issued by this office or if you have any questions with respect to preparing geotechnical reports for MnDOT. The information presented here is intended for use as a resource by geotechnical engineering professionals. MnDOT makes no warranty as to the suitability of engineering reports in the style of this sample report, for other geotechnical needs, purposes, clients, or projects.

Minnesota Department of Transportation
MEMO
Mailstop 645
1400 Gervais Avenue
Maplewood, MN 55109

DATE: March 19, 2012

TO: Nancy Daubenberger, State Bridge Engineer
Office of Bridges & Structures

FROM: Hossana Teklyes, Assist. Foundations Engineer
Geotechnical Engineering Section
Foundations Unit

CONCUR: Rich Lamb, Project Engineer
Geotechnical Engineering Section
Foundation Unit

Gary Person, Foundations Engineer
Geotechnical Engineering Section
Foundations Unit

SUBJECT: S.P. 8308-44, Bridge 83040
TH 60 EB over Railroad, 6.1 mi W of W JCT of TH 4
Subsurface investigation a & Foundation Analysis

Project Description

This report provides a Foundation Analysis and Recommendations for constructing Bridge 83040. The new three-span bridge will be 187 ft. length by 45’ wide and will use 36” prestressed concrete beams. The bridge will be supported with integral type abutments and rectangular column piers.

Field Investigation and Foundation Conditions

Two foundation borings (SPT) were taken at this site by Mn/DOT in September of 2012. Copies of these borings are included with this report.

West Abutment & Pier 1(Boring T13)

The foundation soils encountered at the West Abutment and Pier location were generally found to consist of 5-10 ft. of dense plastic fine sandy loam soil followed by 30 – 35 ft. of stiff clay loam soil. This is followed by 25-30 ft. of very dense plastic sandy loam soil.

Water was not encountered during the drilling of this boring. No bedrock was encountered during the drilling of this boring.

East Abutment & Pier 2(Boring T14)

The foundations soils encountered at the East Abutment and Pier location were generally found to consist of 10 -15 ft. of dense plastic sandy loam soil followed by 25-30 ft. of stiff clay soil. This is followed by 25-30 ft. of very dense plastic sandy loam soil.

Water was not encountered during the drilling of this boring. No bedrock was encountered during the drilling of this boring.

Geotechnical Lab Testing

One dimensional consolidation tests were performed on fifteen soil samples at varying depths in an effort to characterize the compressible nature of the cohesive soils. The results showed that the foundation soils are slightly over-consolidated in the upper 50 ft. and then are normally consolidated at deeper depths. The average consolidation parameters are shown below.

- Initial void ratio (e_o)………………...0.6
- Compression Index (C_c)…………….0.15
- Recompression Index (C_r)…………..0.015
- Coefficient of Consolidation (C_v)…..0.25 ft^2/day (range 0.2-0.5)
- Secondary Compression Index (C_α)…0.005 – 0.01

Foundation Analysis

Approximate roadway and footing elevations were determined from a Bridge Plan provided by the Preliminary Bridge Design Section. Recommended foundation types are presented in Table 1.

Approach Embankment Settlement

Approach embankments were analyzed for settlement (magnitude and time rate). For purposes of this report only, the approach embankments are defined to extend from the abutments to 250 to 270 ft. behind the abutments (Sta. 960+00 West Abutment and Sta. 967+00 East Abutment). In addition, the following assumptions were used in the embankment analysis using the FoSSA(2) program.

- Embankment width……………65-80 ft.
- Embankment fill heights………1-25 ft.
- Unit weight of fill……………..120 pcf
- Side slope angle……………….1: 4 to 1: 3
- Drainage path length (Hv)…….5 ft.

Based on these assumptions and using the consolidation test results, we then computed the magnitude and time rate of settlement for the approach embankments using conventional consolidation theory. The results showed that both approaches may be expected to settle 3- 6 in. (primary settlement). This settlement will occur over a period of 2-3 months as the moisture in the cohesive soils gets slowly squeezed out. In addition to primary settlement, we estimate that the underlying foundation soils may experience 1- 2 in. of long term or secondary consolidation after the primary consolidation has ended. The calculation also showed that a 10 ft. surcharge will reduce the settlement waiting period significantly if needed. See figure 1 below showing time rate of settlement.

Location	***Max Fill height assumed***	***Anticipated settlement***	***Recommended Waiting Period***	***Recommended Waiting Period with 10 ft. Surcharge***	***Borings used***
West Abutment	25 ft.	3-6 in.	90 days	30 days	T13
East Abutment	25 ft.	3-6 in.	90 days	30 days	T14

Table 1: Anticipated Settlement and recommended Waiting Period

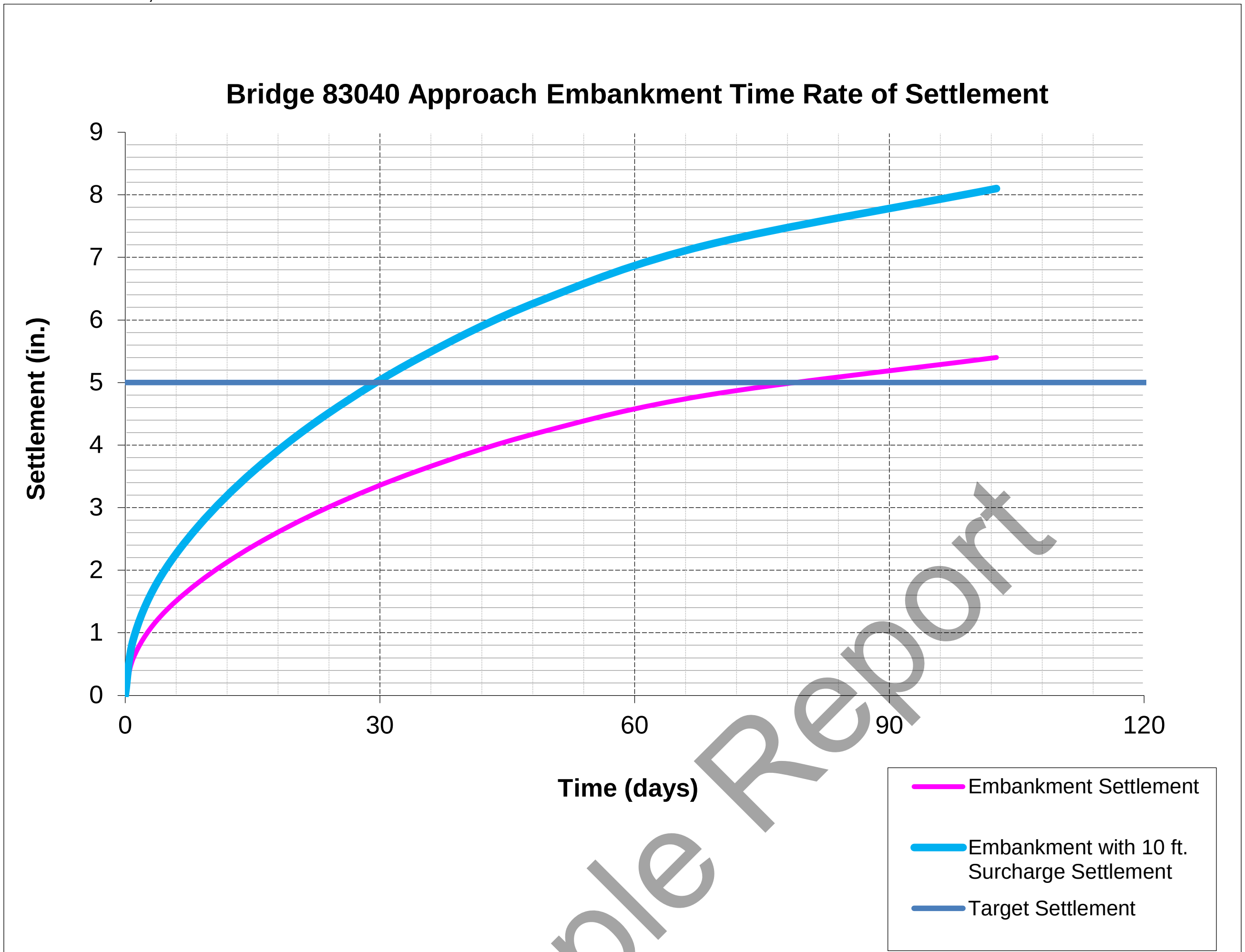


Figure 1: These curves are based on 6 in. & 9 in. settlement for the Embankment & Embankment with surcharge respectively.

Substructure Foundations

Driven piles were analyzed as the foundation for the abutments and pier locations. A static pile capacity analysis was performed for the pile foundations using the DRIVEN program. Two different pile sections were analyzed:
12 in. and 16 in. diameter steel pipe piles. A bearing capacity graph was developed for each pile section at each bridge substructure. Each graph represents the LRFD Nominal Resistance of soil bearing capacity based on the pile bearing elevation. Assumed set-up factors of 1.2 and 1.5 were used in modeling the granular and cohesive soils respectively. The capacities shown are the LRFD Nominal Resistances at the strength limit and shall be reduced by a factor, φ. The reduction factor, φ shall be determined in accordance with applicable design codes

	BR# 83040			
Location	***West Abutment***	***Pier 1***	***Pier 2***	***East Abutment***
Foundation	Pipe Pile	Pipe Pile	Pipe Pile	Pipe Pile
Boring Used for Pile capacity analysis	T13	T13	T14	T14
Approximate Bottom of Footing Elevation	1190 ft.	1167 ft.	1167 ft.	1190 ft.

Table 2: Recommended Foundation Types and Assumed Footing Elevations.

Pile Downdrag Analysis

To effectively remove downdrag loads on the Piles, it is recommended that a three month waiting period be observed before piles are driven at the abutments. If a 10 ft. surcharge is added to the fill heights, this waiting period may be reduced to one month. This waiting period may be reduced if settlement monitoring and pore pressure measurements show that the foundation soils have completed the consolidation process.

Recommendation

Based on the existing conditions along with an analysis of the project soils, we recommend:

1. Topsoil and other organic material be removed from areas where fill is to be placed. These soils should be excavated and replaced with Granular Borrow (Mn/DOT spec. 3149.2B1) and compacted to 95% of Standard Proctor.

2. The approach embankments be constructed to their full height and width and allowed to remain in-place for three months prior to any construction starting at the abutments. This waiting period may be reduced to 1 month if an additional 10 ft. of fill is placed over the full height and width of the embankment.

3. The bridge be supported with closed-end steel pipe foundations. Pile section and estimated pile length to be determined based on the attached geotechnical nominal bearing resistance graphs (tons) and drivability analysis. The graphs are grouped by foundation element and pipe pile size (North abutment 12", 16" and South abutment 12", 16")

4. Further investigation utilizing wave equation analysis must be performed to determine the drivability of the pile. In addition, the wave equation analysis can determine the driving stresses and blow count based upon hammer size. Thus, the wall thickness and required hammer size can be determined to reach a desired ultimate capacity.

5. A minimum of three settlement plates should be installed near the East and West embankments to monitor and evaluate the rate and amount of settlement. A piezometer should also be installed 25 to 30 ft. into the ground to monitor the pore water pressure (See recommendation #6). If the data from the settlement plates and piezometer indicate that settlement is leveling off or pore water is dissipating, the waiting period may be reduced. It should also be noted that if settlement is excessive and is not leveling off or pore water pressure is not dissipating fast enough; the waiting period may need to be extended. Settlement plates and piezometer be installed prior to any addition of fill material.

