ADDENDUM NO. 3

DATE: July 21, 2021

PROJECT: **Old Grand Ave. (1st St. to Fire Station) Watermain Project 8400**

OWNER: VILLAGE OF GURNEE

TO: PROSPECTIVE BIDDERS

This Addendum forms a part of the Contract Documents and modifies the Bidding Documents approved for bid, with the amendments as noted below.

This Addendum consists of the Geotechnical Engineering Report for the Railroad Crossing. This Addendum contains the following revisions:

CHANGES TO THE CONTRACT DOCUMENTS AND SPECIFICATIONS

Geotechnical Engineering Report:

- Please add the Geotechnical Engineering Report to the contract documents. This report is for reference only. The Contractor will still be responsible for any additional design criteria and settling/monitoring plan specified by the Canadian Pacific Railroad. Please see the RAIL ROAD PERMITTING special provision for further clarification.

Signed: N. Leach

Village of Gurnee
Nicholas Leach
Project Engineer

Please acknowledge receipt of this Addendum by signing below and faxing or emailing a copy of the Addendum to the Village of Gurnee, Engineering Department at (847)-623-9475 or nleach@village.gurnee.il.us. Failure to do may disqualify the Bidder.

______________________	______________________
Firm	By
______________________	______________________
Name	Title

Geotechnical Engineering Report

Old Grand Avenue Watermain

Canadian Pacific Crossing

Gurnee, Illinois

PSI Report Number: 00474399-1
December 18, 2020

intertek psi

4421 West Harrison Street
Hillside, Illinois 60162
phone: (708) 236-0720
fax: (708) 236-0721
intertek.com/building
psiusa.com

December 18, 2020

Village of Gurnee
325 N. O'Plaine
Gurnee, IL 60031

Attn: Ms. Heather L. Galan, P.E.
Village Engineer / Assistant Public Works Director
HGalan@village.gurnee.il.us

Re: Geotechnical Engineering Report
Old Grand Avenue Watermain
Canadian Pacific Railroad Crossing
Gurnee, Illinois
PSI Report No.: 00474399

Dear Ms. Galan:

Professional Service Industries, Inc. (PSI), an Intertek company, is pleased to submit this Geotechnical Engineering Report for the proposed Old Grand Avenue Watermain installation crossing at the Canadian Pacific Railroad in Gurnee, Illinois. Included in this report are the results of the subsurface exploration and recommendations concerning the construction of the proposed watermain.

PSI appreciates the opportunity to have provided the Village of Gurnee with PSI's geotechnical engineering services and looks forward to participation in the construction phase of this project. If you have any questions concerning this report or if we may be of further service in any manner, please contact our office.

Respectfully submitted,

Professional Service Industries, Inc.

David T. Lewandowski

Reda Bakeer
Digitally signed by Reda Bakeer
Date: 2020.12.18 08:58:22 -06'00'

David T. Lewandowski, P.E.
Project Engineer

Reda Bakeer, Ph.D.
Principal Consultant

GEOTECHNICAL ENGINEERING REPORT

For the

OLD GRAND AVENUE WATERMAIN
CANADIAN PACIFIC RAILROAD CROSSING
GURNEE, ILLINOIS

Prepared for

VILLAGE OF GURNEE
325 N. O'PLAINE
GURNEE, ILLINOIS 60031

Prepared by

PROFESSIONAL SERVICE INDUSTRIES, INC.
4421 WEST HARRISON STREET
HILLSIDE, ILLINOIS 60162
TELEPHONE (708) 236-0720

PSI REPORT NO.: 00474399-1

DECEMBER 18, 2020

intertek psi

DAVID T. LEWANDOWSKI
062-052799
LICENSED PROFESSIONAL ENGINEER
STATE OF ILLINOIS

David T. Lewandowski, P.E.
Project Engineer

Reda Bakeer
Digitally signed by Reda Bakeer
Date: 2020.12.18 08:58:43 -06'00'

Reda Bakeer, Ph.D.
Principal Consultant

The above Professional Engineering Seal and signature is an electronic reproduction of the original seal and signature. Original hard copies can be provided upon request. This electronic reproduction shall not be constructed as an original or certified document.

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1. PROJECT INFORMATION

1.1 PROJECT AUTHORIZATION

This report presents results of the geotechnical subsurface exploration and evaluation conducted by Professional Service Industries, Inc. (PSI) for the Village of Gurnee, Inc., in connection with the proposed watermain to be installed beneath the Canadian Pacific Railway tracks in Gurnee, Illinois. The following table summarizes, in a chronological order, the project authorization history for the services performed and presented in this report by PSI.

PROJECT TITLE: OLD GRAND AVENUE WATERMAIN - GURNEE, ILLINOIS		
Document/Reference No.	**Date**	**Requested/Provided By**
Email: Request for Proposal	6/29/2020	Mr. Nicholas Leach – Village of Gurnee
PSI Proposal No. 0047-316660	7/21/2020	PSI
Signed Proposal	8/10/2020	Mr. Patrick Muetz - Village of Gurnee

1.2 PROJECT DESCRIPTION

Based on the information provided by the Village of Gurnee and Canadian Pacific (CP) Railway, the Village is planning to install an underground watermain that will cross beneath the existing CP double tracks located approximately 300 feet north of the existing CP bridge at Old Grand Avenue. It is understood that the Jack-and-Bore (J&B) trenchless technique will be used to install the watermain.

A tree line exists just beyond the existing double-track railroad embankment. Gurnee Park District property, namely Viking Park, lies just west of the tree line/rail right-of-way (ROW). Village property lies just east of the eastern railroad right-of-way. A paved bicycle/walking path lies within the Village Property and runs roughly parallel to the tracks. Outside of the bicycle path the ground is covered with landscape grass and trees.

The Village provided PSI with a Geotechnical Plan and Profile sheet prepared by Clark Dietz showing the existing ground surface profile, and details, alignment, elevations and stationing of the proposed watermain crossing. The proposed Certa-Lok C900 PVC watermain will be 12 inches in diameter. About 101 linear feet of the PVC pipe watermain within the railroad embankment ROW lines will be encased within a 36-inch diameter steel pipe sleeve to be installed using the J&B trenchless technique. Centerline of the PVC pipe watermain will coincide with that of the steel sleeve (casing). In addition, 48-inch diameter vertical vaults will be installed outside the CP ROW lines on either side of the railroad embankment. Tops of the east and west vaults will be located near the existing ground surface grades at El. 676.93 and 671.3 feet, respectively. Meanwhile, bottoms of the east and west vaults will be established at approximately El. 667.5± and 663.7± feet, respectively.

As per the furnished plan and profile, the steel pipe sleeve will be installed with the J&B trenchless technique to span between a 10-foot wide and 20-foot long West Pit at the west CP ROW line at about Sta. 18+85 and a 10-foot wide and 30-foot long East Pit at the east CP ROW line at about Sta. 19+86. Top of the steel pipe sleeve will be at the approximately 9- and 5-foot depths (about EL. 670± and 667± feet) below the existing grades at the east and west CP ROW lines, respectively. Therefore, invert of the 36-inch dimeter steel pipe sleeve will vary between about El. 667± and 664± feet on the east and west sides, respectively. Invert of the uncased east segment of the PVC pipe watermain will vary from about El. 667± feet near Sta. 21+00 to about El. 668± feet at the east end of the steel pipe sleeve. Invert of the uncased west segment of the PVC pipe watermain will vary from about El. 663± feet near Sta. 18+00 to about El. 665± feet at the west end of the steel pipe sleeve (casing).

The following table lists the material and information provided to PSI for this project:

DESCRIPTION OF MATERIAL	PROVIDER/SOURCE	DATE
Email: Project Description	Village of Gurnee	7/07/2020
Email: Location Map, Geotechnical Plan (boring locations)	Village of Gurnee	7/07/2020
Phone Conversation: Project Description	Village of Gurnee	7/07/2020
Email: Plan and Profile Sheet	Village of Gurnee	11/03/2020
Email: CP Geotechnical Protocol - Utility Installation dated 2/25/2020	CP	11/05/2020
Email: Track Movement Monitoring Guidelines for Trenchless Pipe Installation Rev 06-18-18	CP	11/05/2020
Email: Thresholds Track Settlement Monitoring Review and Alert requirements	CP	11/05/2020
Email: Train Types and Speeds	CP	11/10/2020

The geotechnical recommendations presented in this report are based on the available project information, the proposed location and orientation of the proposed watermain at the site and the subsurface materials described in this report. If any of the information we have been given or assumed is incorrect, please contact us so that we may amend the recommendations presented accordingly. PSI will not be responsible for the implementation of its recommendations when it is not notified in advance and in writing of changes in the project.

1.3 PURPOSE/SCOPE OF SERVICES

The purpose of this exploration was to explore the subsurface conditions at the subject site to delineate the subsurface material stratification, groundwater levels, soil design parameters, and construction recommendations to be used to install the watermain crossing. The Client provided the requested scope of services which included drilling two (2) Standard Penetration Test (SPT) type soil borings in general accordance with the applicable ASTM standards and procedures, installation of a standpipe piezometer (monitoring well), performing select laboratory testing, and preparing this report. SPT soil borings B-1 and B-2 were drilled in the areas of the J&B West Pit and East Pit, respectively, and they both extended to their planned depth of about 30 feet below the existing grade (beg). Based on the furnished profile and plan, ground surface in the area of boring B-1 made on the west side of the railroad embankment varies between approximately El. 671½ and 672½ feet. Meanwhile, ground surface in the area of boring B-2 made on the east side of the railroad embankment varies between approximately El. 677 and 678½ feet. Therefore, the ground surface in the area of B-2 is about 4½ to 7 feet higher than the ground surface in the area of B-1.

Standpipe piezometer SP-1 was installed adjacent to B-1 and extended to an approximate tip depth of 15 feet beg on the west side of the crossing. In addition, PSI performed hand-auger boring HA-2 adjacent to B-2 on the east side of the crossing to an approximate depth of 7½ feet beg.

This report briefly outlines the testing procedures, presents available project information, describes the site and subsurface conditions, and presents geotechnical recommendations regarding the following:

- A discussion of subsurface conditions encountered including soil properties;
- A summary of groundwater conditions encountered during the field investigation including the observed groundwater levels within the boreholes and the presence of any perched water levels at the borehole locations;
- An evaluation of the data as it relates to the proposed construction;
- Recommendations for J&B installation given the soil profile encountered and possible presence of obstructions undetected at the boring locations;
- An estimate of the expected extent and magnitude of ground movement due to the watermain installation;
- Measures to be undertaken to preserve safety of rail operations and structural integrity of the railroad embankment;
- Recommendations for settlement monitoring during the J&B installation;
- A contingency plan and notification procedure to be implemented in the event of excessive/unexpected movements during the J&B installation; and
- Recommendations for the placement and compaction of structural backfill.

Any statements in this report or on the boring logs regarding odors, colors, and unusual or suspicious items or conditions are strictly for informational purposes. Furthermore, PSI was not requested to provide any service to investigate or detect the presence of moisture, mold or other biological contaminants in or around any structure, or any service that was designed or intended to prevent or lower the risk of the occurrence of the amplification of the same. Mold is ubiquitous to the environment with mold amplification occurring when building materials are impacted by moisture. As such, PSI cannot be held responsible for the occurrence or recurrence of mold amplification.

2. DRILLING, FIELD AND LAB TESTING PROCEDURES

2.1 DRILLING AND SAMPLING PROCEDURES

The soil borings and standpipe piezometer installation were performed using a track mounted Geoprobe drill rig, a 7822DT, equipped with a rotary head. Conventional 2¼-inch diameter hollow-stem augers were used to advance the boreholes. Representative samples from the SPT soil borings were obtained employing the split-spoon sampling procedures in accordance with the applicable ASTM standards. Upon completion of the SPT soil borings, PSI returned to the site on 10/06/2020 and performed a hand-auger boring, HA-2, adjacent to boring B-2 on the east side of the railroad embankment. The purpose of this additional exploration was to obtain additional soil samples for laboratory testing.

The standpipe piezometer, SP-1, was installed approximately 3 feet east of boring B-1 drilled on the west side of the railroad embankment. The purpose of SP-1 was to monitor subsurface groundwater level upon completion of drilling. The standpipe piezometer borehole was drilled to the planned depth of approximately 15 feet beg. The piezometer is comprised of a 2-inch diameter slotted PVC well screen, 10 feet long (approximately 5 feet beg to 15 feet beg) surrounded by a sand filter pack. The top part of the installation is a 2-inch PVC casing with a bentonite annular seal. The casing is covered with a rubber "butterfly" cap with a lock. The well installation is protected with a metal manhole cover installed flush with the existing ground surface.

SP-1 remains to be functional and could be used by the Contractor to monitor water level during the J&B installation of the steel pipe sleeve (casing) and construction of the uncased PVC pipe watermain segments and the two (2) proposed vaults. Well abandonment is not included in our scope of work discussed herein. Abandonment is an additional service that can be performed for an additional charge upon request.

2.2 FIELD TESTS AND MEASUREMENTS

PENETRATION TESTS - During the drilling and sampling process, the Standard Penetration Test (SPT) was performed at regular intervals to obtain the standard penetration resistance of the soil. The standard penetration value (N) is defined as the number of blows of a 140-pound hammer falling thirty (30) inches, required to advance the split-spoon sampler one (1) foot into the soil. The sampler is lowered to the bottom of the drilled hole and the number of blows is recorded for each of three (3) successive increments of six (6) inches penetration. The "N" value is obtained by adding the second and third incremental numbers. Results of the SPT indicate the relative density and comparative consistency of the soils, and thereby provide a basis for estimating the relative strength and compressibility within the individual subsurface soil profile components.

WATER LEVEL MEASUREMENTS - Water level observations were performed in the soil borings during and upon completion of drilling operations. These measurements are noted on the boring logs presented herewith.

Upon completion of the borings, subsequent water level readings were taken in the standpipe piezometer, SP-1. Those measurements are presented in a table in the Groundwater Conditions section of this report.

Seasonal variations, temperature and recent rainfall conditions may influence the levels of the groundwater table and volume of water will depend on the permeability of the soils.

GRAB SAMPLES - During the PSI's hand-auger exploration, representative grab samples were taken from boring HA-2. The grab samples were used to perform classification, grain-size analysis, moisture content determination, and Atterberg limit testing. These samples are often highly disturbed and cannot be used for determination of in-situ shear strength or density.

BORING LOCATIONS – The boring locations were selected by PSI personnel within several feet away from the identification stakes placed by the Village to identify the centerline of the watermain. The approximate boring locations are shown on the Boring Location Map in the **Appendix**.

