

CCI & Associates Inc.



Settlement Analysis

DOCUMENT No. [REDACTED]
CCI PROJECT [REDACTED]

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To: [REDACTED]
From: CCI & Associates Inc.
Date: 2021-10-12
Re: [REDACTED]
CCI # [REDACTED]

1 INTRODUCTION

[REDACTED] planning the replacement of an NPS 10 distribution line within [REDACTED]. As part of the project, the pipeline is required to cross [REDACTED]. It is understood that the proposed crossing will be installed utilizing Horizontal Directional Drilling (HDD) trenchless methodology, intending to minimize the impact to [REDACTED] operations and surrounding structures. To obtain the required approvals for the proposed crossing, settlement analysis must be completed showing minimal movement of the rail tracks is expected.

In response to your request, CCI & Associates Inc. (CCI) is pleased to provide this settlement analysis assessing the potential surface settlement along the surface [REDACTED] as a result of the HDD installation. Authorization to proceed with the settlement analysis was received from [REDACTED].

2 CROSSING SITE CONDITIONS

2.1 Site Description

As noted, the project site is located in the [REDACTED], approximately [REDACTED]. On a southwest-northeast alignment, the proposed crossing passes beneath [REDACTED] tracks, associated embankment approximately 5 to 10 ft high, and [REDACTED] a single lane roadway. To the northeast of [REDACTED], the crossing area is surrounded by residential structures. To the southwest [REDACTED], the crossing area is surrounded by a large grass field to the north and a densely populated collection of medium-sized trees to the south.

2.2 Subsurface Conditions

To form a basis for preparing the settlement analysis, the subsurface conditions have been assessed using publicly available water wells, geological mapping and CCI's experience in the project area. Although many driller's wells are available in the area, the three (3) nearest wells reviewed were located approximately 800 to 900 ft north of the proposed crossing alignment. No site-specific boreholes are available for the project. The three nearest wells have been provided in Appendix A.

Based on the drillers notes from the water wells, overburden material was encountered from surface to a depth of at least 25 ft, the total depth of the wells. Based on driller notes, the overburden was described as highly variable in the area, comprising deposits of clay, sand, sandy clay, and clayey sand. During the drilling of the wells, no groundwater was encountered; however, the groundwater could elevate based on seasonal fluctuations and precipitation events.

The soil lithology described within the water wells are consistent with the surficial geology maps and CCI's experience in the area. The project area falls [REDACTED] which, in general, describes the overburden soil as fine-grained sand and silt that overlies sandstone and/or mudstone (bedrock). Bedrock is not anticipated for the crossing depths for this project.

Compact was used as the soil type for the analysis, however, there is uncertainty associated with using water well logs and associated desktop review to complete the settlement analysis. It is recommended to complete a site-specific geotechnical investigation to confirm the assumptions made in this analysis.

3 SETTLEMENT ANALYSIS

3.1 Overview

Two types of settlement analysis were completed for the proposed crossing. A finite element analysis was completed using RocScience RS2 software. As well, a normal probability estimation method analysis was completed to model potential settlement by analytical methods.

In general, and given the anticipated subsurface conditions based on water well drilling logs and surficial geological maps, the assessment of ground surface movement (i.e., settlement) has considered the following:

- The minimum depth of the bore is proposed to be approximately 15 ft and located below the railway. This depth measurement is taken from the crown of the borehole wall and the railway tracks.
- Based on available geotechnical information, the bore is expected to be installed through poorly graded, loose sand.
- In the short term, the borehole wall, assumed to be 16" in diameter, will be supported by pressurized bentonite drilling fluid, limiting potential for collapse or sloughing of sand through which the borehole is constructed.
- In the long term, the 10" diameter pipeline will be installed within the open borehole, providing approximately 3" of annulus separating the pipe from the borehole wall.

To help reduce unanticipated surface settlement or heaving and minimizing loss of ground, the contractor should maintain good workmanship and follow industry best practices during drilling operations. During construction, a visual assessment of the volume of excavated soil from the drilling operations should be completed and compared with the expected cuttings volume. The assessment does not include the potential for over excavation at localized areas along the HDD alignment.