6. The piezometer be a single 'drive-point' type, vibrating wire, and be installed within the footprint of the east and west approach embankments. The piezometer be buried 25 to 30 ft. below existing ground. The piezometer should have a sufficiently long cable length such that it can be buried/installed without cable splices. The sensor will require an operating range of at least 2MPa (minimum overpressure of 2X the range), with a resolution of 0.025% F.S. (minimum). This sensor will need to be installed by a geotechnical consultant or contractor with a drilling, cone penetration, or a similar rig/unit capable of pushing the sensor into the clay layer. The sensor cable should be protected (in conduit or similar) from where it exits the borehole to a location outside the embankment construction where data from the sensor can be safely collected periodically during the duration of the embankment backfilling and waiting period.

The piezometer will need to be read periodically by a geotechnical engineer, consultant, or contractor, using a standard vibrating-wire gage readout device; an automated data logger may also be used. I t is recommended that the piezometer data be collected on a similar schedule as the settlement plate readings. ***(Refer to the DRAFT Mn/DOT Geotechnical Manual, Appendix G, attached)***. Note that it may be desirable to take more frequent readings if there is interest in advancing surcharges.

Collected data be transmitted to the Foundations Unit for review. The pore-water dissipation data indicated by the piezometer records will be used in conjunction with the project requirements to develop the required degree of consolidation acceptable for work to proceed. Depending on the shape of the pore water pressure dissipation curve, the waiting period may be reduced if the observed behavior indicates that consolidation is occurring faster than predicted (it should be noted, however, that there are some situations where the observed behavior may indicate that the waiting period may need to be extended to ensure adequate long-term performance of the structure).

7. The footings be buried a minimum of 4.5 feet below the final ground line for frost protection.

8. Where applicable, slopes of a minimum of (2H: 1V) are recommended for stability. Erosion control measures should be installed as per the Hydraulic Engineer's recommendations.

9. Adequate provisions for drainage be provided behind the abutment. Refer to Mn/DOT Standard Plan 5-297.225.

If you have any additional questions regarding these recommendations, or require further assistance, please contact this office.

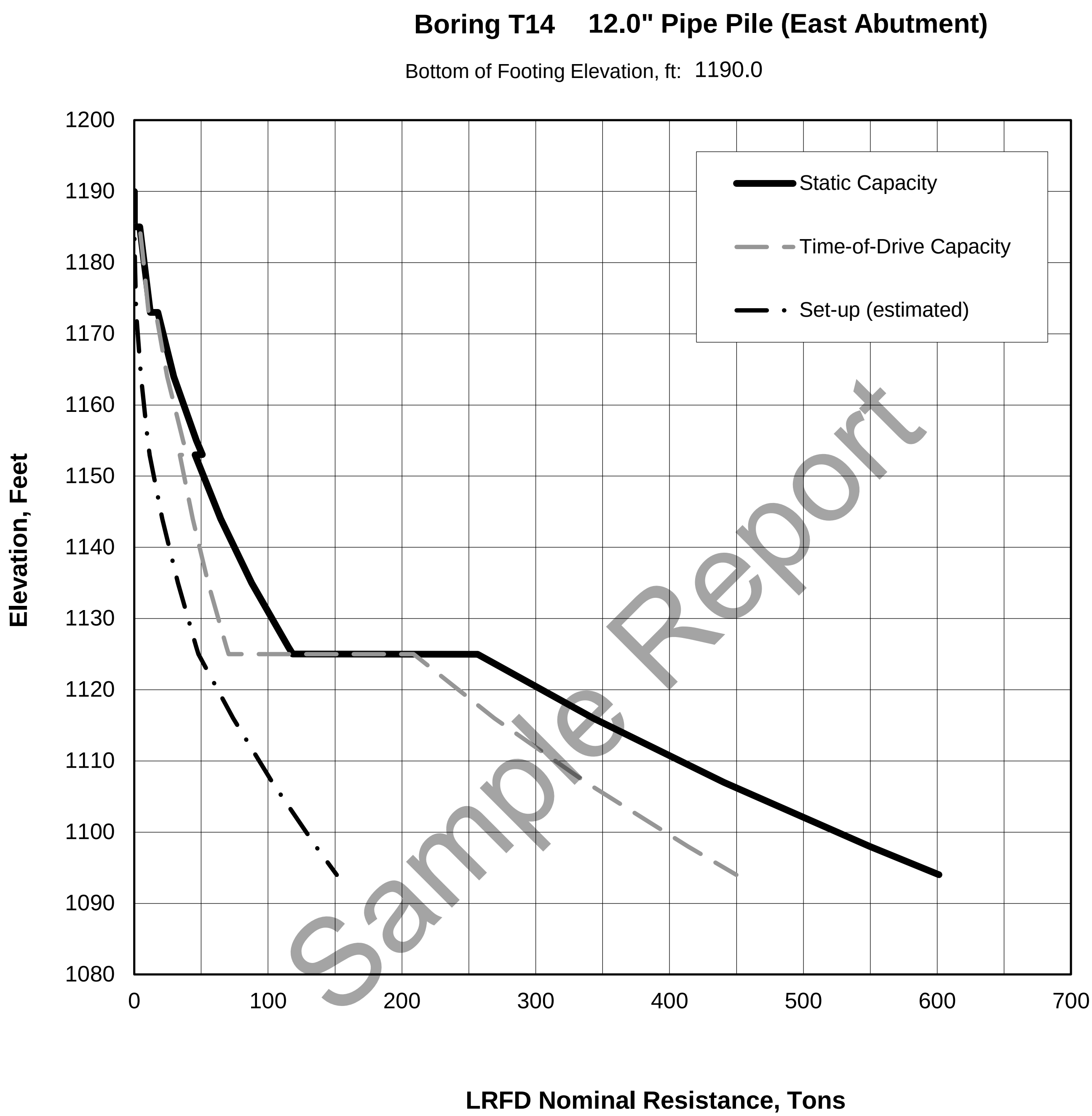
Attachments:

Pile Capacity Graphs
Draft Mn/DOT Geotechnical Manual, Appendix G
Boring Plan & Profile
SPT Boring Logs T013-T14 (Unique numbers 75647-75648)

cc:

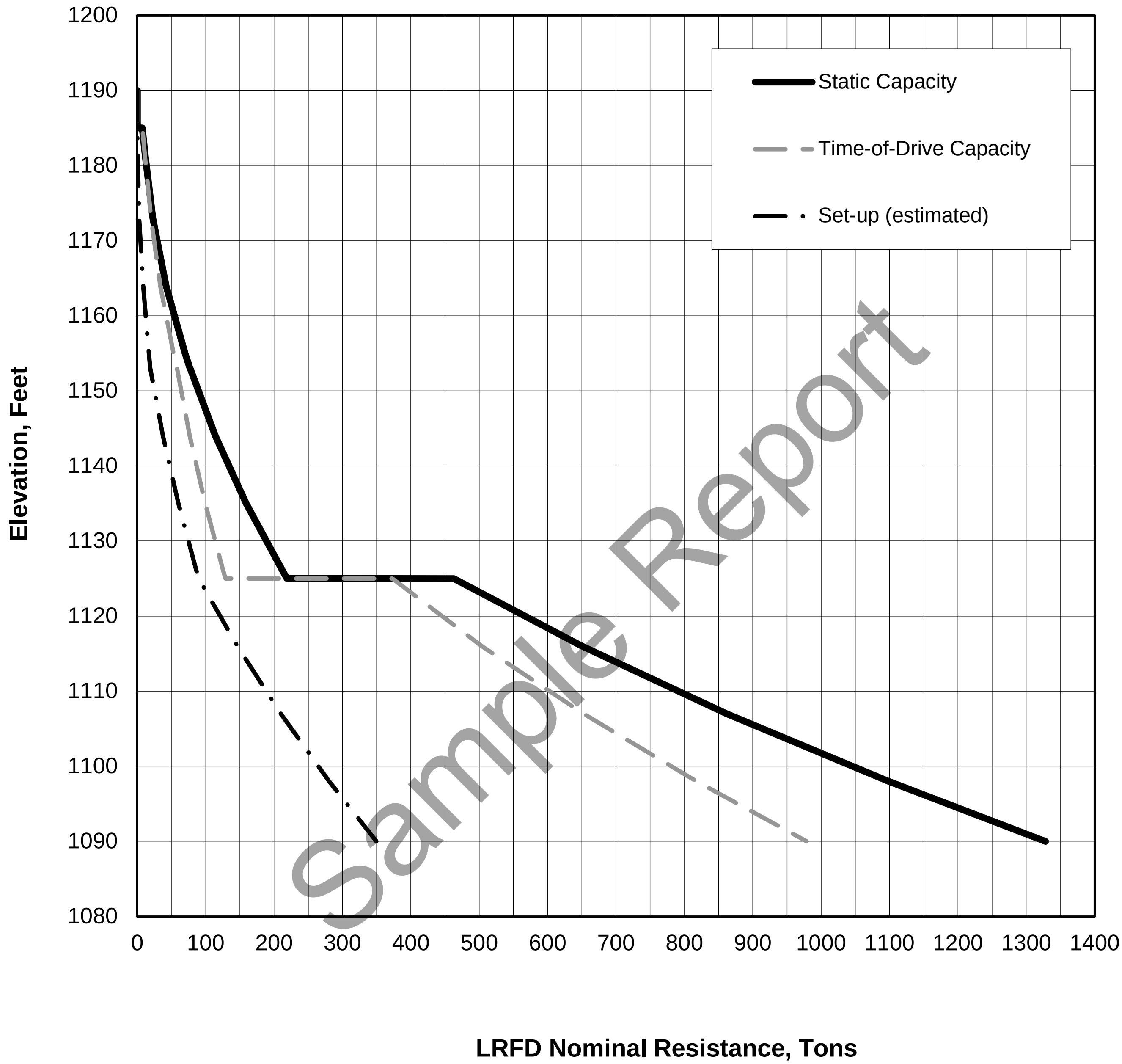
E. Lutgen
K. Molnau
C. Kremer
J. Hager

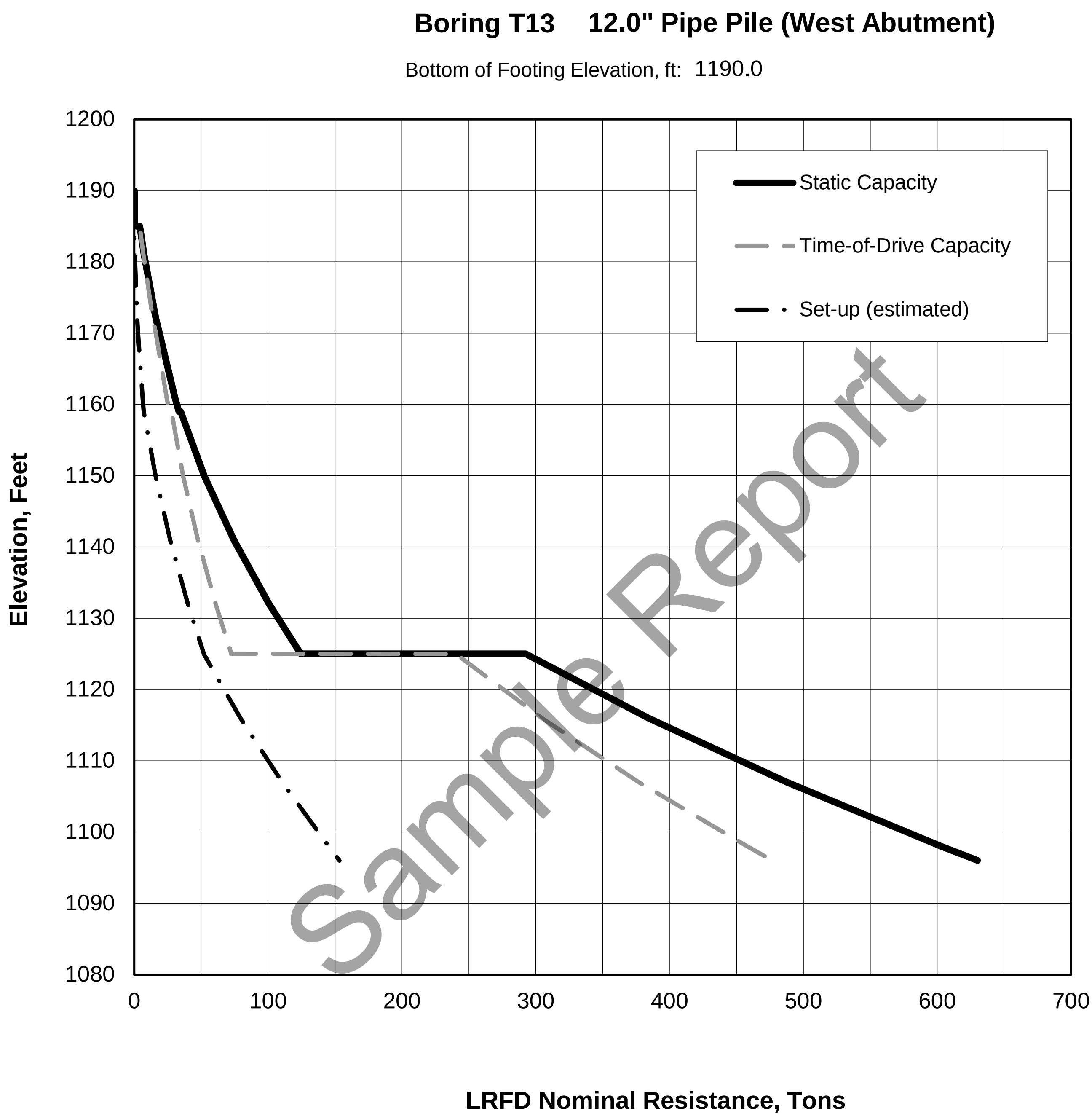
File


Boring T14 12.0" Pipe Pile (East Abutment)
Bottom of Footing Elevation, ft: 1190.0
Elevation, Feet
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
0
100
200
300
400
500
600
700
Static Capacity
Time-of-Drive Capacity
Set-up (estimated)
LRFD Nominal Resistance, Tons

Boring T14   16.0" Pipe Pile (East Abutment)

Bottom of Footing Elevation, ft: 1190.0




Boring T13 12.0" Pipe Pile (West Abutment)
Bottom of Footing Elevation, ft: 1190.0
Static Capacity
Time-of-Drive Capacity
Set-up (estimated)
Elevation, Feet
1200
1190
1180
1170
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1090
1080
0
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200
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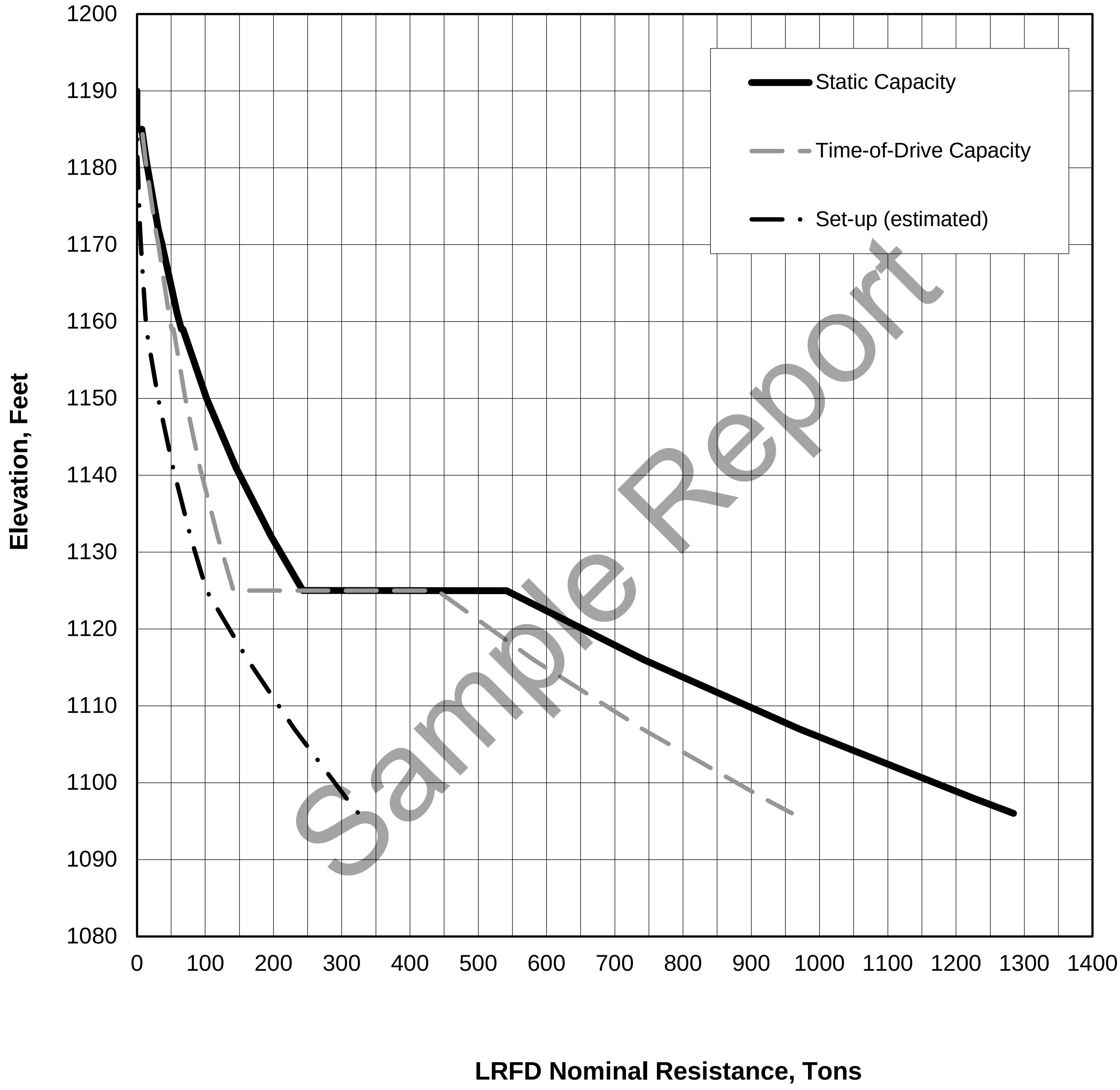
LRFD Nominal Resistance, Tons

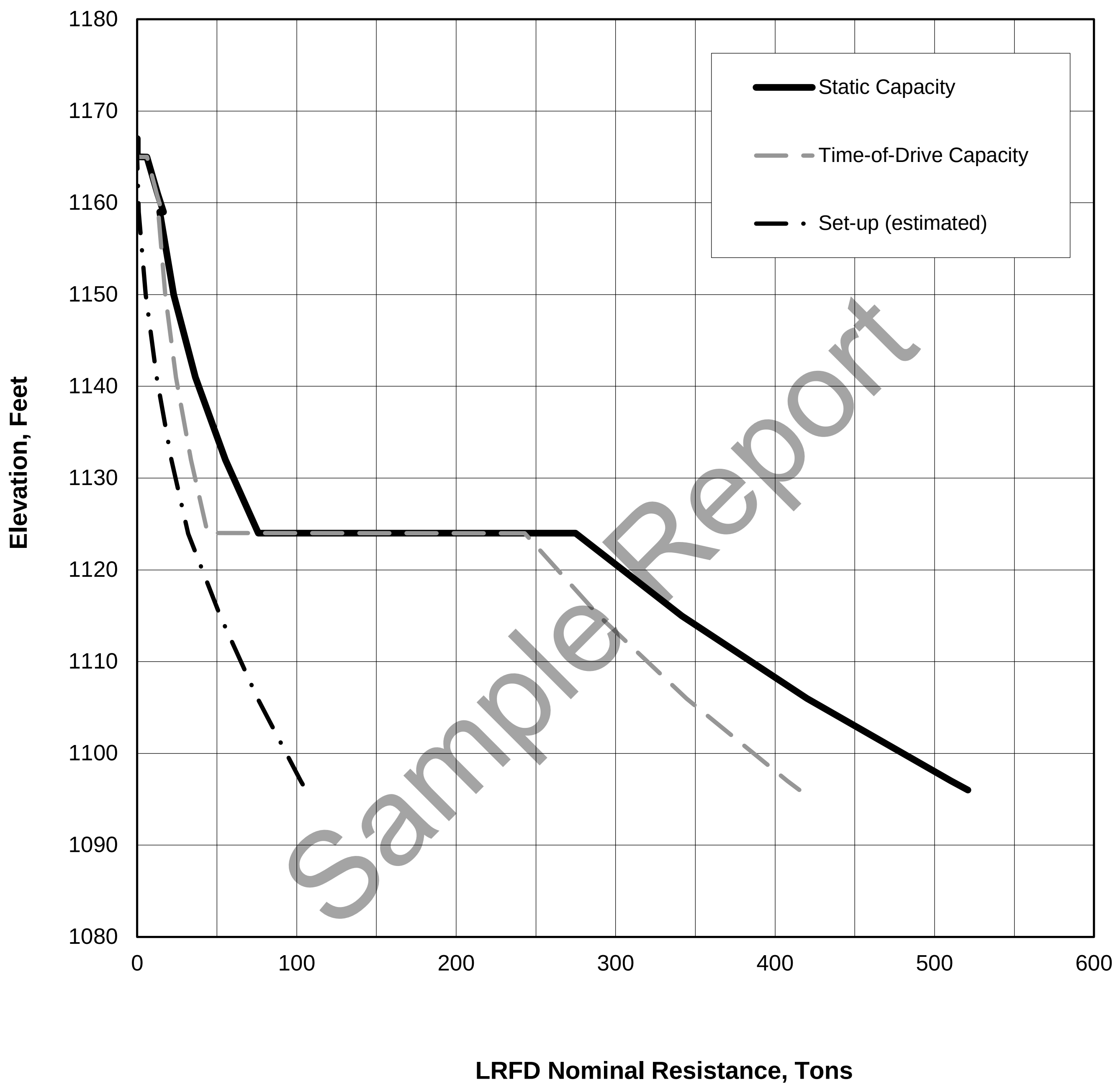
Boring T13 16.0" Pipe Pile (West Abutment)

Bottom of Footing Elevation, ft: 1190.0



Boring T13 12.0" Pipe Pile (Pier 1)