As previously discussed, ground surface in the area of boring B-1 made on the west side of the railroad embankment varies between approximately El. 671½ and 672½ feet. Meanwhile, ground surface in the area of boring B-2 made on the east side of the railroad embankment varies between approximately El. 677 and 678½ feet. Therefore, the ground surface in the area of borings B-2 and HA-2 is about 4½ to 7 feet higher than the ground surface in the area of B-1 and SP-1.

2.3 Laboratory Testing Program

In addition to the field exploration, a supplemental geotechnical laboratory-testing program was conducted to determine pertinent engineering characteristics of the subsurface materials at the exploration locations.

Laboratory Determination of Water (Moisture) Content of Soil by Mass - For many materials, water content is one of the most significant parameters used in establishing a correlation with the soil behavior and its index properties. Water content is used in expressing the phase relationship of air, water, and solids in a given volume of material. In fine-grained cohesive soils, consistency of a given soil type depends on its water content. Water content of a soil, along with its liquid and plastic limits as determined by Atterberg Limit testing, express its relative consistency or Liquidity Index.

Unconfined Compressive Strength of Cohesive Soils (Q_r) - The primary purpose of the unconfined compressive strength test is to obtain the compressive strength of soils that possess sufficient cohesion to permit testing in the unconfined state. The values of the unconfined compressive strength, as determined from soil samples obtained from the split-spoon sampler (IDOT approved Rimac Q_r), must be considered recognizing the manner in which they were obtained because the split-spoon sampling techniques provide representative, but somewhat disturbed, soil sample.

Atterberg Limits – The Atterberg Limits are defined as the Liquid Limit (LL) and Plastic Limit (PL) states of a given soil. These limits are used to determine the moisture content ranges where the soil characteristics change from behaving more like a semi-fluid at the Liquid Limit end to where the soil behaves more like individual soil particles at the Plastic Limit end. The Liquid Limit is often used to indicate if a soil is of low or high plasticity. The Plasticity Index (PI) is the difference between the Liquid Limit and Plastic Limit of a given soil. The Plasticity Index is used in conjunction with the Liquid Limit to assess if the material will behave like a silt or clay. The material can also be classified as an organic material by comparing the Liquid Limit of the natural material to the Liquid Limit of the sample after being oven-dried.

Grain Size Analysis – The purpose of determining the grain or particle size distribution of a sample is to classify and characterize the density of materials, determine the packing arrangement of the particles and estimate the shear strength and permeability of the soil matrix. To determine the grain size of coarse particles, sieves of varying standard opening sizes are used. Hydrometer analysis is used to determine the grain size of materials finer than fine sand sized particles. In addition to classification, the grain size distribution is important for use in filter material design between two materials, estimating permeability of a soil, and liquefaction and swell potential of a soil.

The phases of the laboratory testing program were conducted in general accordance with the applicable ASTM standards. The results of these tests are to be found on the accompanying boring logs given in the **Appendix**.

3. SITE AND SUBSURFACE CONDITIONS

3.1 SITE LOCATION AND DESCRIPTION

The area to the west of the existing double-track railroad embankment is lined with mature trees. Viking Park lies just west of the tree line and the CP right-of-way line. A photo of this area is shown below.

Facing East from within Viking Park (Boring B-1 Area)

The area east of the existing CP right-of-way line is the Village property that includes a bicycle/pedestrian path. A photo of this area is included below.

Facing West from Village Property & Bicycle Path (Boring B-2 Area)

3.2 Subsurface Conditions

PSI completed a total of three (3) soil borings, two (2) SPT borings and one hand-auger boring, along the alignment of the proposed watermain. SPT borings B-1 and B-2 extended to a final depth of approximately 30 feet beg. Hand-auger boring HA-2 extended down to an approximate depth of 7½ feet beg. The approximate boring locations are shown on the Boring Location Map in the **Appendix**. The locations of the soil borings were selected in the field by PSI in reference to the stakes placed by the Client along the watermain alignment.

The SPT soil borings were advanced utilizing 2¼-inch inside diameter, hollow-stem auger drilling methods. Soil samples were routinely obtained during the drilling process. In addition, the hand-auger boring was performed manually. Several grab samples were collected from the hand-auger equipment. Select soil samples were later tested in the laboratory to obtain soil material properties for the recommendations. Drilling, sampling, and laboratory testing were accomplished in general accordance with the applicable ASTM standard procedures. The types of subsurface materials encountered in the soil borings have been visually classified in general accordance with ASTM D2487 and ASTM D2488. The results of the visual classifications, Standard Penetration Tests, moisture content tests and water level observations are presented on the boring logs given in the **Appendix** of this report. Representative samples of the soils were placed in sample jars and are now stored in the laboratory for further analysis, if requested. Unless notified to the contrary, all samples will be disposed of after 60 days following the date of this report. As previously discussed, the ground surface in the area of B-2 and HA-2 is about 4½ to 7 feet higher than the ground surface in the area of B-1.

<u>Organic Surficial Soil</u>: At the location of boring B-1 drilled within Viking Park (west of RR track), the ground surface was underlain by black silty clay, topsoil. This surficial organic topsoil extended to approximately 8 inches beg.

<u>Existing Undocumented Fill</u>: At B-2 drilled within the Village property (east of RR track), the ground surface was underlain by disturbed, mixed black silty, clayey sand with debris (gravel, cinders, brick pieces) to a depth of about 4 feet beg. A sample of this stratum exhibited a moisture content of 16%.

<u>Natural Cohesive Strata</u>: The topsoil in B-1 and the undocumented fill in B-2 were underlain by undisturbed, naturally occurring lean clay, sandy lean clay, silty clay, sandy silty clay, and clayey silt to depths ranging from about 24½ feet beg in B-2 and to the terminal depth of about 30 feet in B-1. Samples of these strata exhibited moisture contents ranging from 12% to 22%. Their consistencies were stiff to very stiff as indicated by the SPT N-values of 7 to 26 blows per foot (bpf), Rimac (Q_r) values of 1.6 and 2.3 tons per square feet (tsf), and hand penetrometer (Q_p) values of 1.25 to 4 tsf.

<u>Intermittent Sand / Silt Strata</u>: Strata of poorly graded sand, silty (clayey) sand, and sandy silt were encountered at depths ranging from about 6 feet to 22 feet beg within the natural cohesive soil strata. Their relative densities were medium dense to dense as indicated by the SPT N-values ranging from 11 to 34 bpf.

<u>Silt Stratum</u>: In B-2, the lean clay stratum was underlain by a layer of silt to about the 27 foot depth beg. Its relative density was medium dense as indicated by an SPT N-value of 22 bpf.

<u>Poorly Graded Sand Stratum</u>: In B-2, the silt stratum was underlain by poorly-graded sand with gravel to the terminal depth of about 30 feet beg. Its relative density was very dense as indicated by an SPT N-value of 51 bpf.

The subsurface description is of a generalized nature to highlight the major subsurface stratification features and material characteristics at the boring locations. The boring logs included in the **Appendix** should be reviewed for specific information at the individual boring locations. These records include soil descriptions, stratifications, penetration resistances, locations of the samples and laboratory test data. The stratifications shown on the boring logs represent the conditions only at the actual boring locations. Variations may occur and should be expected between the boring locations. The stratifications represent the approximate boundary between subsurface materials and the actual transition may be gradual. Water level information obtained during field operations is also shown on these boring logs.

3.3 GROUNDWATER CONDITIONS

In soil borings B-1 and B-2, groundwater was observed at approximate depths of 12 feet and 28 feet beg during drilling and immediately upon completion, respectively. During hand-auguring of boring HA-2, free water was detected at an approximate depth of 7 feet beg. Free water was apparent within the predominant granular soils (sand and sandy silt) and more permeable seams (silt or sand) interbedded within the natural cohesive soils. These water level observations provide an approximate indication of the groundwater conditions at the time when the borings were drilled.

To provide water level observations over an approximate one-month period, standpipe piezometer SP-1 was installed adjacent to boring B-1 drilled on the west side of the railroad embankment. The measurement dates and associated water level readings taken by PSI are included in the table below.

MEASUREMENT DATE	WATER LEVEL DEPTH (FEET BEG)
9/18/2020	5.9
9/28/2020	5.8
10/06/2020	6.5
10/19/2020	6.5

As previously discussed, the ground surface in the area of B-2 and HA-2 is about 4½ to 7 feet higher than the ground surface in the area of B-1 and SP-1. The relatively shallow water levels detected at the locations of B-1 and SP-1 could be due to the development of a perched condition in the relatively more granular sand and silt strata underlain by a low permeable silty clay stratum. Meanwhile, boring B-2 indicated a groundwater level at the 28-foot depth beg.

The design frost depth in the geographical area of the project is at the 4-foot depth beg. As stated in *Section 5 on Page 6 of 37 of the CP Geotechnical Protocol - Utility Installation* dated 2/25/2020, "*No construction and installation of pipeline and utility crossing(s) will take place from January 1st to March 31st. This restriction is particularly critical to areas where frost penetrates the ground and may make it difficult to observe surface settlement and loss of soil from underneath the track substructure due to misperception of a levelled frozen surface. Such conditions pose a risk to the stability of CP's track and its substructure during thawing season and are not acceptable.*

In areas where the applicant does not consider frost as a potential risk, the applicant is required to assure and demonstrate to CP as to why winter work restriction is not applicable to their proposed work. Exceptions to winter work restriction will be evaluated on case by case basis."

Fluctuations in the groundwater level should be anticipated throughout the year depending on variations in climatological conditions and other factors not apparent at the time of the water level readings in the borings or standpipe piezometer. Additionally, discontinuous zones of perched water may exist within the soils. The possibility of groundwater level fluctuation should be considered when developing the design and construction plans for the project. PSI recommends that the Contractor determine the actual groundwater level at the site at the time of the construction activities. In this regard, SP-1 remained to be functional as of our last reading taken on 10/19/2020. Therefore, it could be used by the Contractor to monitor water level during the J&B installation of the steel pipe sleeve (casing) and the uncased PVC pipe watermain segments and construction of the two (2) proposed vaults outside the CP ROW lines.

4. GEOTECHNICAL EVALUATION AND RECOMMENDATIONS

4.1 CROSSING DESIGN INFORMATION

The Village provided PSI with a Geotechnical Plan and Profile sheet prepared by Clark Dietz showing the existing ground surface profile and details, alignment, elevations and stationing of the proposed watermain crossing. The proposed Certa-Lok C900 PVC watermain will be 12 inches in diameter. About 101 linear feet of the PVC pipe watermain within the railroad embankment ROW lines will be encased within a 36-inch diameter steel pipe sleeve to be installed using the J&B trenchless technique. Centerline of the PVC pipe watermain will coincide with that of the steel sleeve (casing). In addition, 48-inch diameter vertical vaults will be installed outside the CP ROW lines on either side of the railroad embankment. Tops of the east and west vaults will be located near the existing ground surface grades at El. 676.93 and 671.3 feet, respectively. Meanwhile, bottoms of the east and west vaults will be established at approximately El. 667.5± and 663.7± feet, respectively.

As per the furnished plan and profile, the steel pipe sleeve will be installed with the J&B trenchless technique to span between a 10-foot wide and 20-foot long West Pit at the west CP ROW line at about Sta. 18+85 and a 10-foot wide and 30-foot long East Pit at the east CP ROW line at about Sta. 19+86. Top of the steel pipe sleeve will be at the approximately 9- and 5-foot depths (about EL. 670± and 667± feet) below the existing grades at the east and west CP ROW lines, respectively. Therefore, invert of the 36-inch dimeter steel pipe sleeve will vary between about El. 667± and 664± feet on the east and west sides, respectively. Invert of the uncased east segment of the PVC pipe watermain will vary from about El. 667± feet near Sta. 21+00 to about El. 668± feet at the east end of the steel pipe sleeve. Invert of the uncased west segment of the PVC pipe watermain will vary from about El. 663± feet near Sta. 18+00 to about El. 665± feet at the west end of the steel pipe sleeve (casing).

Based on the furnished profile and plan, ground surface in the area of boring B-1 and SP-1 on the west side of the railroad embankment varies between approximately El. 671½ and 672½ feet. Meanwhile, ground surface in the area of borings B-2 and HA-2 made on the east side of the railroad embankment varies between approximately El. 677 and 678½ feet. Therefore, the ground surface in the area the of J&B East Pit is about 4½ to 7 feet higher than the ground surface in the area of the West Pit.

The Threshold Track Settlement Monitoring Review and Alert values depend on the Track Class, which in turn depends on type and speed of the operating train traffic (i.e., Freight or Passenger). PSI was informed via an email from Mr. Otis Goodman with CP dated 11/10/2020 that both Freight and Passenger trains operate on this mine-line tracks as per the following criterion:

- Track speed for passenger 79 MPH
- Track speed for freight 55 MPH

The furnished table included in the **Appendix** illustrates the applicable Threshold Track Settlement Monitoring Review and Alert and Class of Track. Based on the information in those tables, the threshold values for a **Class 4 Track** govern (Passenger Train operating at 80 mph or Freight Train operating at 60 mph) in the watermain crossing area. For a Class 4 Track, the Alert Threshold and Review Threshold values are 16 mm (0.629 inch) and 8 mm (0.314 inch), respectively, which shall govern the subject J&B trenchless installation.

4.2 J&B Design Basis

It is understood that the proposed construction will include about 101 linear feet of the PVC pipe watermain within the railroad embankment ROW lines encased within a 36-inch diameter steel pipe sleeve installed using the J&B trenchless technique. Therefore, the J&B installation and the 36-inch diameter steel sleeve (casing) constitute an **Intermediate Process Level** based in the *Process Identification Criterion* outlined in *Table 1 in Section 6 on Pages 6 - 8 of 37 of the CP Geotechnical Protocol - Utility Installation* dated 2/25/2020.

The foregoing CP document identifies the **Base of Rail (BOR)** as "*is the bottom surface of the rail and is frequently used as a local datum from which vertical measurements are referenced. If an external datum is utilized the elevation of the BOR will be identified*." The furnished profile does not indicate the BOR elevation at the crossing location. Therefore, top of the railroad embankment, which is typically lower than the BOR, is conservatively used in the analyses and discussions presented in this report as the reference datum. However, the design documents should refer to the actual BOR elevation or identify the external datum used as per the CP requirements.

Based on the furnished cross sectional profile, top of the existing railroad embankment is at about El. 681± and 680½± feet on the east and west sides, respectively. In addition, top of the steel pipe casing is at about El. 669± and 668± feet under the east and west sides of the embankment top, respectively. Therefore, top of the steel pipe casing will be at least 8 feet below the BOR.

The foregoing CP document identifies the **Zone of Potential Track Loading (ZPTL)** as **"***is considered as the area under the track and within a 1V to 1.5H soil zone extending down from a point at the level of the BOR and 2 m (6.6 ft.) from the centerline of track as shown in Figure 3*."