As noted, the analysis assumed an annulus of 3", radially. The analysis was performed using the RS2 finite element analysis software created by RocScience Inc.

3.2 Finite Element Analysis Input

A cross section profile showing the proposed NPS 10 pipeline within a 16" borehole where the alignment crosses the railway at its minimum required cover (15 ft) has been modelled using RS2 to simulate the trenchless installation. The geotechnical model was analysed with a 6-node triangular element graded mesh, with the NPS 10 pipeline centered in the borehole with 15 ft of soil cover between the crown and rail tracks. The lithology and associated parameters were interpreted from the local water well drilling reports [REDACTED] online database

and surficial geological maps. The soil types and associated parameters used in the model is provided in Table 1, below.

Table 1: Soil Parameters for the Settlement Analysis

Soil Description	Bulk Unit Weight (lbs/ft ³)	Effective Friction Angle (°)	Effective Cohesion (lbs/ft ²)	Young's Modulus (lbs/ft ²)	Poisson's Ratio
Ballast (assumed)	140	40	0	3,000,000	0.3
Poorly Graded Sand	120	30	0	325,000	0.3

The analysis was modelled in three stages, as described below:

- Stage 1: in-situ with the railway load.
- Stage 2: 16-inch borehole excavated with a drilling fluid pressure equal to an estimated hydrostatic drilling fluid pressure of 1,500 lb/ft². inside the borehole.
- Stage 3: 10-inch pipe located within the center of the excavation and a left-over cuttings mixture in the annulus of the excavation.

The results presented in the below sections reference settlement expected in the third Stage. A representative geotechnical model showing the geometry, layers and mesh used for the analysis is shown on Figure 1, attached.

A sensitivity analysis was conducted for different surface loads to represent train loads up to 2,000 lb/ft² (typical Cooper E80 loading). Minimal changes of surficial settlement from the results displayed below were noted.

3.3 Normal Probability Estimation Method Analysis

Using a normal probability estimation method, an expected settlement trough width and maximum potential settlement was determined. This analysis predicts a settlement trough and depth by volume equivalent to the annulus space excavated around the product pipe created during installation. Additional numerical reduction factors are used to account for soil mass loosening, arching and drilling fluid/cuttings remaining in the borehole following construction.

3.4 Results

The results of the analysis show that the maximum displacement expected below the rail tracks is 1/10 inch of settlement at 15 ft depth of cover. As well, the results indicate that the maximum displacement in the soil immediately adjacent to the borehole occurred at the crown of the bore. It revealed plastic deformation and inward movement of approximately 2.3 inches.

A graphical representation of the surficial settlement of the model is shown on Figure 2, attached.

It is understood that pressured drilling fluid will be present within the borehole for the construction duration. The fluid minimizes the risk of collapse of the annulus while the soil is disturbed during the installation process. This phenomenon reduces the risk of surface settlement.

As noted, no site-specific subsurface data has been obtained at the crossing area. The results are based off interpretation from drillers logs from nearby water wells, which could result in some error. Site-specific boreholes should be obtained. In addition, the results described above are valid for an annulus that contains a left-over cuttings and bentonite mixture.

Although not anticipated, if full collapse of the overcut were to occur, surface settlements would be larger. Using the normal probability estimation method analysis of this situation, it is estimated that up to 1 inch of settlement could occur with 15 ft of cover.

4 CLOSURE

This report has been prepared in accordance with generally accepted geotechnical principles and practice for the [REDACTED]. No other warranty is expressed or implied.

We trust that this settlement analysis provides the information required at this time. If you have questions or comments, please contact us at your convenience.