Bottom of Footing Elevation, ft: 1167.0




Boring T13 16.0" Pipe Pile (Pier 1)
Bottom of Footing Elevation, ft: 1167.0
Static Capacity
Time-of-Drive Capacity
Set-up (estimated)
Elevation, Feet
1180
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1160
1150
1140
1130
1120
1110
1100
1090
1080
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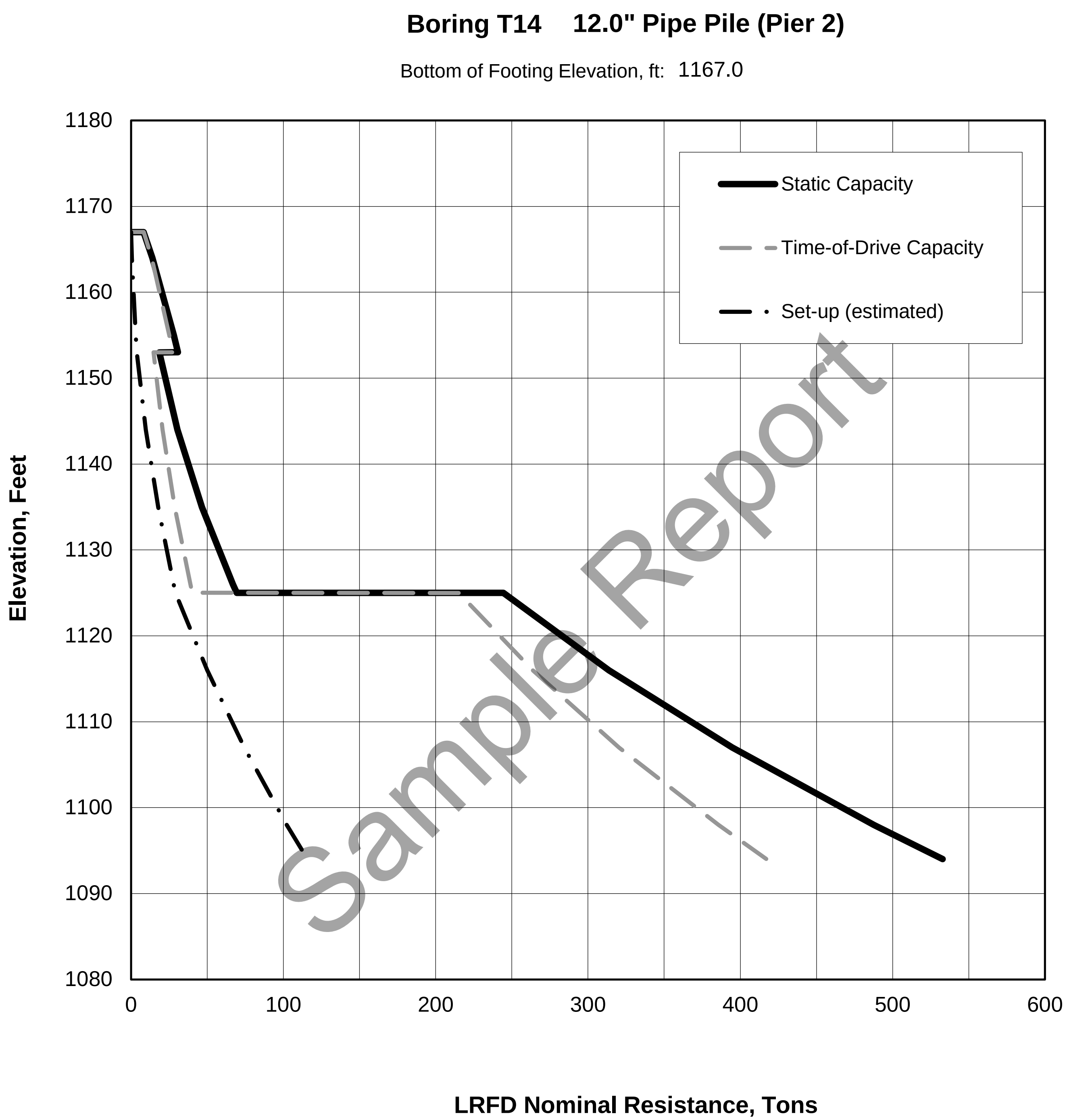
1000
1100
1200
LRFD Nominal Resistance, Tons
Sample Report


Boring T14 12.0" Pipe Pile (Pier 2)
Bottom of Footing Elevation, ft: 1167.0
Static Capacity
Time-of-Drive Capacity
Set-up (estimated)
Elevation, Feet
LRFD Nominal Resistance, Tons
1180
1170
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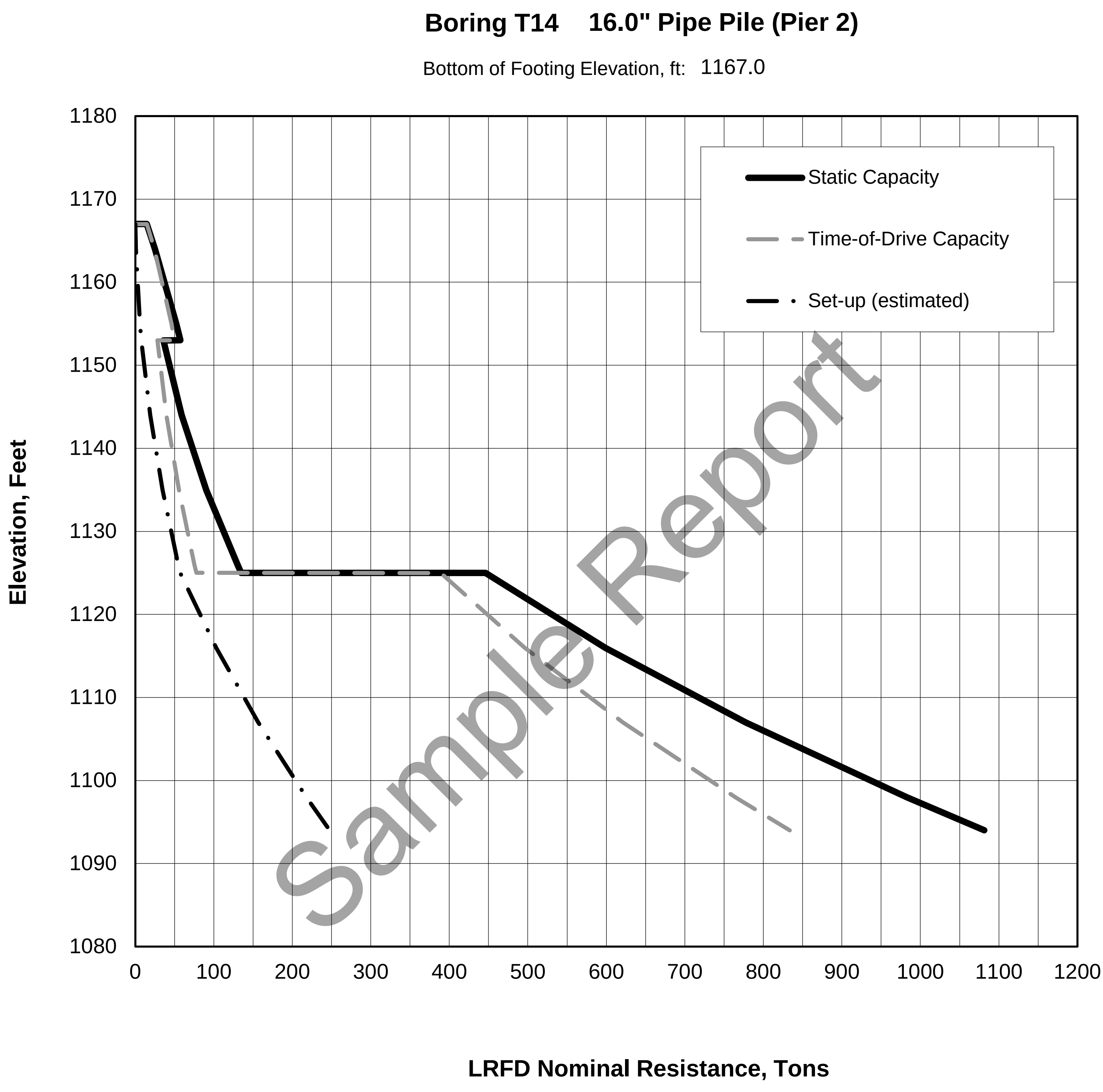
Boring T14 16.0" Pipe Pile (Pier 2)
Bottom of Footing Elevation, ft: 1167.0
Static Capacity
Time-of-Drive Capacity
Set-up (estimated)
Elevation, Feet
LRFD Nominal Resistance, Tons
1180
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General Practice for Installation and Use of Settlement Plates

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Background

Earth materials generally compress an observable amount when load is applied. Soils, in particular, when subject to load, may deflect, consolidate, or densify. Fill materials and native soils may react immediately, slowly, or very slowly, to loadings depending on the type of material and the effect of water on the soil system. The magnitude and rate of compression [or deflection] is often difficult to predict, particularly in cohesive, fine grained, soils such as silt and clay. Deformations in a soil system may be elastic or plastic in nature, or a combination of both.

Sands (coarse grained)

Sandy soils typically display immediate settlement characteristics. These soils consolidate very quickly (the time may vary from nearly instantaneous to several days). Often sands are assumed to have elastic properties and an associated value of material stiffness. Settlement is not generally monitored where a site consists of exclusively sandy (granular) materials. The total strain for a given applied stress is often very small (a few percent), consequently overall deflections are also small.

Clays (fine grained, cohesive)

Clayey soils exhibit consolidation behavior which is fairly well understood, though complex. Stress history, mineralogy, age, moisture content, and geologic formation all play a role in the strength and behavior of clay materials. Generally, clays exhibit a roughly bi-linear behavior pattern. Clays respond to applied stress with relatively low strains until the maximum past pressure is applied, after this point, they tend to respond to increased load at a greatly increased rate of strain. The time rate of consolidation of clay materials is highly dependent on particle sizes of the soil and drainage paths. Thick deposits of high clay content materials may take years to consolidate, even under high stress. Soils with greater silt content, or possessing favorable free drainage conditions (such as sand seams), may consolidate relatively rapidly.

Organic Materials

Organic soils are generally treated as a distinct material category as they contain relatively large amounts of, or exclusively, non-soil materials. Organic materials are subject to decay processes where the material chemically and structurally changes over time. This decay can have profound effects on the strength and behavior properties of the material. Organic soils are typically very dark in color, have very low dry unit weights, and have high moisture contents. Moisture contents in organic material may range from 30% to over 1000%. Texture may range from very fibrous to fluid muck. Typically, organic materials have very large strains associated with any loading condition in excess of the in-situ stress. Large stresses in high moisture peat deposits may result in strains well in excess of 50%. Overall behavior is highly site specific. Consolidation behavior in organic materials is also less uniform as compared to mineral soils, sudden compression 'events' can occur where local changes in structure result in sudden deformations even at constant stress.

For all geomaterials, behavior is dependent on the site geometry (layer thicknesses) and location of the water table, applied loading (stress) conditions, and material properties, such as density, permeability, overconsolidation ratio (OCR), and water content.

General Use

The most common settlement monitoring system is the settlement plate. These instruments may be simply constructed and read manually, or involve relatively complex fluid and electrical sensor systems for remote reading and automated recording. Settlement plates are typically installed in areas where significant settlement is predicted.

They can be used to examine if predicted settlement:

1) is occurring
2) is occurring at predicted rates and magnitudes
3) has occurred to a magnitude of interest (or over a time of interest)
4) is substantially complete
5) is not occurring

Settlement plates may also be installed to monitor heave, either caused by material displacement or frost. Settlement plates may be used alone or in conjunction with other instrumentation including horizontal inclinometers, piezometers, borehole extensometers, and hydraulic remotely-monitored settlement systems.