The pertinent design information for the proposed watermain crossing as outlined in Table 1 of the CP document is summarized in the table on the following page. Figures 1, 2 and 3 taken from the *CP Geotechnical Protocol - Utility Installation* dated 2/25/2020 illustrate the definitions and dimensional requirements for railroad crossing designs are included in the **Appendix** for reference. The final submittal for review should include similar figures illustrating the specific design information of the subject watermain crossing.

<table>
<tr><th colspan="4">Intermediate Process Level Criteria as per Table 1 in the CP Geotechnical Protocol - Utility Installation dated 2/25/2020</th></tr>
<tr><th colspan="2">Item</th><th>CP Criterion</th><th>Steel Pipe Sleeve (Casing)</th></tr>
<tr><td rowspan="4">Dimensions</td><td>Outside diameter of pipe</td><td>300 mm (12 inches) to 1,500 mm (59 inches)</td><td>Design Diameter = 36 inches
Intermediate Level Governs</td></tr>
<tr><td>Cover between BOR and top of pipe</td><td>Greater than 1.5 m (5 ft.) or two (2) pipe diameters whichever is greater governs</td><td>Design Cover = 8 feet > 5 feet
= 8 feet > 2 x 36/12 = 6</td></tr>
<tr><td>Adjacent structures including switches and signals</td><td>Within 2.5 times, cover between BOR and top of pipe.</td><td>Within 2.5 times, cover between BOR and top of pipe (Data not provided to PSI at time of this report)</td></tr>
<tr><td>Depth of pipes outside ZPTL</td><td>Less than 0.91 m (3 ft.) burial within ZPTL</td><td>Minimum Design Depth = 6 feet > 3 feet (east)
= 7 feet > 3 feet (west)
(values to be verified by Design Engineer)</td></tr>
<tr><td rowspan="2">Excavation Criteria</td><td>Excavation close to CP track(s)</td><td>Excavations or jacking/access pits within 10 m (32.8 ft.) of the closest track centerline.</td><td>Minimum Design Distance = 48.6 feet > 33 feet (east)
= 39.1 feet > 33 feet (west)</td></tr>
<tr><td>Crossing angle</td><td>More than 45 degrees off perpendicular to the track.</td><td>Data not provided to PSI at time of this report</td></tr>
<tr><td colspan="2">Construction Method</td><td>Trenchless Method: Trenchless methods include Auger Boring (AB), Pipe Jacking, Pipe Ramming (PR), Horizontal Directional Drilling (HDD) except high pressure fluid jetting method, Microtunnelling (MT) but exclude any type of mining techniques where any stand up time is required before the tunnel support is placed.</td><td>Design Method: Jack and Bore (J&B)</td></tr>
<tr><td colspan="2">Approval Process</td><td colspan="2">Full review of design, geotechnical and construction method. Applicant to pay for the review cost of CP approved service provider.</td></tr>
</table>

Reference is made to *Section 7.0 Minimum Information Requirements, Section 9.0 Process 2 - Intermediate, Section 11 Pre-Construction Meeting Requirement, Section 12.0 Daily Inspection & Reporting during Construction, Section 13.0 Review Steps, Section 14 Abandoned pipe/Track Crossing(s), Appendix C Sample Figures 1 to 3, Appendix B Sample Daily Report and Settlement Report and Appendix C Track Movement Guideline for Trenchless Pipeline Installation of the CP Geotechnical Protocol - Utility Installation* dated 2/25/2020 for additional requirements pertaining to the design of the proposed watermain crossing.

4.3 GEOTECHNICAL CONSIDERATIONS

Based on the subsurface conditions encountered at the boring locations, the soils on either side of the proposed trenchless installation consist of lean clay, sandy lean clay, and silty sand. However, some variations in the subsurface material types and stratification may exist away from the boring locations (e.g., beneath the railroad embankment) which should be considered in the design and the selection of the methods, means and sequence to be used to perform the required construction, excavations and trenchless installation. In this regard, installation depth and its characteristics shall be determined by the Design Engineer and/or Contractor to assure a successful installation as per the requirements set forth in *CP Geotechnical Protocol - Utility Installation* dated 2/25/2020 and other governing agencies (i.e., AREMA, Village of Gurnee, etc.). The methods, means and sequence to be used to perform the required construction, excavations and trenchless installation shall be provided in the Contractor's submittal for review and approval in advance of construction.

Trenchless excavation methods including the J&B technique should generally be satisfactory for the proposed watermain installation considering its invert depth and the subsurface material types and stratification encountered at the boring locations. However given the variation in soil types and shear strength at the boring locations, PSI recommends that the Contractor select the appropriate methods, means and sequence (i.e., equipment and machinery, entry and exist pit locations and depths, inclination and curvature across the alignment, casing, lubricant/grout requirements etc.) based on the anticipated conditions of the project including site topography and subsurface soil conditions, site and alignment restrictions including items such as locations and dimensions of the entry/exit and connection pits, construction schedule, and local knowledge or past experience with similar projects and comparable soil and groundwater conditions.

PSI recommends that the proposed trenchless excavations be performed without prolonged interruptions, especially where it advances through cohesive soils (i.e., lean clay or sandy lean clay). During the installation, pore pressure within the surrounding soils increases and when the directional drilling, J&B or tunneling operations are halted, the generated pore pressure increment dissipates. This process may cause the casing to "freeze" in-place making it very difficult to advance further following a prolonged interruption in the installation process.

Probable cobbles or boulders were encountered at approximately 11 feet beg in B-1. This does not preclude their possible presence at other locations along the proposed watermain alignment, given the geologic depositional environment of the project site. Where large boulders are encountered near the edge of the bore and the surrounding soils are loose or soft, it may be possible for the auger head to push a boulder or cobble radially outward into the surrounding soil. However, pushing the boulder or cobble radially may cause the bore to shift from the intended alignment or could damage the drilling equipment depending on the boulder/cobble size, orientation and hardness. Other buried structures or hard objects (e.g., construction debris, abandoned utility lines, etc.) could be encountered while working in such a developed urban area. The J&B Contractor should verify the site conditions prior to commencing with the excavations and drilling if practical. Where shallow subsurface obstructions or relatively deep cobbles and boulders cannot be excavated or moved away from the auger stem, it may be necessary to bore directly through an obstruction. Therefore, appropriate measures should be provided in the design of the J&B installation and selection of the equipment and machinery to address unforeseen conditions.

The ground surface should be prepared to support the J&B equipment and minimize settlements which may affect the equipment operations and orientation. Based on the borings performed, PSI anticipates that the natural lean clay (B-1) and the existing fill (B-2) should generally be adequate for support of typical J&B equipment. Prior to placement of the J&Bequipment, it is recommended that the existing surficial organic soil be stripped to expose the underlying fill and natural lean clay soils. Subsequently, the ground surface should be scarified and re-compacted to 95% of its maximum dry density as determined per ASTM D1557, for a minimum depth of 12 inches below the final graded surface. Areas of subgrade instability should be anticipated over the existing fill and possibly in other subgrade soils. These areas should be stabilized through undercutting and placement of a geotextile fabric and crushed stone aggregate of sufficient thickness.

Side walls of the entry/exit and connection point pit excavations are not anticipated to remain vertical without sufficient lateral support (i.e., sheeting with internal bracing as needed, etc.) within the existing silty, clayey sand fill soils (B-2) or naturally occurring sandy silty clay (B-1) encountered at the locations of the borings performed, especially where these soils are excavated below the groundwater table without forced dewatering. Where adequate space is available, the excavations may be sloped to achieve a stable condition. Where adequate space is not available, the excavations may be performed as a vertical cut with properly designed and installed bracing or driven interlocking sheet piling. Inclination of the excavation side slopes should be selected based on the type and strength of the retained soil and in accordance with the OSHA requirements.

The following average soil parameters may be used as an aid in the design of temporary excavation retaining structures at this site, based on the borings performed. The soil parameters used in the sheeting or bracing design should be adjusted as necessary based on the actual soil profile encountered at the specific locations of the connection points being excavated/constructed:

Boring B-1 (West Side of RR Tracks)

Estimated Average Short-Term Soil Parameters (B-1)				
Stratum	**Typical Depth Range (ft.)**	**Estimated Total/Submerged Unit Weight (pcf)**	**Angle of Internal Friction (degrees °)**	**Undrained Shear Strength, c_u (psf)**
Silty Clay Topsoil	0 - 1	110	0	NA
Lean Clay	1 - 3	130	0	1.9
Sandy Silty Clay	3 - 5½	129	0	1.2
Lean Clay	5½ - 8½	69	0	1.7
Silty Sand	8½ - 10½	61	33	0
Silty Clay / Clayey Silt	10½ - 17	71	0	3.2
Sand with gravel	17 - 22	60	32	0
Lean Clay	22 - 30	65	0	1.1

Boring B-2 (East Side of RR Tracks)

Estimated Average Short-Term Soil Parameters (B-2)				
Stratum	**Typical Depth Range (ft.)**	**Estimated Total/Submerged Unit Weight (pcf)**	**Angle of Internal Friction (degrees °)**	**Undrained Shear Strength, c_u (psf)**
Existing Fill	0 - 4	113	30	0
Lean Clay	4 - 6	128	0	1.1
Silty, Clayey Sand – Sandy Silt	6 - 8	53	30	0
Sandy Lean Clay	8 - 11	64	0	1.0
Lean Clay	11 - 24½	70	0	2.0
Silt	24½- 27	59	32	0
Sand with gravel	27 - 30	60	33	0

No borings were made within the east and west ROW lines along the railroad embankment. Therefore, the properties of the embankment material are unknown. For the purpose of analyses, it could be assumed to consist of the typical materials used by CP and/or AREMA in their standard cross sections. Meanwhile, design of the J&B installation should be conservatively based on the more critical conditions (i.e., worst case scenario) encountered in the borings made on either side of the railroad embankment while considering the difference in surface grades in the areas explored.

The foregoing estimated design soil parameters represent ultimate values at the specific boring locations and appropriate factors of safety should be used in the design. Submerged unit weights should be used below the groundwater level. Groundwater or perched water was encountered within intermittent more permeable strata in the natural cohesive soils at an approximate depth of 6 feet beg (EL. 665± feet) at the location of SP-1 and within the sandy silt in HA-2 at an approximate depth of 7 feet beg (EL. 670± feet).

In general, poorly-graded fine granular materials (i.e., sand and silts) are more susceptible to experiencing dynamic liquefaction, or a significant loss in shear strength, due to vibrations induced by earthquakes, construction equipment, machinery, etc. particularly when those materials are fully saturated. Granular strata along the banks and side slopes of a channel (i.e., drainage canal, swale, trench, etc.) could also experience "static liquefaction" during a "sudden drawdown" event or a rapid rise and fall in water level in the channel. A sudden drop of water level in the channel does not allow sufficient time for the pore water pressure increment generated in the granular stratum under the higher water level to dissipate resulting in a loss in shear strength. This scenario is experienced at some locations along a major waterway when its stage drops rapidly following a flood event.

In view of the above, the subject site is in a low risk area with regard to experiencing dynamic or static liquefaction during a seismic or sudden drawdown event, respectively. As previously discussed, the stratigraphy encountered at the boring locations indicate that the soils encountered along the alignment of the proposed trenchless installation are anticipated to predominately consist of stiff lean clay / sandy lean clay, dense silty sand, and medium dense sandy silt. The silty sand and sandy silt strata encountered at or below the groundwater level are susceptible to experiencing liquefaction and/or loss in their shear strength when disturbed or vibrated, and/or due to an increase in their moisture content. Therefore, a potential risk exists that should be considered by the Design Engineer and the Contractor in the design and selection of the methods, means and sequence to be used for construction including equipment and machinery, sheet pile installation and withdrawal, advancement and withdrawal of the proposed pipe through the bored cavity, dewatering and rewatering operations, etc. The potential for settlement due to densification or liquefaction of near surface more granular materials should be accounted for in design and selection of the boring equipment and machinery.

The potential for settlement due to densification of the upper existing fill, black silty clayey sand with cinders, in B-2 could be reduced by an undercut and placement of a geotextile fabric and crushed stone aggregate. The first layer of stone over the fabric can be a coarse graded crushed stone (IDOT CA-1, 3-inch maximum particle size) compacted in place. This will create a stable working platform for support of the construction equipment.

Open-cut excavations, shoring or sheeting design should include surcharge loads from adjacent structures, construction equipment operating immediately adjacent to the excavation or other surface loads in or adjacent to the excavation such as excavated soil piles or imported backfill material stockpiles. To minimize surcharge loads at the top of the excavation, the excavated materials should be stockpiled away from the edge of the excavation a distance at least equal to the depth of the excavation. If sufficient space is not available within the construction easement to stockpile the excavated soil at a safe distance from the edge of the excavation, it will be necessary to provide adequately designed sheeting or shoring to support the surcharge loads. Open-cut excavations, shoring and/or sheeting plans shall be provided in the Contractor's submittal for review and approval in advance of construction.

The J&B entry/exit and connection point excavations should be backfilled as soon as practical after the watermain has been properly installed and tested for integrity and functionality. The bottom and sides of the excavation should be lined with a geotextile fabric. Backfill materials should be placed in maximum lifts of 8 inches of loose material and should be compacted to the required density specifications within the range of ±2% of the optimum moisture content value as determined by ASTM D1557. The moisture/density relationship of the material to be used as backfill should be evaluated by PSI's engineer prior to placement in the field. The use a 12-inch layer of coarse graded crushed stone, 2-inch or 3-inch maximum particle size, may be required on the geotextile fabric at the base of the excavation. This material can provide a suitable platform for additional fill placement.

Where the proposed entry/exit and connection point excavations are located within the influence of roadway, sidewalk, bicycle path, or driveway pavements, PSI recommends that the excavations be backfilled with dense-graded aggregate (i.e. IDOT CA-6). In landscaped areas, natural backfill materials free of topsoil or organic materials may be used as backfill. Each lift of compacted-engineered fill should be tested by a qualified testing firm prior to placement of subsequent lifts. Special compaction should be done around all utilities using pneumatic tampers or plate compactors in thin lifts.

4.4 GENERAL SITE EXCAVATION RECOMMENDATIONS

Groundwater or perched water was encountered during drilling, hand augering, and within the standpipe piezometer at an approximate depth of 6 feet beg (EL. 665± feet) in SP-1 and 7 feet beg (EL. 670± feet) in HA-2. As previously discussed, the ground surface in the area of B-2 and HA-2 is about 4½ to 7 feet higher than the ground surface in the area of B-1 and SP-1. The relatively shallow water levels detected at the locations of B-1 and SP-1 could be due to the development of the perched condition in the relatively more granular sand and silt strata underlain by a low permeable silty clay stratum. Meanwhile, boring B-2 indicated a groundwater level at the 28-foot depth beg.