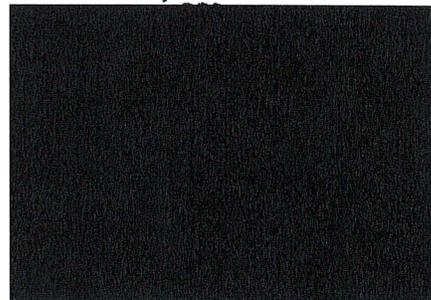
On behalf of CCI & Associates Inc.
[REDACTED]

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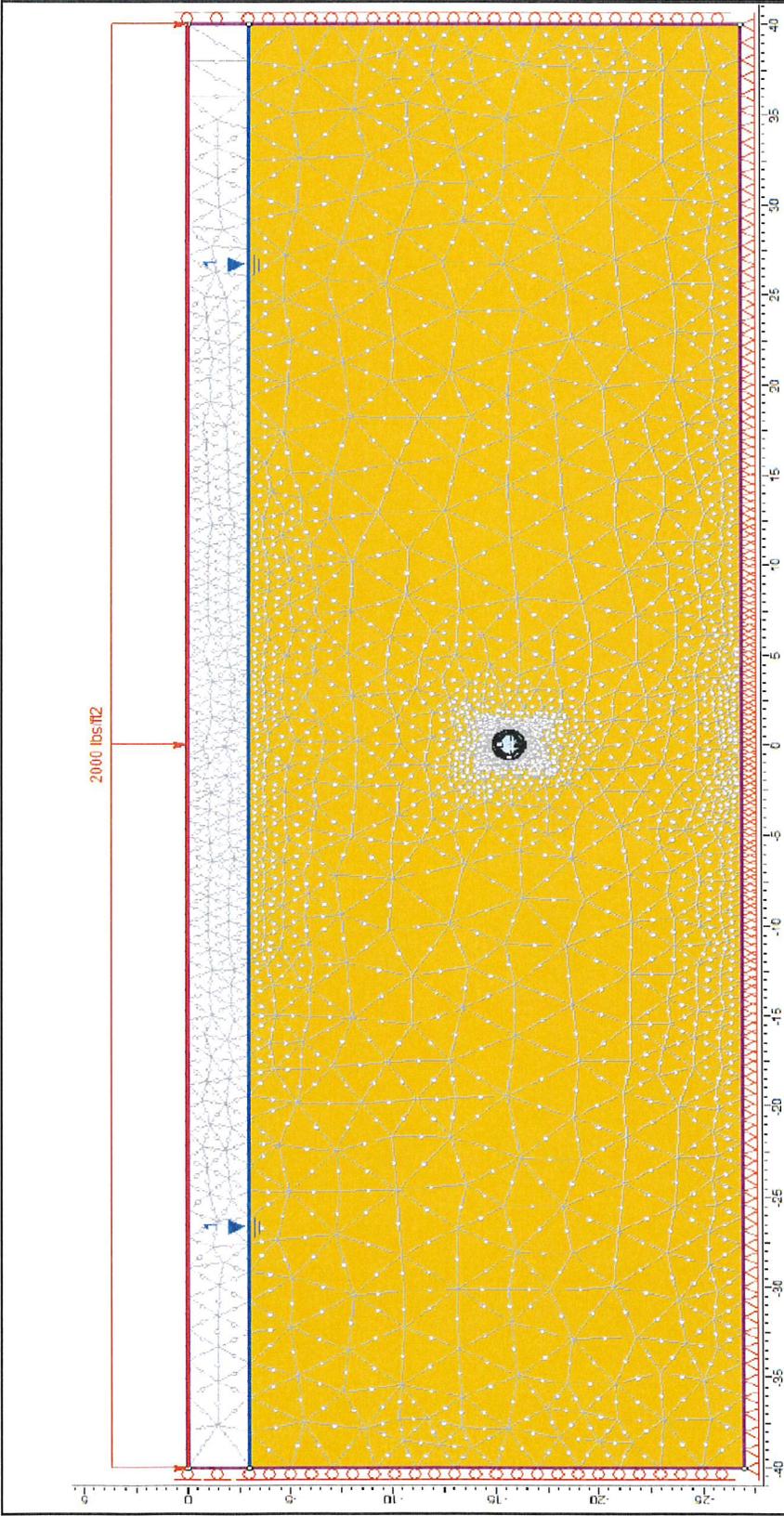
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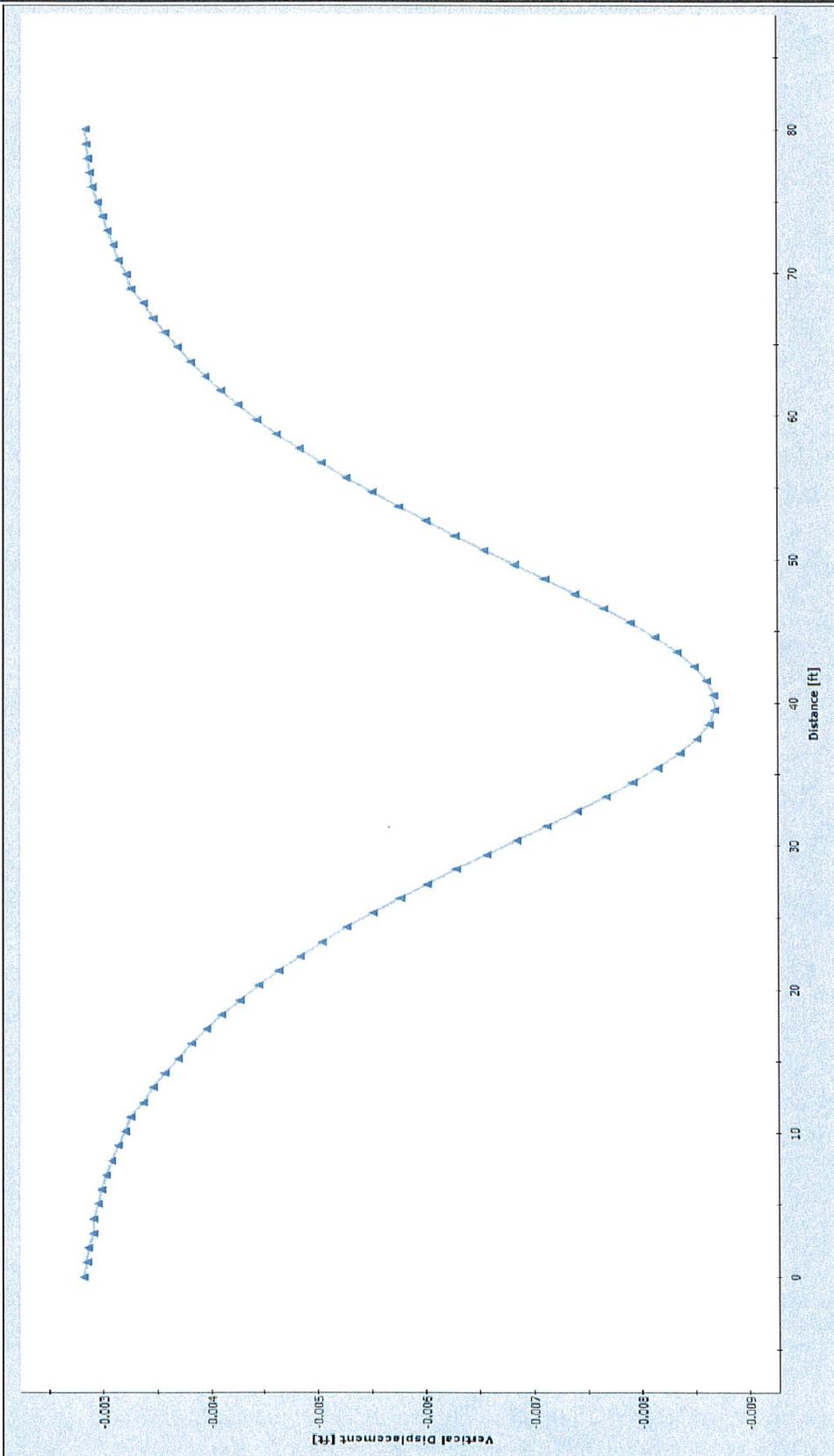


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Figures



 INC.	
 Crossing Cross Section Model	
Report No. 	FIGURE 1



	
ESTIMATED SURFACE SETTLEMENT  CROSSING	
Report No: 	FIGURE 2

Appendix A

Water Well Driller Logs