Construction

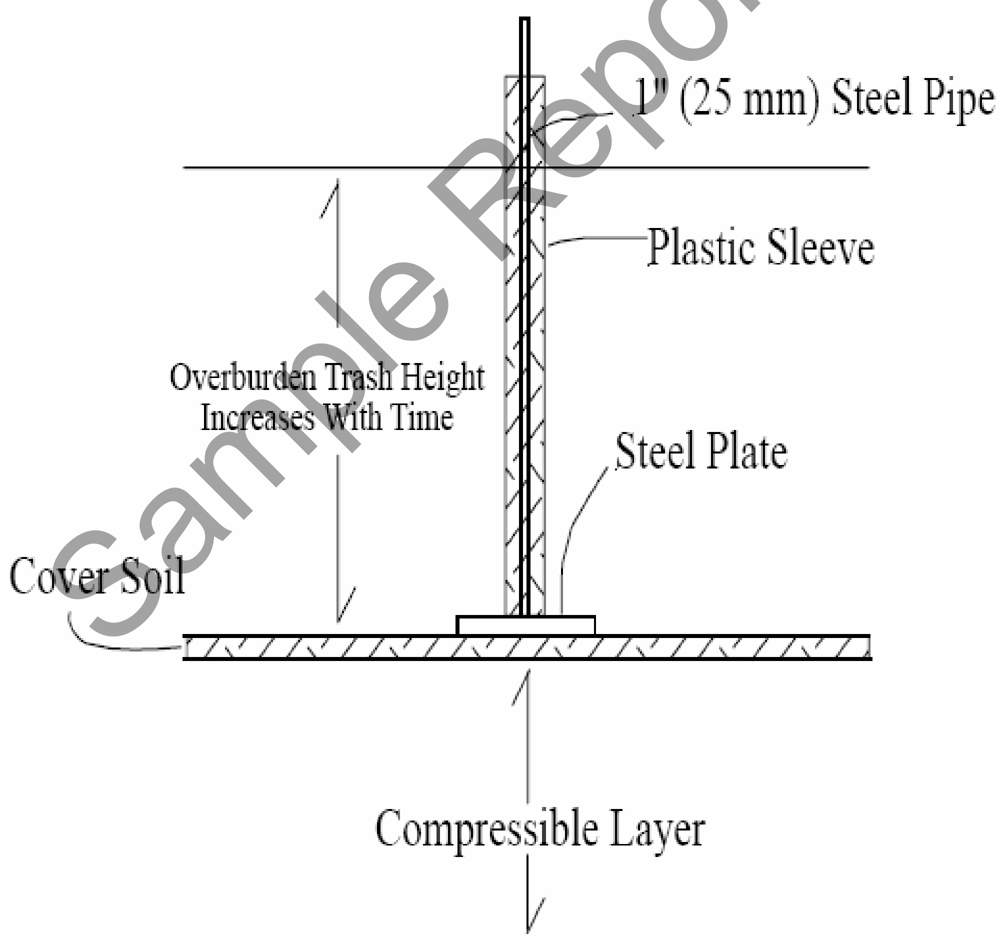
Typical settlement plate construction is outlined in the included diagram. The base platform is typically made of plywood but may also be a steel plate or concrete pad. A reference rod (riser pipe), with threaded end connections, is attached to the platform. As fill is placed over the settlement plate additional segments of pipe are added.

Note that where high quality readings of the behavior at the plate elevation are of interest, and/or where extra protection is required, a PVC protection pipe should also be placed around the threaded riser pipe. The plastic pipe should be of sufficient diameter to accommodate any couplers used to connect the riser rods.

Settlement plates may be placed at any given elevation of interest. Typically they are installed on the existing ground surface prior to the construction of embankment fill. They may also be placed in excavations, at reinforcing interfaces, or within embankments to monitor settlement characteristics.

Settlement is determined by periodically measuring the elevation of the top of the reference rod. The elevation of the base platform elevation must be measured before the embankment construction begins. Subsequent readings should be taken periodically during the embankment construction and whenever additional riser pipes are attached.

Stable benchmarks should be used for a reference elevation datum and should be located away from all possible vertical movement or other disturbance. Depending on the importance of the installations it may be necessary to use multiple benchmarks for redundancy and survey elevations between them at regular intervals for validation.



Applications

The Foundations Unit generally recommends the use of settlement plates where soil settlements have been predicted to be of a large (or undeterminable) magnitude, and could cause construction or operational difficulties to roadways or structures.

Other units within Mn/DOT may specify the use of settlement plates if there is concern with respect to roadway or structural performance due to poor or unknown soil conditions.

Bridge Abutment Foundations (Piling)

Bridge Abutment Foundations (Spread Footings)

Bridge Approach Embankments

Embankments

Waiting periods, if specified, should be adhered to. Failure to postpone construction until after consolidation settlement has been allowed to occur at problematic sites can result in significant construction difficulties, structural damage, delays, reconstruction, and associated incurred costs.

Waiting Periods

Settlement plates are frequently used where a “waiting period” for construction has been recommended. Waiting periods are a minimum specified time to allow consolidation settlement to occur, generally after fills over soft or compressible soils or large fills have been placed. Waiting periods are determined from predictions based on the geotechnical site investigation and associated testing and analysis.

Waiting periods are used to prevent pavement distress, differential settlement of hydraulic structures, curbing, wingwalls, or other structures, and to prevent ‘pile dragload.’ Pile dragload is a condition where compressible soils in or below the fill layer adhere to structural piling and impart an additional downward acting load into the pile as the soils consolidate, possibly overstressing it. Additionally, if the piling is not founded on a firm layer, settlements in the piling may be excessive due to the added load and reduced area of resisting soil support.

Monitoring of the actual ground behavior, with settlement plates, can be used to determine if work may begin in advance of the minimum waiting period time. It should also be noted that if settlement is excessive, the waiting period may be extended.

Site Plan and Location Selection

Settlement plates should be located such that construction traffic in the vicinity is minimized if at all possible. Plate installations and riser pipes should be clearly and adequately marked to protect the riser pipes from impact or obliteration during fill placement, grading, and other construction activities that will be ongoing during the monitoring process.

Note also that the bench-mark (or fixed reference elevation) used to survey the settlement plates must also remain intact through the monitoring process. A stadia rod may be used to obtain the fill elevation if the top of fill is not visible from the survey point; both the elevation of the riser pipe and the top of fill should be surveyed for use in settlement data analysis.

Installation

Settlement plates should be installed prior to any addition of fill material. Refer to the installation diagram [Figure 3-2.10, Mn/DOT Geotechnical and Pavement Manual, Part 1, April 1, 1994]. Ground elevation and the elevation of the settlement plate riser pipe should be established and recorded prior to placement of the fill material to establish a baseline reading.

The plates should then be monitored regularly through the fill placement process and the following waiting period to determine the total soil movements, some of which occur during the fill placement process. It is important that the plates be surveyed immediately at the time of installation.

For a typical bridge, consisting of two abutments, two settlement plates are installed. Note that settlement plates are generally not required at bridge piers, as there is usually a minimum of fill at these locations. A greater number of settlement plates may be warranted if fills are large in either height or lateral extent, if there is risk that they will destroyed by construction traffic, or for redundancy if the site is of particular importance.

Settlement plates should be installed slightly below grade as in Figure 3-2.10, Mn/DOT Geotechnical and Pavement Manual, Part 1, April 1, 1994. Care should be taken in installing the plates, reading elevations, and extending riser pipes.

Survey Data

The riser pipe should be surveyed to a fixed datum or bench mark well outside the embankment fill area. The height of fill should also be surveyed and recorded at each monitoring interval. It is important that original installation data and subsequent monitoring data be clearly recorded for each settlement plate installation. Added sections of riser pipe, and their lengths, should be clearly noted in the data log.

It is important to install and read them correctly to verify that settlement. As settlements are relatively small, surveys should be conducted to the greatest accuracy reasonably obtainable under field conditions. In general, GPS systems are not accurate or precise enough in the “z” axis (height) to be used for settlement plate data acquisition.

Monitoring Intervals (Data Collection Reading Frequency)

It is essential that the settlement plates be surveyed as soon as they are placed.

During initial construction of the fill and any time thereafter when fill is being actively placed, the settlement plates should be read every two to three days.

After the fill placement has been completed, the plates may [generally] be read weekly. When fill is being placed, the amount of fill (lift heights) should be recorded for use in settlement data interpretation.

Any extreme or unusual events should also be recorded, such as rainstorms, local flooding, or seismic activity (either natural or nearby blasting). If the plates are damaged and/or repaired or relocated, this should also be noted.

All settlement data should be sent to the Foundations Unit for review and interpretation. Refer to the section on transmitting data at the top of the following page.

It is preferred that the same surveyors read the settlement plates over the course of the monitoring period to reduce the opportunity for error. Project data and elevation readings should be reported in appropriate units (either in U.S. Customary Units or SI units, depending on the project).

The location of the plates should be surveyed at the time of installation and include Roadway Station and Offset and either Latitude and Longitude or UTM coordinates (X,Y), as well as the elevation. The survey reference system should be indicated.

If there are a large number of plates on a particular project, it is also important that they be clearly named/numbered to ensure that there is no confusion in the data recorded for each installation.

Some projects may require a more frequent or specific interval for reading, depending on the criticality of the project. Staged embankment fills over soft soils may require especially frequent monitoring.

Transmitting Data

Data may be submitted to the Foundations Unit electronically, via fax, or through the mail. Electronic data transfer is preferred as errors are somewhat less likely. If information is mailed or faxed, it is important that the information be legible. Data should be clearly labeled with the State Project number, Highway or Site, Bridge or Structure # (if applicable) Plate # (if applicable), Location (i.e. east or west abutment) and Roadway Station/Offset, Date, Elevation of the Top of Fill, and Riser Pipe Elevation. Added lengths of riser pipe should also be indicated, as appropriate.

The foundations unit direct fax number is 651-779-5510. Electronic mail addresses are available for each project engineer in the unit.

Please contact the Foundations Engineer, Gary Person, at PH: 651.366.5598, e-mail: *gary.person@dot.state.mn.us* for the engineer assigned for a specific project.

Analysis

The Foundations Unit will interpret the data and associated settlement behavior. If the behavior is such that construction may proceed in advance of any given waiting periods or is such that construction should be postponed, the appropriate offices will be notified.

Data Interpretation
Impact on Waiting Periods

Waiting periods are determined on a case by case basis after a geotechnical review of the site. The installation of settlement plates does not necessarily ensure a reduction in the waiting period duration. The Foundations Unit will assess the data from the settlement plates to determine if the soil consolidation is substantially complete or at such a stage where the majority of the predicted settlement has occurred.

Samples of Settlement Plate Graphs with Common Errors

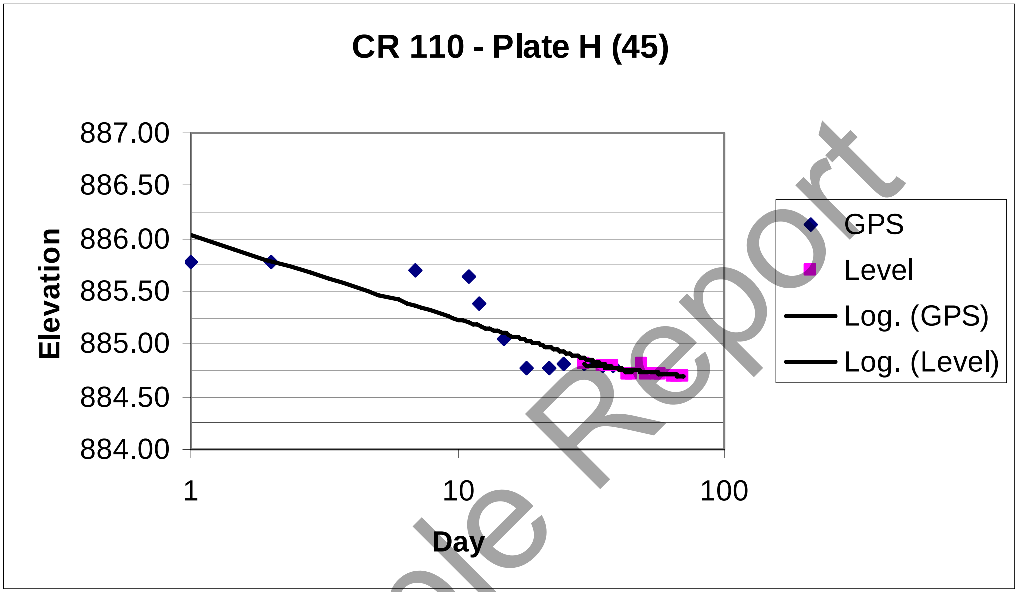


Figure 1. Some elevations were shot with GPS and others using a level. GPS elevations are generally of insufficient precision for resolving the small movements anticipated at most sites.