Therefore, difficulty with groundwater seepage should be anticipated during open excavations associated with the proposed directional drilling connection points. PSI recommends that the Contractor verify the actual groundwater and seepage conditions at the time of the construction activities and propose site-specific groundwater control methods for the Engineer's approval, including the disposal of discharge water. The de-watering system, including the type, size, depth and spacing of de-watering wells, if used, should be properly designed by an experienced local dewatering contractor utilizing the soil borings performed along the proposed alignment as well as the available public well information and records in the vicinity of the proposed project.

In general, it is our opinion that the methods, means and sequence of the J&B installation, including dewatering, should be the responsibility of the Contractor who should be experienced in this type construction. Design of all open construction excavations, braced excavations and temporary retaining structures associated with the entry/exit pits, vaults, etc. shall be performed by a Professional Engineer considering lateral earth induced by the surrounding soils and all anticipated internal and external loads (e.g., construction equipment, train traffic, etc.) within its vicinity. Considering the depth of excavations of the entry and exit pits, it is believed that sheet pile cofferdams with internal bracing and shoring, as needed, should be considered for their support. No analyses were made to develop lateral pressures that would be imposed on the proposed sheet pile walls of the underground structure excavations and pipe installation trenches. The design of these cofferdam systems should be the responsibility of the Contractor and their Engineers who should be experienced in these type analyses and construction. The designs of open construction excavations, braced excavations and temporary retaining structures associated with the entry/exit pits, vaults, etc. shall assure safety and stability of the railroad embankment and other structures in their vicinity. Detailed designs of open construction excavations, braced excavations and temporary retaining structures shall be included in the Contractor’s submittal for review and approval in advance of construction.

The sandy lean clay and silty sand subsoils encountered at the bottom of the proposed pits are subject to a loss in shear strength due to reworking or poor groundwater control. Based on the borings, it is believed that infiltration of groundwater into short-term shallow excavations could be effectively controlled with normal sump pumping. However, a dewatering system (well points, wells, etc.) may be needed to assure good stability with regard to bottom heave for long-term and relatively deep excavations. In this regard, the piezometric head in the permeable soils should be maintained at or below the elevation of the bottom excavation. Lack of groundwater control could affect the stability of the excavations. In any event, it is recommended that all excavations be backfilled as soon as possible to avoid long-term pumping which could result in a general lowering of the water table and associated areal settlements. The dewatering/rewatering plan shall be included in the Contractor’s submittal for review and approval in advance of construction.

4.5 ANTICIPATED MOVEMENTS

Ground movements induced by the advancement of the "circular cavity" associated with the proposed trenchless watermain installation were computed using the closed-form solution and analytical formulas proposed by Loganathan (2011) shown in **Figures 1 and 2** which were coded by PSI into a spreadsheet.

Figure 1: Closed-Form Solutions Presented by Loganathan (2011).

The closed-form solutions presented by Loganathan and Poulos are shown in Equations 4.1, 4.2 and 4.3. These solutions predict the tunnelling-induced ground movements reasonably well, as will be demonstrated below.

Surface Settlement

$$U_{z=0} = \varepsilon_0 R^2 . \frac{4H(1-\nu)}{H^2+x^2} . \exp\left\{-\frac{1.38x^2}{(H\cot\beta+R)^2}\right\} \tag{4.1}$$

Subsurface Settlement

$$U_z = \varepsilon_0 R^2\left(-\frac{z-H}{x^2+(z-H)^2}+(3-4\nu)\frac{z+H}{x^2+(z+H)^2}-\frac{2z[x^2-(z+H)^2]}{[x^2+(z+H)^2]^2}\right) \cdot \exp\left\{-\left[\frac{1.38x^2}{(H\cot\beta+R)^2}+\frac{0.69z^2}{H^2}\right]\right\} \tag{4.2}$$

Lateral Deformation

$$U_x = -\varepsilon_0 R^2 x\left[\frac{1}{x^2+(H-z)^2}+\frac{3-4\nu}{x^2+(H+z)^2}-\frac{4z(z+H)}{(x^2+(H+z)^2)^2}\right] \cdot \exp\left\{-\left[\frac{1.38x^2}{(H\cot\beta+R)^2}+\frac{0.69z^2}{H^2}\right]\right\} \tag{4.3}$$

Where:

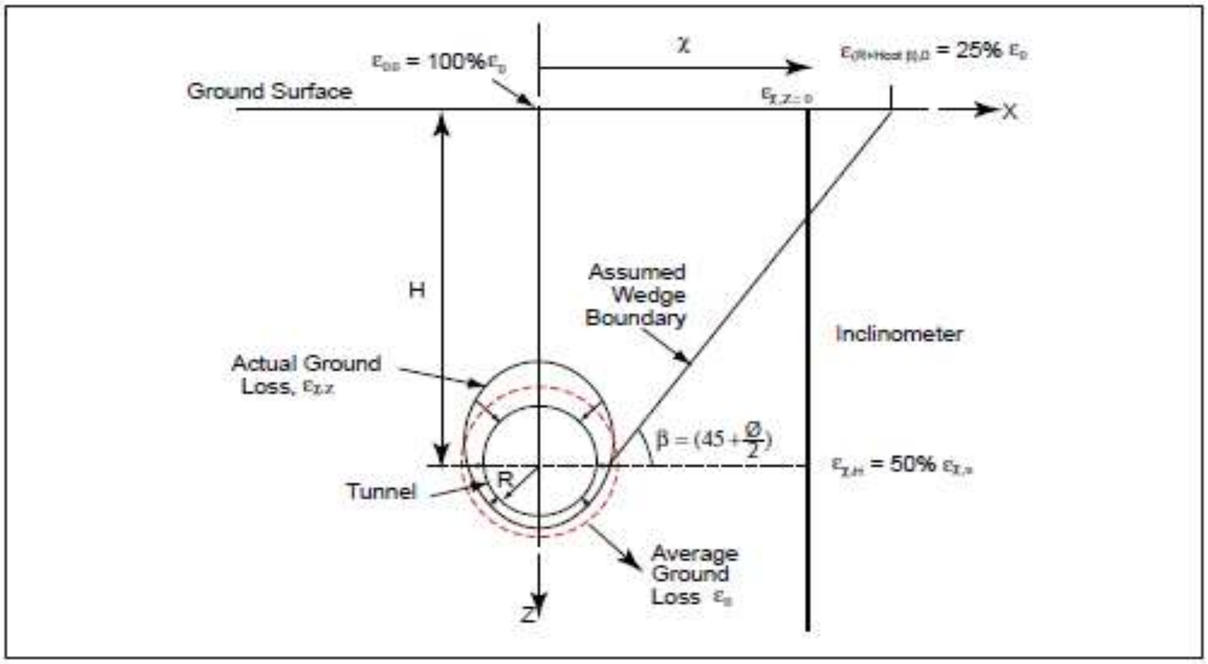
$U_{z=0}$ = ground surface settlement
U_z = subsurface settlement
U_x= lateral soil movement
R = tunnel radius
z = depth below ground surface
H = depth of tunnel axis level
ν = Poisson's ratio of soil
ε_0 = average ground loss ratio (not a displacement)
x = lateral distance from tunnel centre line
β = Limit angle = 45 + ϕ/2.

These equations allow rapid estimation of ground deformation and require only an estimate of the Poisson's ratio (ν) of the soil. Poisson's ratio indirectly represents the characteristics of coefficient of lateral earth pressure (k_0) value of the ground. The k_0 values should be estimated from the relationship shown in Equation 4.4.

(Bowles, 1996)
$$k_0 = \frac{\nu}{(1-\nu)} \tag{4.4}$$

Although Equations 4.1, 4.2 and 4.3 appear long, they are easy to work with using a simple worksheet (see Appendix A2). In addition, these closed-form solutions can be easily incorporated in numerical modelling programmes to impose ground movements external to the model soil-structure interaction problem to predict induced effects on adjacent piles.

Figure 2: Definition of the Terms Used by Loganathan (2011).



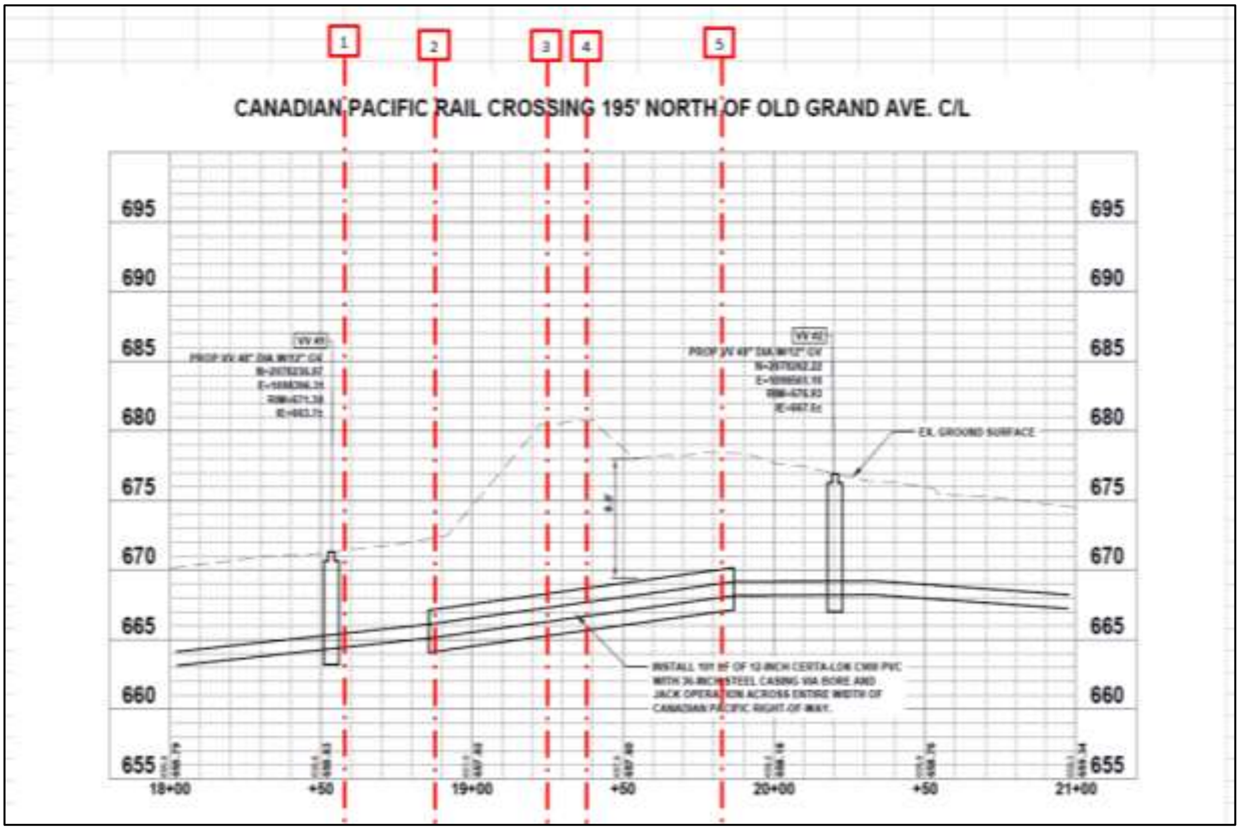
The analyses performed using the PSI spreadsheet considered the most critical cross sections indicated in the drawing furnished by the Village of Gurnee for the Canadian Pacific Crossing North of Old Grand Avenue. Those north/south (N/S) cross sections normal to the generally east/west (E/W) alignment of the watermain crossing are as follows and illustrated in **Figure 3**:

1. The 12-inch diameter PVC pipe at Sta. 18+55 at the west CP ROW line
2. The 36-inch diameter steel sleeve (casing) at Sta. 18+85 at the west CP ROW line
3. The 36-inch diameter steel sleeve (casing) at Sta. 19+24 at the west RR track
4. The 36-inch diameter steel sleeve (casing) at Sta. 19+38 at the east RR track
5. The 36-inch diameter steel sleeve (casing) at Sta. 19+85 at the east CP ROW line

The two (2) most critical cross sections are No. 3 and 4 at Sta. 19+24 and Sta. 19+38, respectively, which depict the larger diameter J&B circular cavity, or subsurface opening, associated with the trenchless installation of the steel sleeve (casing) directly under the crown (top) of the railroad (RR) embankment or approximately below the Base of Rail (BOR).

Results of the analyses are summarized in the table on the following page and plots showing the estimated ground surface settlement profile at each of the foregoing five (5) cross sections are presented in the Cross Sections / Estimated Settlements section of the **Appendix**. Results of the analyses yield the conclusion that the anticipated ground surface settlement decreases with distance away from the centerline of the pipeline and with the radius of the cavity. Column 5 in the table indicates the anticipated settlement directly above the cavity at the cross section and station analyzed. Therefore, the anticipated settlement under the east and west tracks at Sta. 18+55, Sta. 18+85 and Sta. 19+85 will be less than the values indicated in Column 5, as shown in the plots given in the **Appendix**. Meanwhile, the values in Column 5 at Sta. 19+24 and Sta. 19+38 indicate the estimated settlements under the west and east racks, respectively.

Figure 3: The N/S Cross Sections Analyzed.



Analyzed Cross Section		Top of Cavity Depth Below Existing Ground Surface (feet)	Trenchless Cavity Diameter (feet)	<u>Maximum</u> Ground Surface Settlement at Cavity Location (inch)
No.	Sta.			
1	18+55	6	1 (PVC Pipe)	0.01
2	18+85	5	3 (Steel Casing)	0.06
3	19+24	12.25	3 (Steel Casing)	0.03 (West Track)
4	19+38	11.95	3 (Steel Casing)	0.03 (East Track)
5	19+85	8	3 (Steel Casing)	0.04

As previously discussed, the Threshold Track Settlement Monitoring Review and Alert values depend on the Track Class, which in turn depends on type and speed of the operating train traffic (i.e., Freight or Passenger). PSI was informed via an email from Mr. Otis Goodman with CP dated 11/10/2020 that both Freight and Passenger trains operate on this mine-line tracks as per the following criterion:

- Track speed for passenger 79 MPH
- Track speed for freight 55 MPH

The furnished table included in the **Appendix** illustrate the applicable Threshold Track Settlement Monitoring Review and Alert and Class of Track. Based on the information in the table, the threshold values for a **Class 4 Track** govern (Passenger Train operating at 80 mph or Freight Train operating at 60 mph) in the watermain crossing area. <u>For a Class 4 Track, the Alert Threshold and Review Threshold</u> values are 16 mm (0.629 inch) and 8 mm (0.314 inch), respectively, which shall govern the subject J&B trenchless installation. Results of the analyses indicate that the maximum track/ground surface settlement are much lower than the **Class 4 Track** <u>Alert</u> Threshold and <u>Review</u> Threshold values of 16 mm (0.629 inch) and 8 mm (0.314 inch), respectively

4.6 GENERAL CONSTRUCTION MONITORING RECOMMENDATIONS

Surface features including roads, pavements, and utilities should be monitored by the Contractor for settlement caused by ground loss and collapse of the soil above and around the bore due to alterations of the stresses in the soil and from settlement or distress associated with the proposed boring and jacking processes. Ground movement associated with the J&B process is influenced by the method of construction, equipment used and the quality of workmanship as well as the subsurface soil conditions encountered.