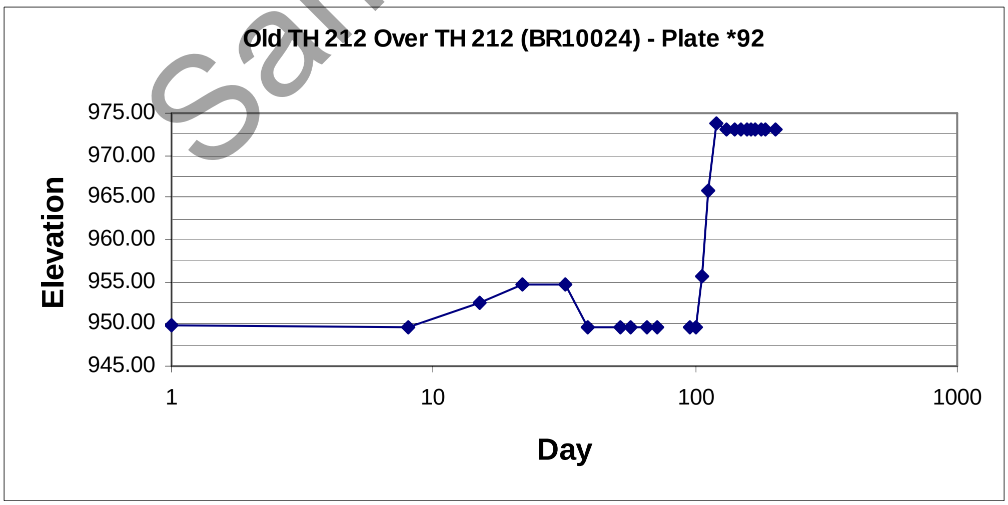


Figure 2. The height of additional sections of rods were probably not recorded and subtracted out from the measurements associated with this settlement plate.

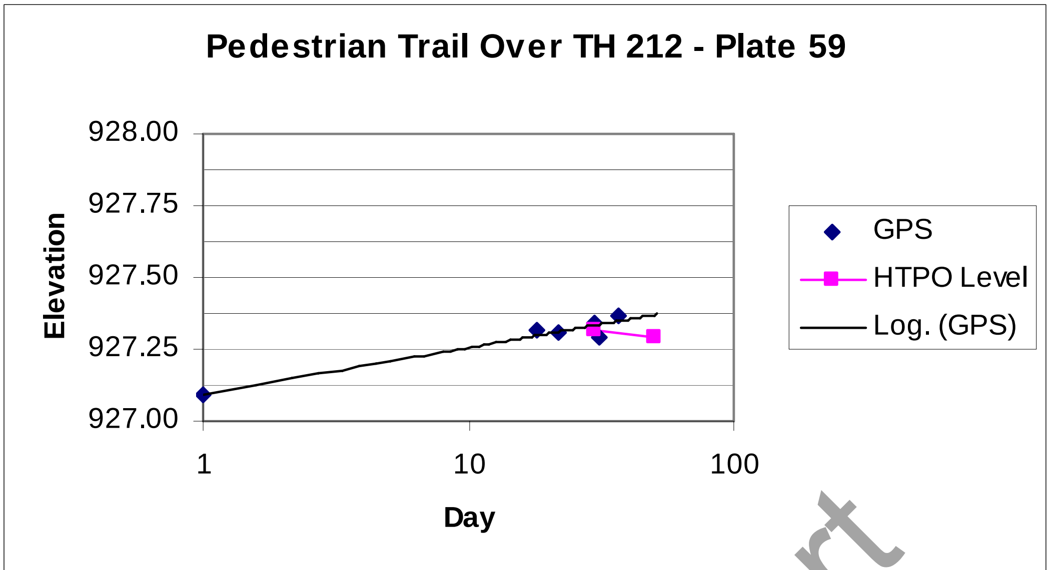


Figure 3. This graph shows the relatively large scatter associated with the GPS data points as compared to those shot with a level. Additionally, the readings should have been taken more frequently earlier

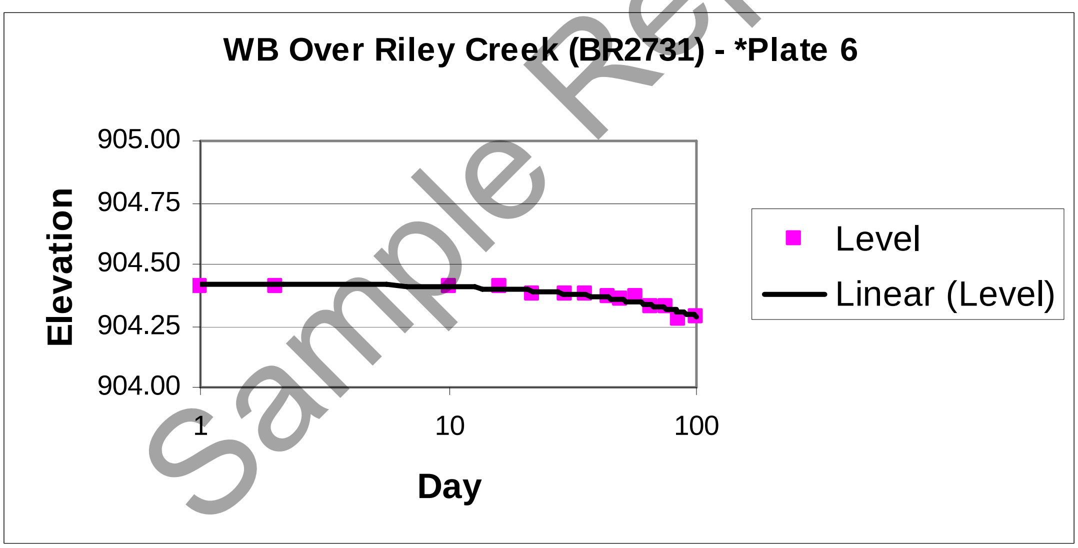


Figure 4. This graph is the best of those presented above (Figures 1-4) and shows anticipated behavior (monotonically decreasing plate elevation).

Sample of Well Organized Settlement Plate Table

Figure 5 (page 11, at the end of the document [landscape]). This table shows settlement plate data to an appropriate precision for multiple plates. The information is clearly presented (plates are labeled with stationing and lifts dates and reading dates are included along the vertical axis).

Special Cases

In general, the reading schedules and installation instructions herein, and as shown in Figure 3-2.10, on page 3- 2.0(38) in the Mn/DOT Geotechnical and Pavement Manual, apply.

If there are modifications to these standards they will be included in the project plans and special provisions. Depending on the performance and behavior of the settlement plates, modifications to the reading frequency may be made by the project engineer.

Alternate Methods and Related Equipment

Some critical installations, locations with confined working areas, or areas at or near structures may require the use of buried, piezometers, settlement cells, horizontal inclinometers, or accelerometer arrays. These systems can be combined with traditional settlement plates or used on their own where the use of settlement plates is impractical or the data quality is especially important to the project.

Piezometers may be used to monitor the dissipation of excess pore water pressure that is induced by embankment loading on cohesive (non-free-draining) materials. These instruments do not measure settlement directly, but they can be used to determine the rate of consolidation and if any pore-water overpressure exists, which are useful in assessing whether soil movements are complete for a given loading stage. Several types exist; vibrating-wire type are recommended.

Settlement cells usually employ a piezometer system to determine changes in elevation based on changes in pressure in a system with a fixed reference frame. Typically, a settlement cell will be referenced to a fixed fluid reservoir (either installed in a fixed stratum in a boring or at a fixed location offset a horizontal distance from the area of interest). The down-side of these types of sensors is that they are sensitive to installation damage, temperature, and generally require a specialty contractor to install, set-up, calibrate, and read/maintain. The benefit is that there are no poles to interfere with construction operations (or traffic) at the top of the loaded/instrumented area.

Horizontal inclinometers, as the name implies, are slope inclinometer casings installed parallel to the ground, usually through an embankment. These systems use a specialty probe that senses deflections in the casing as it is passed through the system. The system requires a return-pulley at one end, if the casing does not pass fully through the embankment. This system is relatively easy to install and can sense relatively small changes in deflection. The system must be referenced at either (or both) end(s) to a fixed datum or extended to a distance where movement is not occurring to ensure that readings are accurate.

Similar to a horizontal inclinometer, an accelerometer array is a linear element placed within the area of interest for settlement monitoring. These systems employ a string of accelerometers that are left in-place and connected to a data acquisition system for periodic automated reading. The accelerometers record shifts in the orientation of the array with respect to gravity. This system also requires a fixed (or referenced) datum. The benefits of this system are the relatively robust performance of the array, the precision (generally movements as small as 2 mm can be resolved) the automated data collection. These systems, are however, usually comparatively expensive and therefore recommended mostly for long-term performance monitoring of structures, research, or critical applications. If the array is not strained to failure, the sensors can usually be pulled and re-used, which decreases the project cost considerably- and in some instances a savings over traditional horizontal inclinometers could be realized through labor and travel cost reductions (particularly if the site is not conveniently located).

Note that some portions of all the above systems are sacrificial and cannot be recovered. Installation and monitoring should be performed by geotechnical engineers who are familiar with construction instrumentation.

For additional Information:

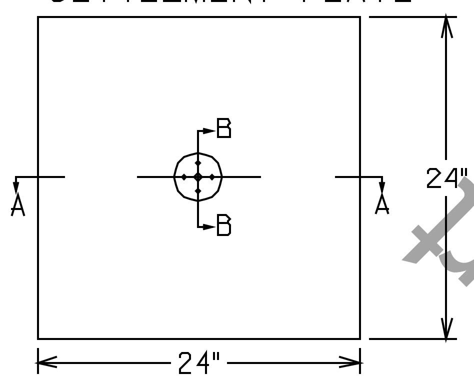
Please contact the Mn/DOT Foundations Unit for any clarification or questions.

Reference: Figure 3-2.10
[page 3- 2.0(38)] Mn/DOT Geotechnical and Pavement Manual

SETTLEMENT PLATES
TH 284 ROUNDABOUT AND RECONSTRUCTION
S.P. NO. 1014-02
BMI # C12.37227

			PLATE 1		PLATE 2		PLATE 3		PLATE 4		PLATE 5		PLATE 6	
			STA 308+00 35' LT		STA 307+50 35' LT		STA 307+00 35' LT		STA 306+50 35' LT		STA 306+00 35' LT		STA 305+50 35' LT	
LIFT	DATE	DAY	ELEVATION	SETTLEMENT	ELEVATION	SETTLEMENT	ELEVATION	SETTLEMENT	ELEVATION	SETTLEMENT	ELEVATION	SETTLEMENT	ELEVATION	SETTLEMENT
LTP	8/20/2008	WEDNESDAY	961.03	0.00	957.67	0.00	955.51	0.00	953.87	0.00	954.06	0.00	954.09	0.00
	8/22/2008	FRIDAY	961.04	0.01	957.68	0.01	955.52	0.01	953.88	0.01	954.07	0.01	954.10	0.01
	8/25/2008	MONDAY	961.03	0.00	957.67	0.00	955.51	0.00	953.87	0.00	954.07	0.01	954.09	0.00
	8/27/2008	WEDNESDAY	961.03	0.00	957.68	0.01	955.51	0.00	953.88	0.01	954.07	0.01	954.09	0.00
	8/29/2008	FRIDAY	961.03	0.00	957.67	0.00	955.51	0.00	953.88	0.01	954.07	0.01	954.09	0.00
RSS #1	9/3/2008	WEDNESDAY	961.02	-0.01	957.66	-0.01	955.50	-0.01	953.86	-0.01	954.06	0.00	954.08	-0.01
	9/5/2008	FRIDAY	961.01	-0.02	957.66	-0.01	955.49	-0.02	953.85	-0.02	954.05	-0.01	954.08	-0.01
RSS #2	9/8/2008	MONDAY	961.01	-0.02	957.65	-0.02	955.49	-0.02	953.85	-0.02	954.05	-0.01	954.08	-0.01
	9/10/2008	WEDNESDAY	961.00	-0.03	957.64	-0.03	955.48	-0.03	953.83	-0.04	954.03	-0.03	954.06	-0.03
	9/12/2008	FRIDAY	961.00	-0.03	957.64	-0.03	955.47	-0.04	953.83	-0.04	954.04	-0.02	954.06	-0.03
	9/15/2008	MONDAY	960.99	-0.04	957.63	-0.04	955.46	-0.05	953.82	-0.05	954.02	-0.04	954.05	-0.04

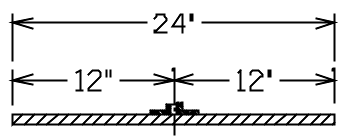
SETTLEMENT PLATE



PLAN VIEW

SETTLEMENT PLATE SHALL BE CONSTRUCTED OF ¾' PLYWOOD (EXTERIOR).

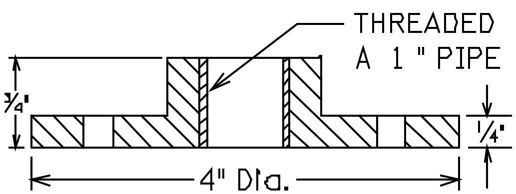
SECTION A-A



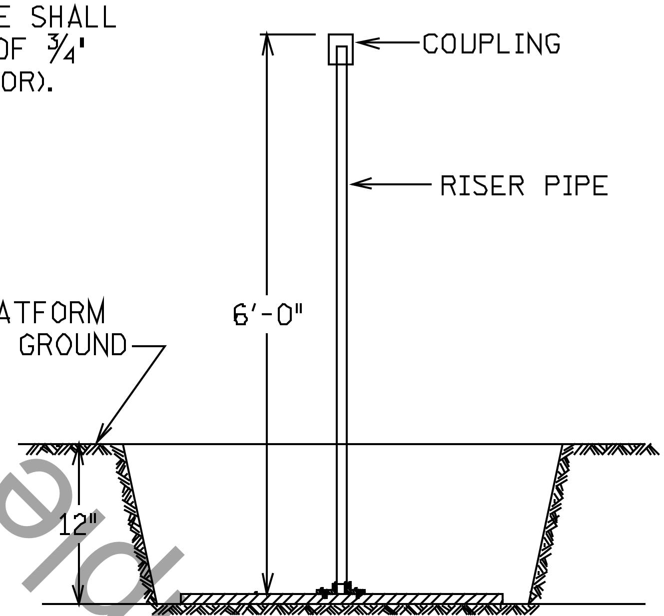
FLOOR FLANGE SHALL BE BOLTED TO THE PLATE WITH A MINIMUM OF THREE ¼' BY 1-1/2' BOLTS

SECTION B-B

STANDARD BLACK ¾" FLOOR FLANGE

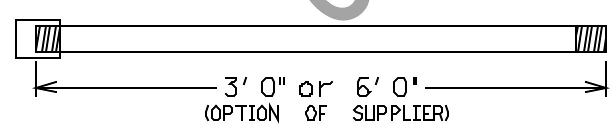


SETTLEMENT PLATE INSTALLATION



IN SEATING THE PLATE, THE 12" TRENCH SHALL BE BACKFILLED WITH GRANULAR BORROW (Mn/DOT Spec. 3149.2A) AND COMPACTED WITH ORDINARY COMPACTION (Mn/DOT Spec. 2105.3F2)

RISER PIPE & COUPLING



RISER PIPE SHALL BE A 1 ' STANDARD WEIGHT BLACK STEEL PIPE (ASTM A120)

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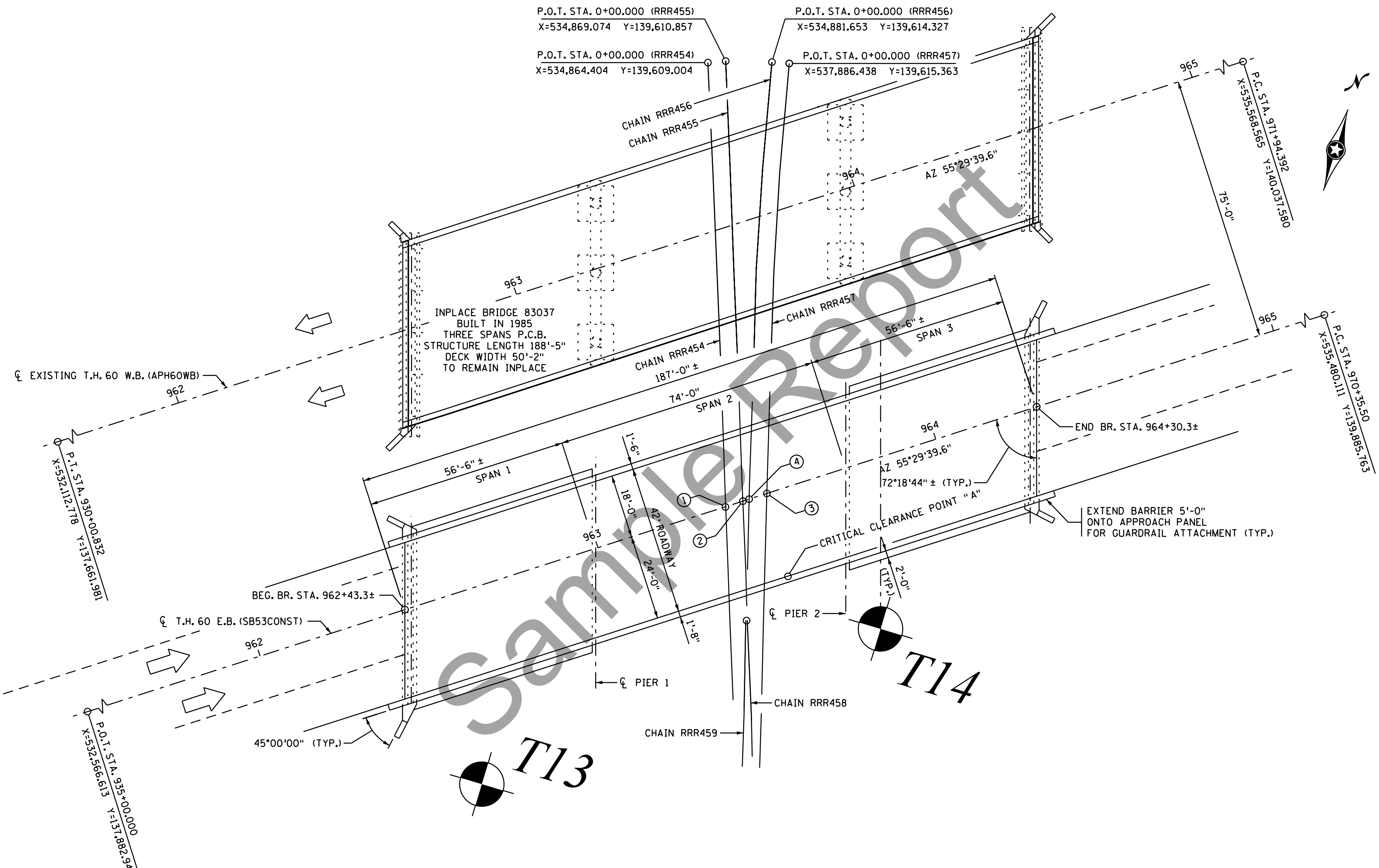
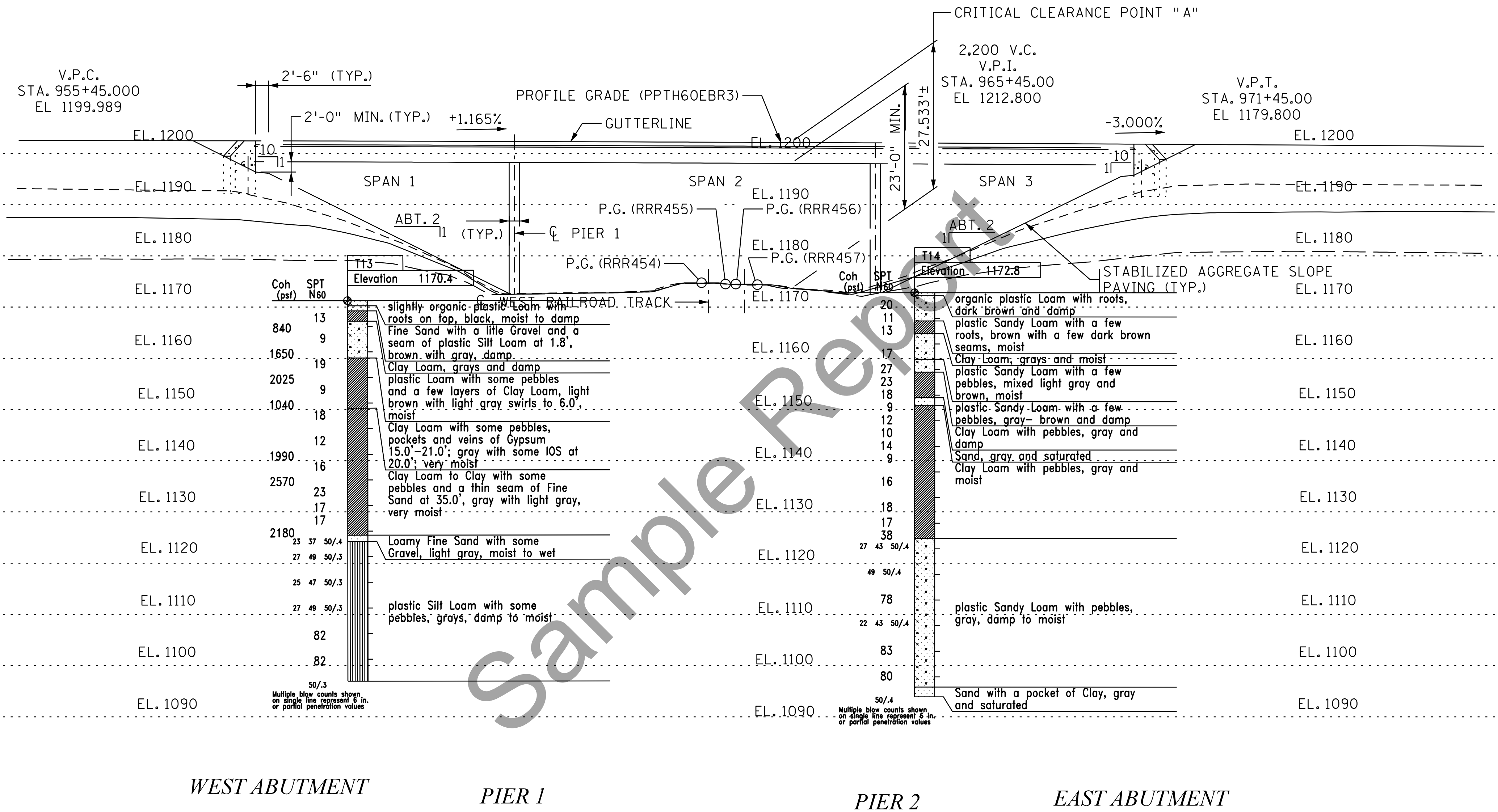


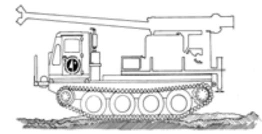
BRIDGE 83040 PLAN



BRIDGE 83040 PROFILE

Minnesota Department of Transportation Geotechnical Section

Boring Log Descriptive Terminology (English Units)



USER NOTES, ABBREVIATIONS AND DEFINITIONS - Additional information available in Geotechnical Manual.