A detailed QA/QC program should be developed and strictly followed throughout the project. This may include performing a thorough preconstruction inspection of the site and structure conditions including any existing distress, cracks, movements, etc. The QA/QC program should include close monitoring of construction vibrations and movements, stability of excavations, dewatering activities, etc. and their possible impact on the existing structures. This could include the use of instrumentation, sensors, geodetic surveys, etc. In addition, the selected Contractor should be specialized in this type of construction and should be prepared to take all necessary measures to preserve the conditions and integrity of the surrounding structures including the use of any necessary shoring, underpinning, bracing, etc., as needed. Peak vibration background levels should also be determined prior to construction.

We are providing this information solely as a service to our Client. PSI does not assume responsibility for construction site safety or the Contractor's or other party's compliance with local, state, and federal safety or other regulations.

Settlement monitoring of the tracks should be thoroughly monitored per Appendix C of the CP Geotechnical Protocol - Utility Installation dated 2/25/2020: "*The monitoring of track settlement should be carried out by means of surface and subsurface settlement points. The intent of subsurface settlement points is to measure voids created just in the vicinity and above the pipe during construction in order to predict the potential movement of overlying CP tracks*".

The CP Appendix C describes a **Subsurface Settlement Point** as follows: "*The settlement point essentially consists of a small diameter pipe anchored at the bottom of a vertical borehole and an outer casing to isolate the pipe from down drag forces caused by settlement of soil above the anchor (see Figure B). The subsurface settlement points would be installed to 1 m above the crown of the casing profile. The total number of subsurface settlement points within CP Right-of-Way (ROW) along the axis of the proposed pipe crossing(s) would be installed as per the configuration shown in Figure A – Sample Surface and Subsurface Settlement Monitoring Layout*". See the CP detail on the following page.

CP Geotechnical Protocol for
Pipeline and Utility Crossing(s) under Railway Tracks

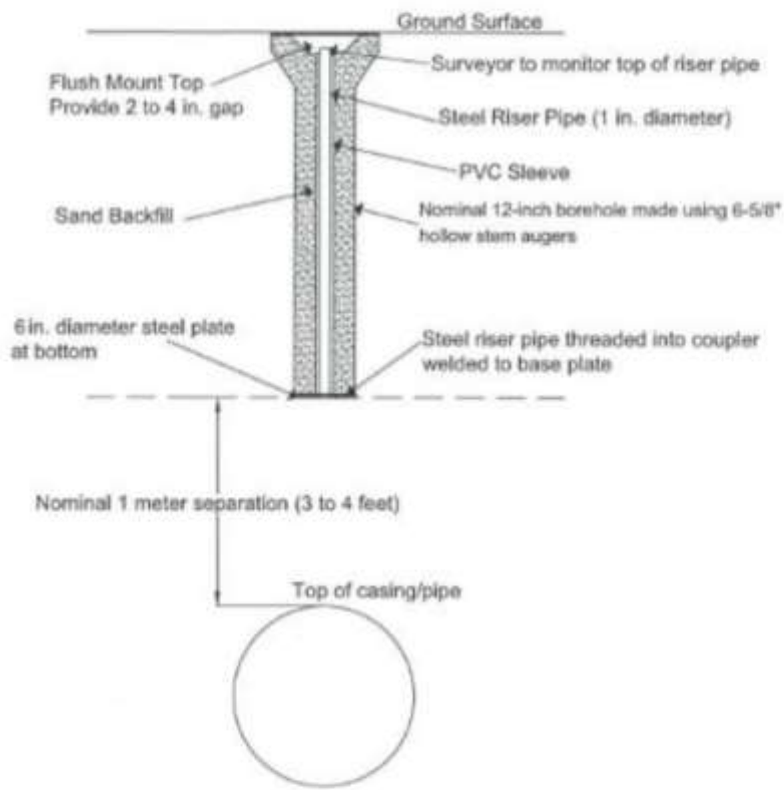


Figure B - Typical Subsurface Settlement Point Detail

The CP Appendix C describes a **Surface Settlement Point** as follows: "*Surface points installed directly along the base of both rails at a spacing of 9.45 m (31 ft.) over the projected settlement trough would be used to monitor differential transversal elevation between both rails. The total number of surface settlement points within CP ROW would be installed as per the configuration shown in Figure A – Sample Surface and Subsurface Settlement Monitoring Layout. These points shall be monitored simultaneously with the subsurface settlement points that would act as a precursor to potential surface movement during pipe installation*".

Settlement monitoring should commence before excavation of the bore pits and drilling. Readings should be taken a minimum of two times per day for two days or more prior to construction. The frequency of settlement monitoring during construction will be determined based upon the volume of train traffic on the subject rail lines. Appendix C defines the frequency as follows:

"Monitoring should proceed through the construction period and should be completed:

1. *For branch lines or lines with low traffic - At least twice daily.*

2. *For main lines and heavy traffic lines - Every 2 hours or after each train, whichever provides the most number of readings while the boring operation is within the ZPTL (Zone of Potential Train Loading)".*

After construction has been completed, monitoring should continue for a minimum three days. In the event deflections are detected, monitoring should continue until the Geotechnical Engineer of Record and CP determine that it is safe to discontinue monitoring.

The CP Appendix C further explains: "*Monitoring measurements should be taken with sufficient frequency (as noted above) to capture the unexpected performance at the earliest possible stage and be evaluated in a timely manner. Additional measures will be proposed should this monitoring protocol be considered insufficient based on the ground conditions or installation process. Track survey preference would be for survey shots to be taken remotely (i.e. off CP property) and without the requirement of a CP Flagger or representative presence on site*".

Per the CP Appendix C: "Two alarm levels are proposed:

<u>Level 1:</u>

"WARNING" *will be indicated on the field memo/report when a settlement of* ***<u>50 percent (%)</u>*** *of the critical monitoring threshold is obtained from the subsurface and/or surface settlement points. A survey of the surface points will then be carried out and work will be authorized to continue if no movement of the subsurface point has been measured from the previous reading. If movement of the rails is recorded, monitoring will be continued until rail movement is stopped. At this point, the drilling work will then be authorized to continue*.

<u>Level 2:</u>

"CRITICAL" *will be indicated on the field memo/report when a settlement of specified monitoring threshold is obtained from the subsurface settlement point. A survey of the surface points will then be carried out and work will be authorized to continue if no movement is measured for at least two (2) readings taken 12 hours apart. If movement of the rails is recorded, monitoring will be continued until movement is stopped and the applicant has submitted a new pipe installation procedure. This procedure must be reviewed and approved by CP Geotechnical Engineering group or CP approved service provider reviewing the monitoring results*.

In the event, the borehole is abandoned, all buried pipe should be removed. The borehole should be grouted in with a non-shrinkable fill, or pressurized grout sufficient to prevent future ground or track settlement (See CP Geotechnical Protocol for Pipeline and Utility Crossing(s) under Railway Tracks dated 2/25/2020). After the grout has cured sufficiently, a new borehole may be started.

The following general Monitoring Plan is offered by PSI for possible consideration by the Contractor during the J&B Canadian Pacific Crossing North of Old Grand Ave. At a minimum, the Contractor's submittal shall prepare a detailed plan to monitor, record and report the following items:

1. Vibrations and ground movement in the RR embankment during:
    - Open excavations
    - Installation and removal of a temporary retaining system (TRS) in an excavation
    - The J&B trenchless installation
    - Sheet pile installation and withdrawal
    - Backfilling of excavations
    - Construction of the east and west vaults

    For a **Class 4 Track**, the Alert Threshold and Review Threshold values are 16 mm (0.629 inch) and 8 mm (0.314 inch), respectively, which shall govern the subject J&B trenchless installation.

    Thresholds of vibration are generally site specific and depend on the type and age of the structure of concern, frequency of ground vibration, subsurface conditions and type of support of the structure. Research by the U.S. Bureau of Mines (USBM) and other investigative groups have established criteria relating the occurrence of structural damage to certain frequencies and level of ground motion. According to the USBM, within the range of 4 to 12 hertz, the maximum particle velocity recommended to preclude the threshold damage to plaster-on-wood for old structures is 0.5 inch per second (ips). Therefore, a threshold of 0.25 ips has been typically adopted by the engineering community.

    A properly constructed railroad embankment should tolerate higher levels considering its construction materials and the typical vibration levels induced by train traffic. Prior to commencing with construction, the Contractor shall perform a study to establish background vibration levels at the subject site during the typical freight and passenger train traffic operating at their normal speeds either on one track, or simultaneously on both tracks if believed possible. Construction activities inducing vibrations below the present background levels at the same location/distance should be of no concern to the existing railroad embankment.

2. Excessive movements in a TRS (i.e., sheet piles, braced excavation, etc.) during:
    - TRS installation
    - The J&B trenchless installation
    - Excavation backfilling
    - TRS withdrawal

3. Water level in at the site particularly if forced dewatering will be used

4. Any water seepage into an open-cut excavation, a braced excavation or through the interlocks of sheet piles.

5. Any heave or boiling at the bottom of an excavation.

6. Any unusual, extremely low, extremely high or running of sheet piles during installation.

PSI also recommends that a thorough pre-construction assessment (PCA) of the construction area be performed to document site conditions before and after the trenchless crossing installation. The methods, means and sequence to be used to perform the required construction, excavations and trenchless installation including the proposed monitoring plan shall be included in the Contractor's submittal for review and approval in advance of construction. PSI offers a full line of construction monitoring services and testing. If these services are of interest, PSI would be pleased to develop a site-specific monitoring program and the associated costs.

The following general Contingency and Notification Procedure Plan is offered by PSI for possible consideration by the Contractor during the J&B Canadian Pacific Crossing North of Old Grand Ave:

If the observed movements in the RR embankment or vibration levels reach the designated threshold values for the project, the Contractor shall cease all construction activities and immediately report the observed conditions to the Village of Gurnee and the Engineer of Record (EOR). Similarly, if monitoring of Items 3 through 7 above indicates unusual conditions, the Contractor shall cease all construction activities and immediately report the observed conditions to the Village of Gurnee and the EOR. The EOR shall timely inform Canadian Pacific of the recorded incident and the proposed remedial measures and/or course of action in advance of implementation which may include abandoning and backfilling an excavation or plugging and abandoning the installed watermain segment in question.

4.7 FEDERAL EXCAVATION REGULATIONS

In Federal Register, Volume 54, No. 209 (October 1989), the United States Department of Labor, Occupational Safety and Health Administration (OSHA) amended its "Construction Standards for Excavations, 29 CFR, Part 1926, Subpart P." This document was issued to better insure the safety of workers entering trenches or excavations. It is mandated by this federal regulation that all excavations, whether they be utility trenches, basement excavations or foundation excavations, be constructed in accordance with the new OSHA guidelines. It is our understanding that these regulations are being strictly enforced. If they are not followed closely, the owner and the contractor could be liable for substantial penalties.

The Contractor is solely responsible for designing and constructing stable, temporary excavations and should shore, slope, or bench the sides of the excavations as required to maintain stability of both the excavation sides and bottom. The Contractor's "responsible person" as defined in "CFR Part 1926," should evaluate the soil exposed in the excavations as part of the contractor's safety procedures. In no case should slope height, slope inclination, or excavation depth, including utility trench excavation depth, exceed those specified in local, state, and federal safety regulations.

Materials removed from the excavation should not be stockpiled immediately adjacent to the excavations, inasmuch as this load may cause a sudden collapse of the embankment.

PSI is providing this information solely as a service to our client. PSI is not assuming responsibility for construction site safety or the Contractor's activities; such responsibility is not being implied and should not be inferred. A trench safety plan was beyond the scope of PSI's services for this project. If the excavations are left open and exposed to the elements for a significant length of time, desiccation of the clays may create minute shrinkage cracks which could allow large pieces of clay to collapse or slide into the excavation.

5. GEOTECHNICAL RISK & REPORT LIMITATIONS

5.1 GEOTECHNICAL RISK

The concept of risk is an important aspect of the geotechnical evaluation. The primary reason for this is that the analytical methods used to develop geotechnical recommendations do not comprise an exact science. The analytical tools which geotechnical engineers use are generally empirical and must be used in conjunction with engineering judgment and experience. Therefore, the solutions and recommendations presented in the geotechnical evaluation should not be considered risk-free and, more importantly, are not a guarantee that the interaction between the soils and the proposed structure will perform as planned. The engineering recommendations presented in the preceding section constitutes PSI's professional estimate of those measures that are necessary for the proposed structure to perform according to the proposed design based on the information generated and reference during this evaluation, and PSI's experience in working with these conditions.

5.2 REPORT LIMITATIONS

The recommendations submitted in this report are based on the available subsurface information obtained by PSI and design details furnished by the Village of Gurnee and Canadian Pacific Railroad, for the proposed watermain installation. If there are any revisions to the plans for the proposed watermain, or if deviations from the subsurface conditions noted in this report are encountered during construction, PSI should be retained to determine if changes in the recommendations are required. If PSI is not retained to perform these functions, PSI will not be responsible for the impact of those conditions on the geotechnical recommendations for the project.

The Geotechnical Engineer warrants that the findings, recommendations, specifications, or professional advice contained herein, have been presented after being prepared in accordance with generally accepted professional engineering practice in the fields of foundation engineering, soil mechanics and engineering geology. No other warranties are implied or expressed.

After the plans and specifications are complete, it is recommended that PSI be provided the opportunity to review the final design and specifications, in order to verify that the recommendations are properly interpreted and implemented. At that time, it may be necessary to submit supplementary recommendations. This report has been prepared for the exclusive use of the Village of Gurnee for the specific application to the proposed Old Grand Avenue watermain to be constructed in Gurnee, Illinois.

LIST OF APPENDICES

Boring Location Map

Boring Logs

Laboratory Test Results

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CP Geotechnical Protocol for Pipeline and
Utility Crossing(s) under Railway Tracks

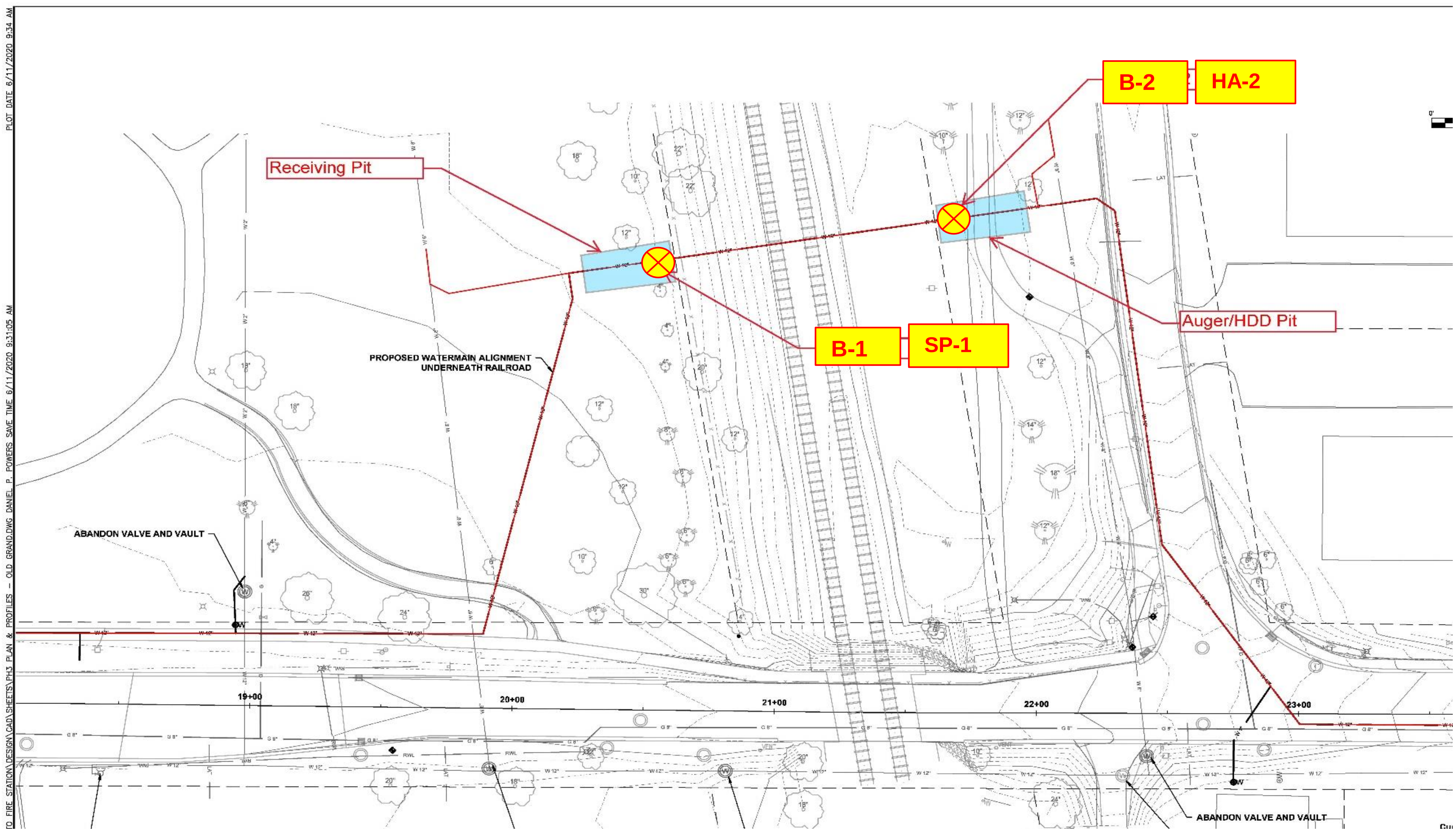
Threshold Track Settlement Monitoring Review and Alert

Cross Sections / Estimated Settlements

General Notes

USCS Soils Classification Chart

Boring Location Map



B-# / HA-# / SP-#
Approximate Boring / Hand Auger / Monitoring Well

The image above was provided by the Client

intertek psi	**Project Name:**	Old Grand Avenue Watermain	**Project No:**	00474399	**Boring Location Map**
			Date:	9/11/2020	
	Location:	Old Grand Avenue and Canadian Pacific RR	**Drawn By:**	DTL	
		Gurnee, Illinois	**Scale:**	NTS	

Boring Logs

BORING B-1

DATE STARTED:	9/18/20	**DRILL COMPANY:**	Strata Earth Services
DATE COMPLETED:	9/18/20	**DRILLER:** Scott	**LOGGED BY:** Zach
COMPLETION DEPTH	30.0 ft	**DRILL RIG:**	
BENCHMARK:	N/A	**DRILLING METHOD:**	Hollow Stem Auger
ELEVATION:	N/A	**SAMPLING METHOD:**	2-in SS
LATITUDE:		**HAMMER TYPE:**	Automatic
LONGITUDE:		**EFFICIENCY**	N/A
STATION: N/A	**OFFSET:** N/A	**REVIEWED BY:**	David T. Lewandowski

Water

While Drilling	12 feet
Upon Completion	Not Observed
Delay	N/A

BORING LOCATION:

See Boring Location Map

REMARKS: USCS Classifications based upon visual classification only

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS)	Moisture, %	Additional Remarks
	0					Black Silty Clay, Topsoil (8"±)				
				1	6	Dark Brown to Brown Lean Clay with sand, moist, very stiff	CL	3-7-8 N=15	22	
	5			2	17	Brown Sandy Silty Clay, moist, stiff	CL-ML	3-4-6 N=10	17	
				3	18	Brown/Gray Lean Clay with sand, moist, stiff	CL	4-5-9 N=14	17	LL = 30 PL = 18
	10			4	2	Brown/Gray Silty Sand, moist, dense	SM	14-15-19 N=34	18	No recovery
				5	0	Gray Silty Clay with sand (probable cobbles or boulders), moist	CL-ML	15-23-27 N=50	17	No recovery LL = 22 PL = 15
	15			6	18	Gray Clayey Silt, moist, medium dense	ML	13-10-16 N=26	13	Fines=84.9%
	20			7	15	Gray Poorly Graded Sand with gravel, wet, medium dense	SP	3-10-14 N=24	10	
	25			8	18	Gray Lean Clay with sand, moist, stiff	CL	3-5-6 N=11	21	
	30			9	18			2-3-4 N=7	21	
						End of Boring at 30 Feet				

STANDARD PENETRATION TEST DATA

N in blows/ft ◎

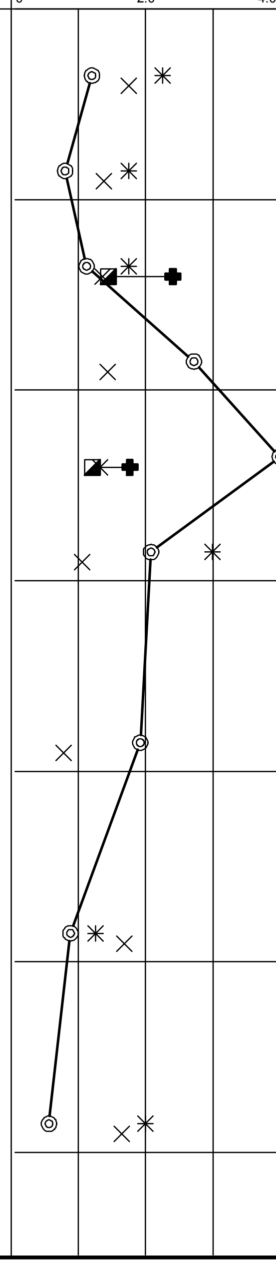
× Moisture ◪ PL ✚ LL

0 25 50

STRENGTH, tsf

▲ Qu ✳ Qp

0 2.0 4.0



Professional Service Industries, Inc.
4421 Harrison Street
Hillside, IL 60162
Telephone: (708) 236-0720

PROJECT NO.:	00474399-1
PROJECT:	Old Grand Avenue Watermain
LOCATION:	Canadian Pacific Railroad
	Gurnee, Illinois

The stratification lines represent approximate boundaries. The transition may be gradual.

DATE STARTED: 9/18/20	**DRILL COMPANY:** Strata Earth Services		
DATE COMPLETED: 9/18/20	**DRILLER:** Scott **LOGGED BY:** Zach		
COMPLETION DEPTH 30.0 ft	**DRILL RIG:**		
BENCHMARK: N/A	**DRILLING METHOD:** Hollow Stem Auger		
ELEVATION: N/A	**SAMPLING METHOD:** 2-in SS		
LATITUDE:	**HAMMER TYPE:** Automatic		
LONGITUDE:	**EFFICIENCY** N/A		
STATION: N/A **OFFSET:** N/A	**REVIEWED BY:** David T. Lewandowski		

BORING B-2

Water		
While Drilling		Not Observed
Upon Completion		28 feet
Delay		N/A

BORING LOCATION:

See Boring Location Map

REMARKS: USCS Classifications based upon visual classification only

Elevation (feet)	Depth, (feet)	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification	SPT Blows per 6-inch (SS)	Moisture, %	Additional Remarks
	0			Fill: Black Silty Clayey Sand with gravel, cinders, brick pieces, moist				
		1	16			3-4-5 N=9	16	
		2	18	Dark Brown to Brown Lean Clay with sand, trace gravel, moist, stiff	CL	3-4-5 N=9	12	
	5							
		3	18	Brown Silty, Clayey Sand, moist, medium dense	SC-SM	3-5-6 N=11	17	
				Brown Sandy Silt, moist, medium dense	ML			
		4	16	Brown/Gray Sandy Lean Clay, trace gravel, moist, stiff	CL	3-4-5 N=9	19	Fines=60.9%
	10							
		5	18	Gray Lean Clay with sand, trace gravel, moist, stiff to very stiff	CL	4-8-11 N=19	15	
		6	18			5-7-12 N=19	14	
	15							
		7	18			4-5-9 N=14	15	Q_r = 1.6 tsf
	20							
		8	18			5-9-13 N=22	14	Q_r = 2.3 tsf
	25			Gray Silt, moist, medium dense	ML			
		9	9	Gray Poorly Graded Sand with gravel (probable cobbles or boulders), wet, very dense	SP	56-40-11 N=51	12	
	30			End of Boring at 30 Feet				

STANDARD PENETRATION TEST DATA: N in blows/ft; Moisture; PL; LL (0, 25, 50). STRENGTH, tsf: Qu; Qp (0, 2.0, 4.0)

intertek psi

Professional Service Industries, Inc.
4421 Harrison Street
Hillside, IL 60162
Telephone: (708) 236-0720

PROJECT NO.: 00474399-1
PROJECT: Old Grand Avenue Watermain
LOCATION: Canadian Pacific Railroad, Gurnee, Illinois

The stratification lines represent approximate boundaries. The transition may be gradual.

DATE STARTED: 10/6/20	**DRILL COMPANY:** PSI, Inc.		
DATE COMPLETED: 10/6/20	**DRILLER:** David L. **LOGGED BY:** David L.		
COMPLETION DEPTH 7.5 ft	**DRILL RIG:**		
BENCHMARK: N/A	**DRILLING METHOD:** Hand Auger		
ELEVATION: N/A	**SAMPLING METHOD:**		
LATITUDE:	**HAMMER TYPE:**		
LONGITUDE:	**EFFICIENCY** N/A		
STATION: N/A **OFFSET:** N/A	**REVIEWED BY:** David T. Lewandowski		

BORING HA-2

Water

While Drilling	7 feet
Upon Completion	N/A
Delay	N/A

BORING LOCATION: See Boring Location Map

REMARKS: USCS Classifications based upon visual classification only

Elevation (feet)	Depth, (feet)	Graphic Log	Sample Type	Sample No.	Recovery (inches)	MATERIAL DESCRIPTION	USCS Classification		Moisture, %	STANDARD PENETRATION TEST DATA N in blows/ft ◎ × Moisture ◪ PL ✚ LL 0 25 50; STRENGTH, tsf ▲ Qu ✳ Qp 0 2.0 4.0	Additional Remarks
	0					Blind Auger (no sampling)					
	5					Dark Brown to Brown Lean Clay with sand, trace gravel, moist	CL				LL = 32 PL = 20 Fines= 78%
						Brown Silty, Clayey Sand, moist	SC-SM				Fines= 33%
						Brown Sandy Silt, wet	ML		16		LL = 19 PL = 16 Fines= 67.5% See Particle-Size Analysis in the Appendix
						End of Hand Auger Boring					

Professional Service Industries, Inc.
4421 Harrison Street
Hillside, IL 60162
Telephone: (708) 236-0720

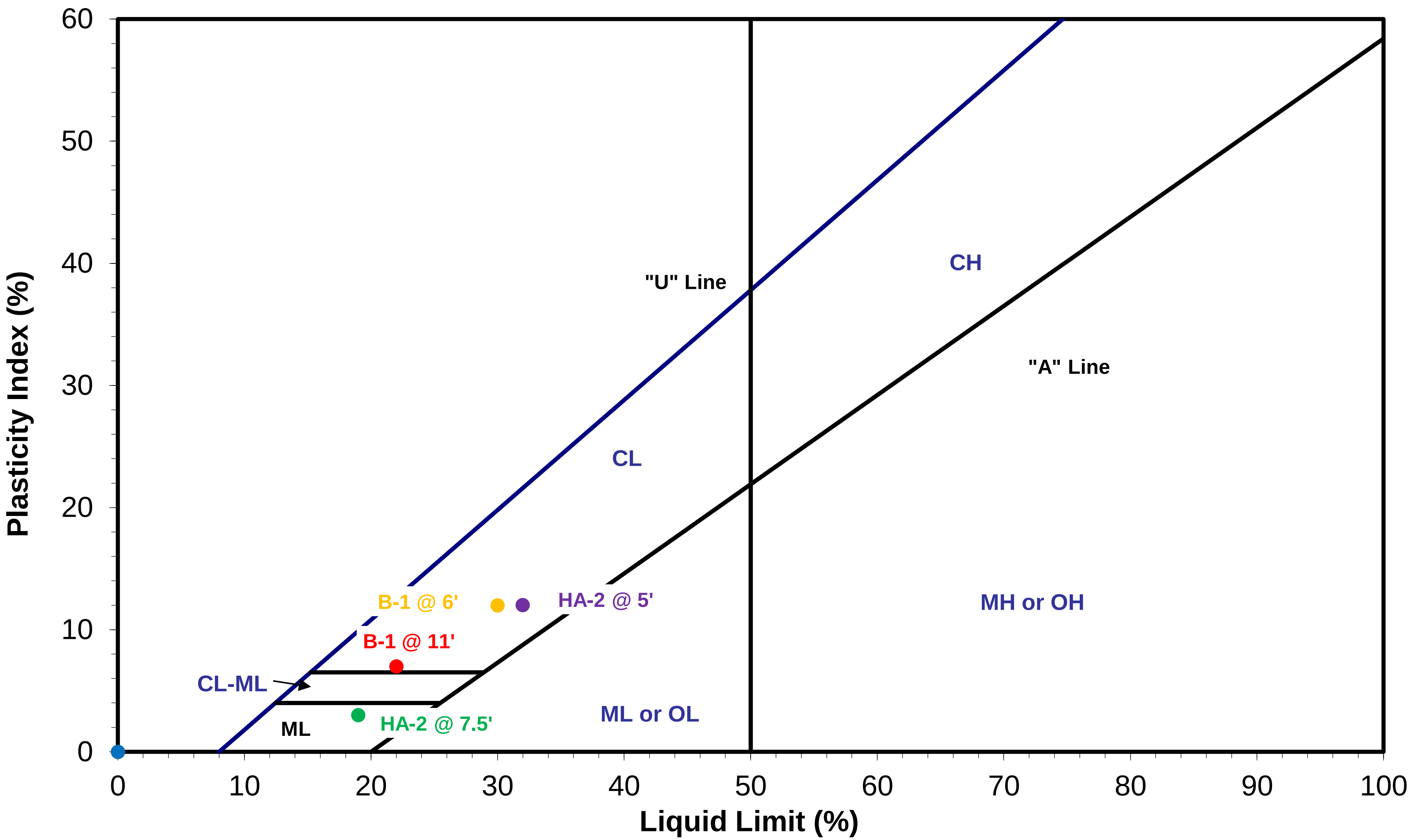
PROJECT NO.: 00474399-1
PROJECT: Old Grand Avenue Watermain
LOCATION: Canadian Pacific Railroad
Gurnee, Illinois

The stratification lines represent approximate boundaries. The transition may be gradual.