This boring was made by ordinary and conventional methods and with care deemed adequate for the Department's design purposes. Since this boring was not taken to gather information relating to the construction of the project, the data noted in the field and recorded may not necessarily be the same as that which a contractor would desire. While the Department believes that the information as to the conditions and materials reported is accurate, it does not warrant that the information is necessarily complete. This information has been edited or abridged and may not reveal all the information which might be useful or of interest to the contractor. Consequently, the Department will make available at its offices, the field logs relating to this boring.

Since subsurface conditions outside each borehole are unknown, and soil, rock and water conditions cannot be relied upon to be consistent or uniform, no warrant is made that conditions adjacent to this boring will necessarily be the same as or similar to those shown on this log. Furthermore, the Department will not be responsible for any interpretations, assumptions, projections or interpolations made by contractors, or other users of this log.

Water levels recorded on this log should be used with discretion since the use of drilling fluids in borings may seriously distort the true field conditions. Also, water levels in cohesive soils often take extended periods of time to reach equilibrium and thus reflect their true field level. Water levels can be expected to vary both seasonally and yearly. The absence of notations on this log regarding water does not necessarily mean that this boring was dry or that the contractor will not encounter subsurface water during the course of construction.

WATER MEASUREMENT

AB .... After Bailing
AC .... After Completion
AF .... After Flushing
w/C .... with Casing
w/M .... with Mud
WSD .... While Sampling/Drilling
w/AUG .... with Hollow Stem Auger

MISCELLANEOUS

NA .... Not Applicable
w/ .... with
w/o .... with out
sat .... saturated

DRILLING OPERATIONS

AUG .... Augered
CD .... Core Drilled
DBD .... Disturbed by Drilling
DBJ .... Disturbed by Jetting
PD .... Plug Drilled
ST .... Split Tube (SPT test)
TW .... Thinwall (Shelby Tube)
WS .... Wash Sample
NSR .... No Sample Retrieved

WH .... Weight of Hammer
WR .... Weight of Rod
Mud .... Drilling Fluids in Sample
CS .... Continuous Sample

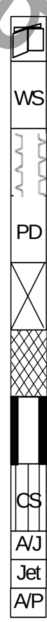
SOIL/CORE TESTS

SPT N_{60} .... ASTM D1586 Modified Blows per foot with 140 lb. hammer and a standard energy of 210 ft-lbs. This energy represents 60% of the potential energy of the system and is the average energy provided by a Rope & Cathead system.
MC .... Moisture Content
COH .... Cohesion
γ .... Sample Density
LL .... Liquid Limit
PI .... Plasticity Index
Φ .... Phi Angle
REC .... Percent Core Recovered
RQD .... Rock Quality Description (Percent of total core interval consisting of unbroken pieces 4 inches or longer)
ACL .... Average Core Length (Average length of core that is greater than 4 inches long)
Core Breaks .... Number of natural core breaks per 2-foot interval.

DISCONTINUITY SPACING

Fractures	Distance	Bedding
Very Close	<2 inches	Very Thin
Close	2-12 inches	Thin
Mod. Close	12-36 inches	Medium
Wide	>36 inches	Thick

DRILLING SYMBOLS



Vane Shear Test
Washed Sample (Collected during plug drilling)
Augered
Plug Drilled
Split Tube Sample (SPT N_{60} 2 in. spilt tube with liners)
Thin Wall Sample (3 in. Shelby Tube)
Core Drilled (NV Core Barrel unless otherwise noted)
Continuous Soil Sample
Augered & Jetted
Jetted
Augered & Plug Drilled

RELATIVE DENSITY

Compactness - Granular Soils	BPF
very loose	0-4
loose	5-10
medium dense	11-24
dense	25-50
very dense	>50

Consistency - Cohesive Soils	BPF
very soft	0-1
soft	2-4
firm	5-8
stiff	9-15
very stiff	16-30
hard	31-60
very hard	> 60

COLOR

blk .... Black   **wht** .... White
grn .... Green   **brn** .... Brown
orng .... Orange   **yel** .... Yellow
dk .... Dark   **lt** .... Light
IOS .... Iron Oxide Stained

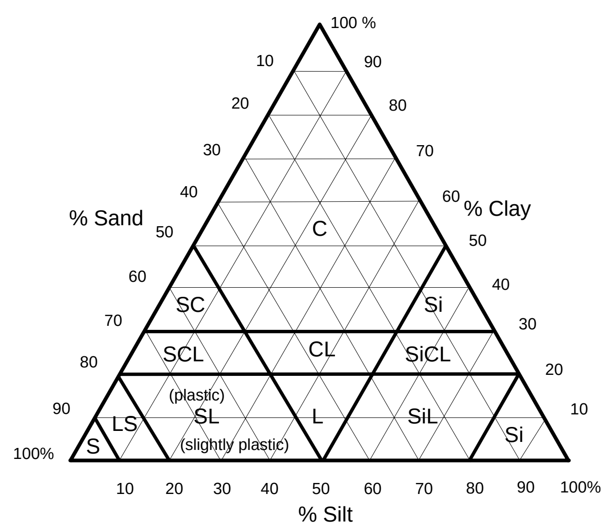
GRAIN SIZE /PLASTICITY

VF .... Very Fine   **pl** .... Plastic
F .... Fine   **slpl** .... Slightly Plastic
Cr .... Coarse

SOIL/ROCK TERMS

C .... Clay   **Lmst** .... Limestone
L .... Loam   **Sst** .... Sandstone
S .... Sand   **Dolo** .... Dolostone
Si .... Silt   **wx** .... weathered
G .... Gravel (No. 10 Sieve to 3 inches)
Bldr .... Boulder (over 3 inches)
T .... till (unsorted, nonstratified glacial deposits)

Mn/DOT Triangular Textural Soil Classification System



MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

UNIQUE NUMBER 75647

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
8308-44	**83037**	**MN Trunk Highway 60**	**T13**	**1170.4** *(Surveyed)*

Location Watonwan Co. Coordinate: X=534861 Y=139395 (ft.)

Latitude (North)=43°57'21.75" Longitude (West)=94°47'03.46"

No Station-Offset Information Available

Drill Machine **207184 CME 850 Track**

Hammer **CME Automatic Calibrated**

SHEET 1 of 1

Drilling Completed **1/5/12**

Depth (ft)	Elev.	Classification
1.0	1169.4	slightly organic plastic Loam with roots on top, black, moist to damp
2.0	1168.4	Fine Sand with a litle Gravel and a seam of plastic Silt Loam at 1.8', brown with gray, damp
4.0	1166.4	Clay Loam, grays and damp
11.2	1159.2	plastic Loam with some pebbles and a few layers of Clay Loam, light brown with light gray swirls to 6.0', moist
21.0	1149.4	Clay Loam with some pebbles, pockets and veins of Gypsum 15.0'-21.0'; gray with some IOS at 20.0'; very moist
45.8	1124.6	Clay Loam to Clay with some pebbles and a thin seam of Fine Sand at 35.0', gray with light gray, very moist
47.0	1123.4	Loamy Fine Sand with some Gravel, light gray, moist to wet
74.3	1096.1	plastic Silt Loam with some pebbles, grays, damp to moist

Bottom of Hole - 74.3'

No water encountered or measured during drilling

Approx. Depth (ft)	SPT N_{60}	MC (%)	COH (psf)	γ (pcf)	Other Tests Or Remarks
0.5		20			
1.5		8			
2.5	13	16			
5		18	840	131	%Si-40.6; %C-17.6
6.5	9	20			
10		20	1650	130	%Si-38.1; %C-18.4
11.5	19	16			
15		21	2025	128	%Si-44.9; %C-25.4
16.5	9	23			
20		27	1040	126	
21.5	18	22			
25		25			
26.5	12	23			
30		21	1990	130	%Si-43.5; %C-27.0
31.5	16	24			
35		20	2570	131	%Si-42.7; %C-27.4
36.5	23	23			
40	17	22			
42.5	17	22			
45		21	2180	130	%Si-41.8; %C-29.9
46.5	23 37 50/.4	15			
48		10			
50	27 49 50/.3	11			
55	25 47 50/.3	14			
60	27 49 50/.3	12			
65	82	14			%Si-49.9; %C-16.9
70	82	13			
74.3	50/.3	MUD			

Index Sheet Code 3.0

Soil Class:DSB Rock Class: Edit: Date: 3/1/12

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MINNESOTA DEPARTMENT OF TRANSPORTATION - GEOTECHNICAL SECTION

LABORATORY LOG & TEST RESULTS - SUBSURFACE EXPLORATION

UNIQUE NUMBER 75648

U.S. Customary Units

State Project	Bridge No. or Job Desc.	Trunk Highway/Location	Boring No.	Ground Elevation
8308-44	**83037**	**MN Trunk Highway 60**	**T14**	**1172.8** (Surveyed)

Location Watonwan Co. Coordinate: X=534959 Y=139471 (ft.)

Latitude (North)=43°57'22.50" Longitude (West)=94°47'02.12"

No Station-Offset Information Available

Drill Machine **207184 CME 850 Track**

Hammer **CME Automatic Calibrated**

SHEET 1 of 1

Drilling Completed **1/11/12**

Depth	Elev.	Classification
0.5	1172.3	organic plastic Loam with roots, dark brown and damp
5.5	1167.3	plastic Sandy Loam with a few roots, brown with a few dark brown seams, moist
8.0	1164.8	Clay Loam, grays and moist
13.0	1159.8	plastic Sandy Loam with a few pebbles, mixed light gray and brown, moist
15.5	1157.3	plastic Sandy Loam with a few pebbles, gray- brown and damp
20.5	1152.3	Clay Loam with pebbles, gray and damp
22.0	1150.8	Sand, gray and saturated
48.0	1124.8	Clay Loam with pebbles, gray and moist
77.0	1095.8	plastic Sandy Loam with pebbles, gray, damp to moist
78.9	1093.9	Sand with a pocket of Clay, gray and saturated

Bottom of Hole - 78.9'

No water encountered or measured during drilling

SPT N_{60}	MC (%)	COH (psf)	γ (pcf)	Other Tests Or Remarks
20	11, 13			
11	16			
13	20			
	21			
17	20			
27	19			
23	15			
18	18			
9	26, 21			
12	26			
10	22			
14	26			
9	26			
	22			
16	24			
	20			
18	21			
17	22			
38	22			
27, 43, 50/.4	11			
49, 50/.4	12			
78	14			
22, 43, 50/.4	13			
83	13			
80	13			
50/.4	20			

REC (%) | RQD (%) | ACL (ft) | Core Breaks | Formation or Member