Laboratory Test Results

Rubino Engineering Inc.

Report of Atterberg Limits Test (ASTM D4318 / AASHTO T89 / AASHTO T90)

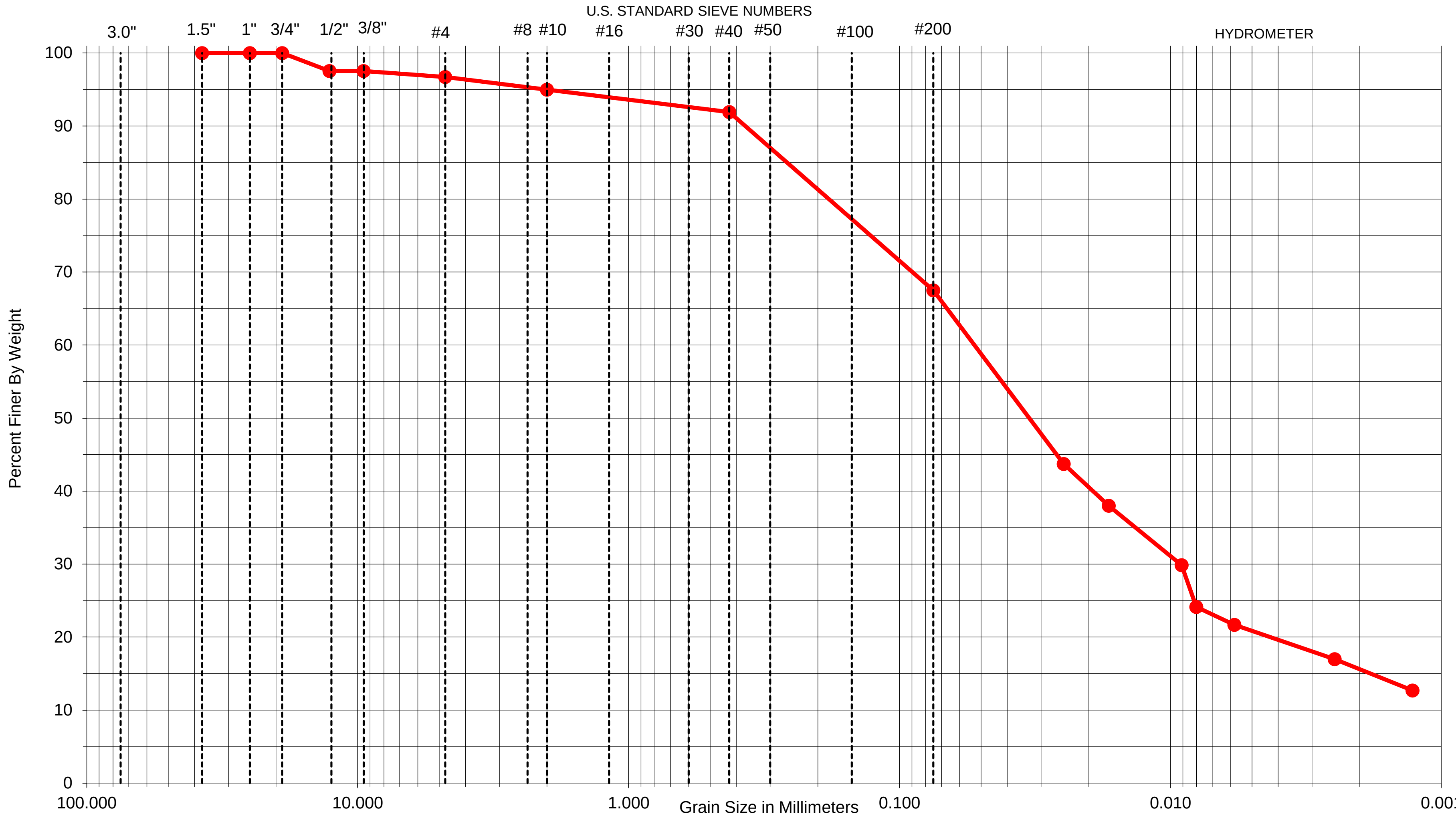


Boring #	B-1 @ 6'	B-1 @ 11'	HA-2 @ 5'	HA-2 @ 7.5'		
LL	30	22	32	19		
PL	18	15	20	16		
PI	12	7	12	3		

Project: PSI Project No. 00474399
Location: Gurnee, IL
Client: Intertek-PSI
Project #: G20.143

rubino ENGINEERING INC.

REPORT OF PARTICLE-SIZE ANALYSIS OF SOIL



Key	Boring No.	Depth	USCS Classification	WC%	ORG%	Cc	Cu	%Gravel	%Sand	%Silt	%Clay	D60	D30	D10
●	HA-2	7.5	Sandy SILT	16	N/A	N/A	N/A	3.3	29.2	52.2	15.3	0.059	0.009	N/A

REPORT OF PARTICLE-SIZE ANALYSIS OF SOIL	**PSI Testing Gurnee, IL**	File No.	**G20.143**

Rubino Engineering Inc ● 425 Shepard Drive● Elgin, IL 60123 ● 847-931-1555 ● 847-931-1560 (Fax)

Sample Figures 1 to 3
CP Geotechnical Protocol for Pipeline and Utility Crossing(s) under Railway Tracks

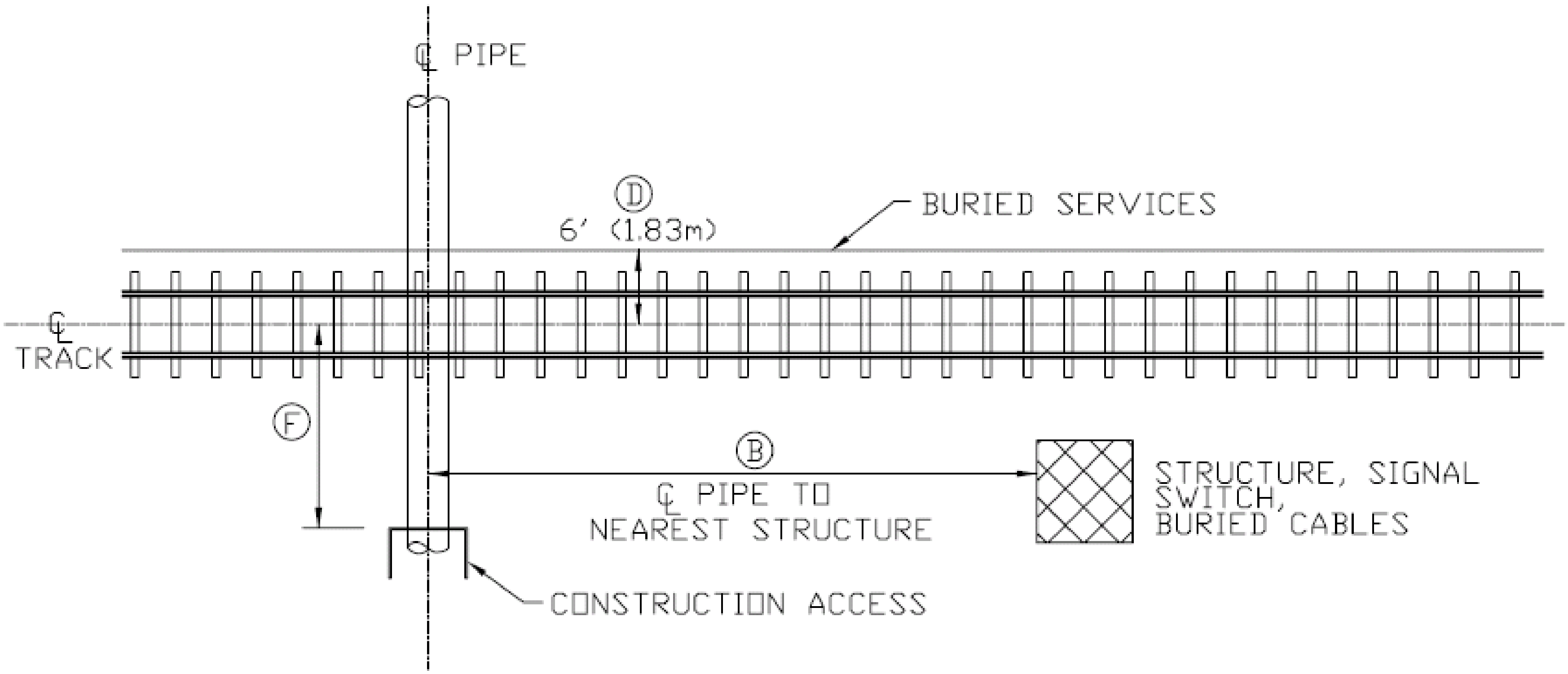


Figure 1 – Plan of the proposed pipe crossing

SAMPLE

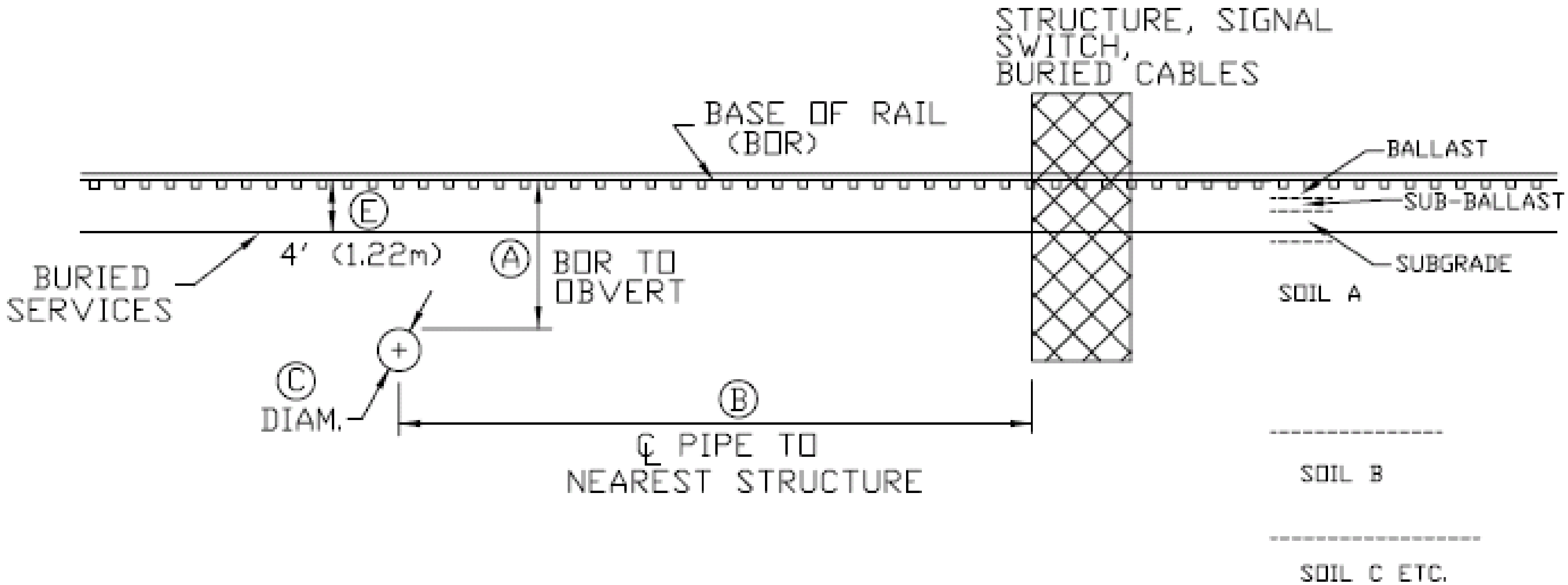
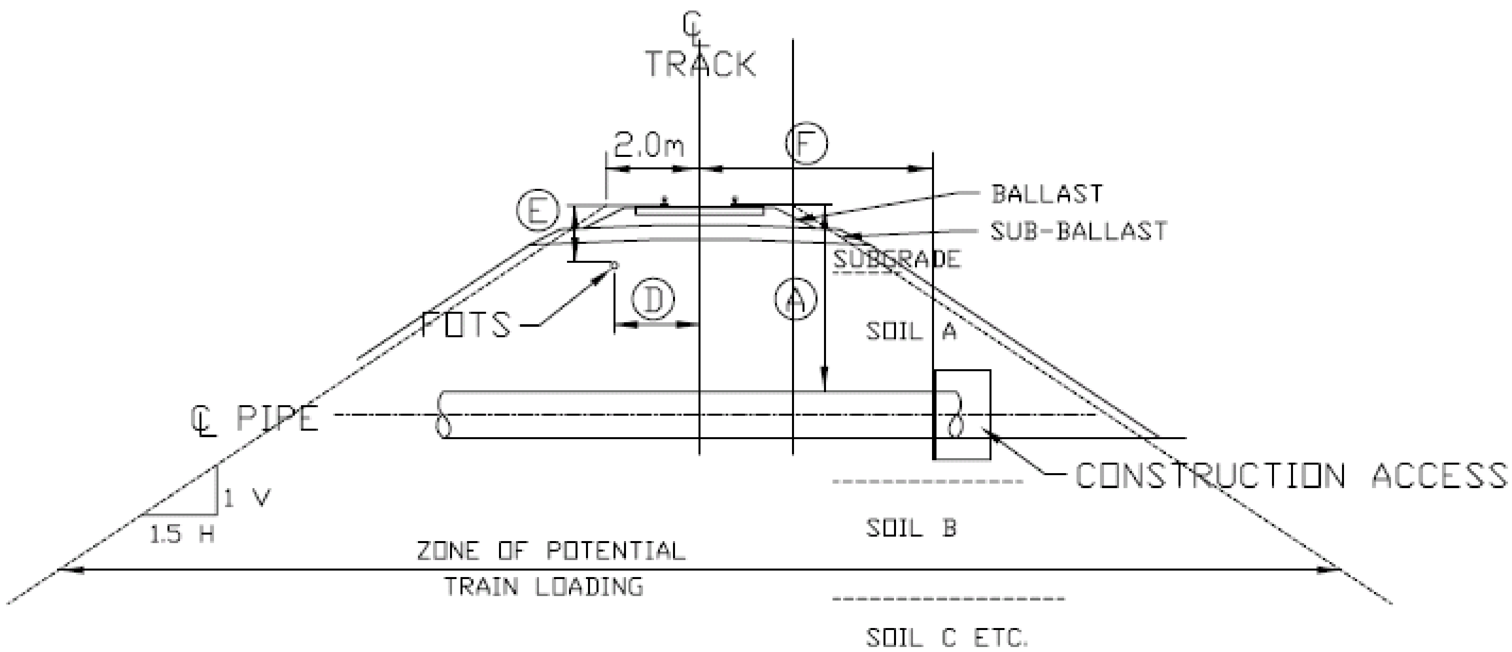


Figure 2 – Profile of the track and proposed pipe crossing along the centerline of track

SAMPLE



FOTS = FIBRE OPTICS TRANSMISSIONS SYSTEM

Figure 3 – Section of Track along centerline of proposed pipe

SAMPLE

Threshold Track Settlement Monitoring Review and Alert

Thresholds Track Settlement Monitoring Review and Alert

Class	Alert Threshold		Review Threshold	
1	22 mm	0.866 inches	11 mm	0.433 inches
2	22 mm	0.866 inches	11 mm	0.433 inches
3	19 mm	0.748 inches	10 mm	0.393 inches
4	16 mm	0.629 inches	8 mm	0.314 inches
5	13 mm	0.511 inches	6 mm	0.236 inches
6	10 mm	0.393 inches	5 mm	0.196 inches

Class of Track

TRACK CLASSES		
Class	Freight Train Speed	Passenger Train Speed
1	10 MPH	15 MPH
2	25 MPH	30 MPH
3	40 MPH	60 MPH
4	60 MPH	80 MPH
5	80 MPH	95 MPH ❶ 90 MPH ❷

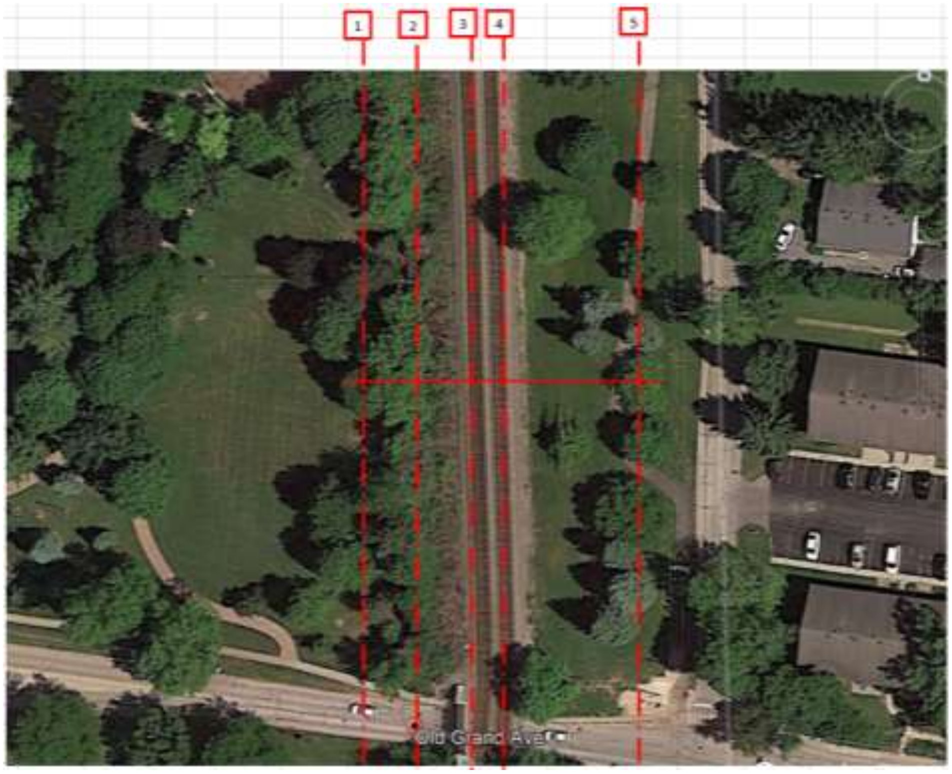
❶ *For LRC Trains, 100 MPH*

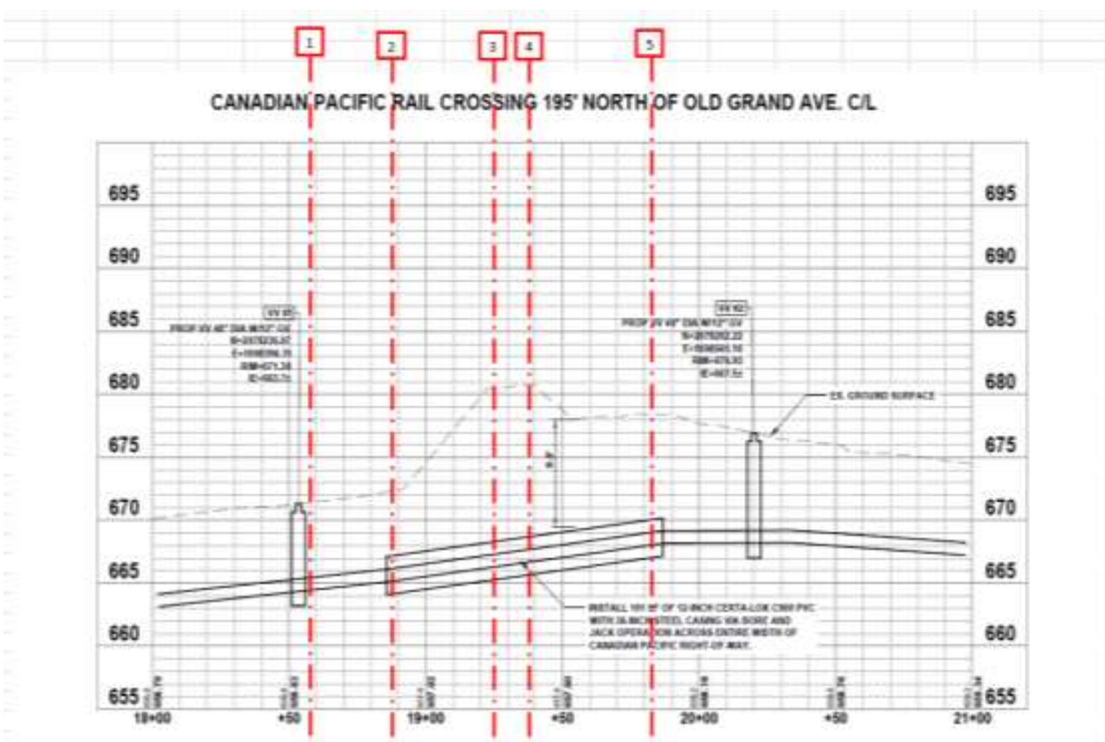
❷ *Applies to US only*

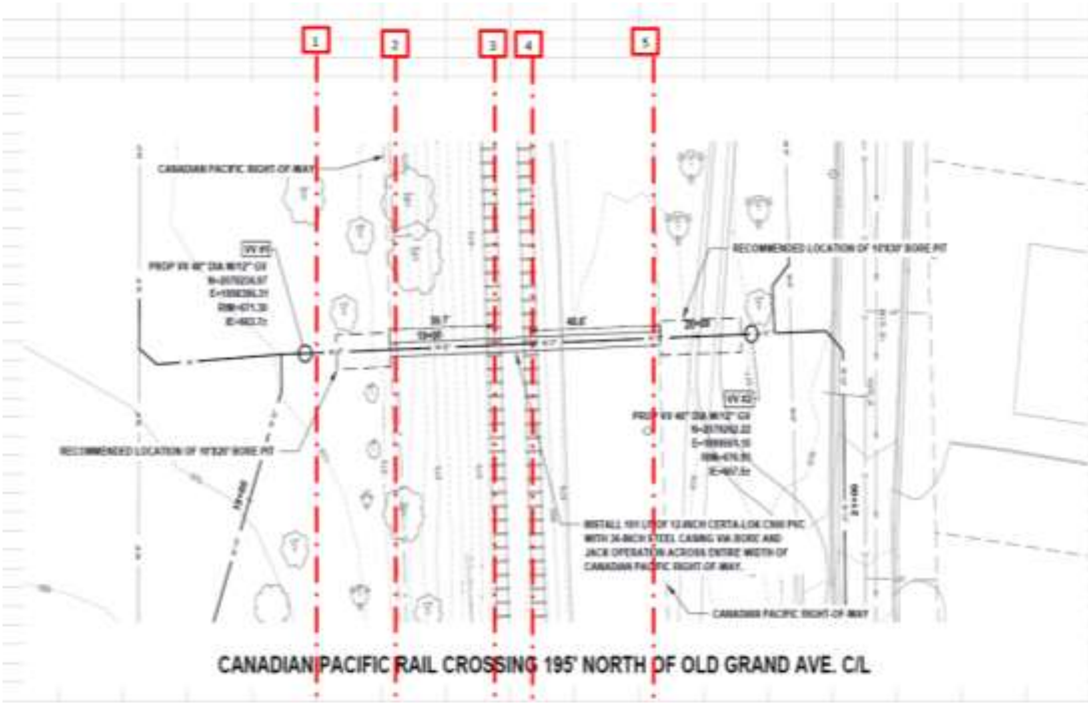
Figure 5-1

Cross Sections / Estimated Settlements

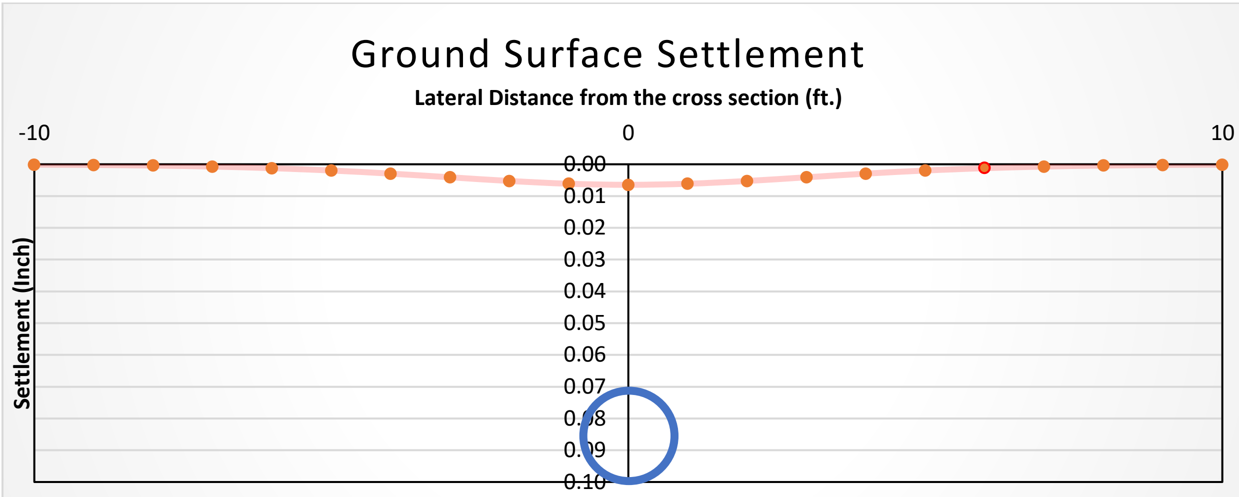
Typical Cross sections selected for the analyses



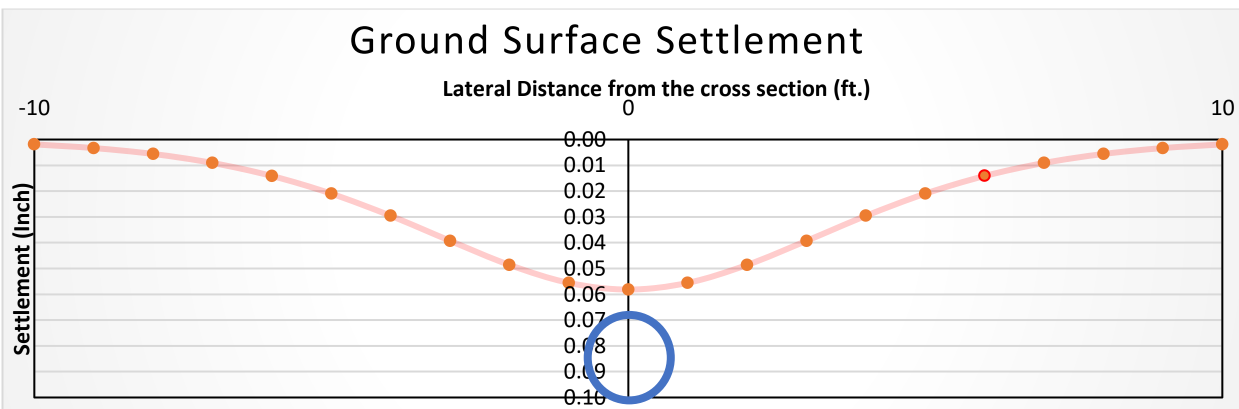



1
2
3
4
5
CANADIAN PACIFIC RIGHT-OF-WAY
CANADIAN PACIFIC RAIL CROSSING 195' NORTH OF OLD GRAND AVE. C/L

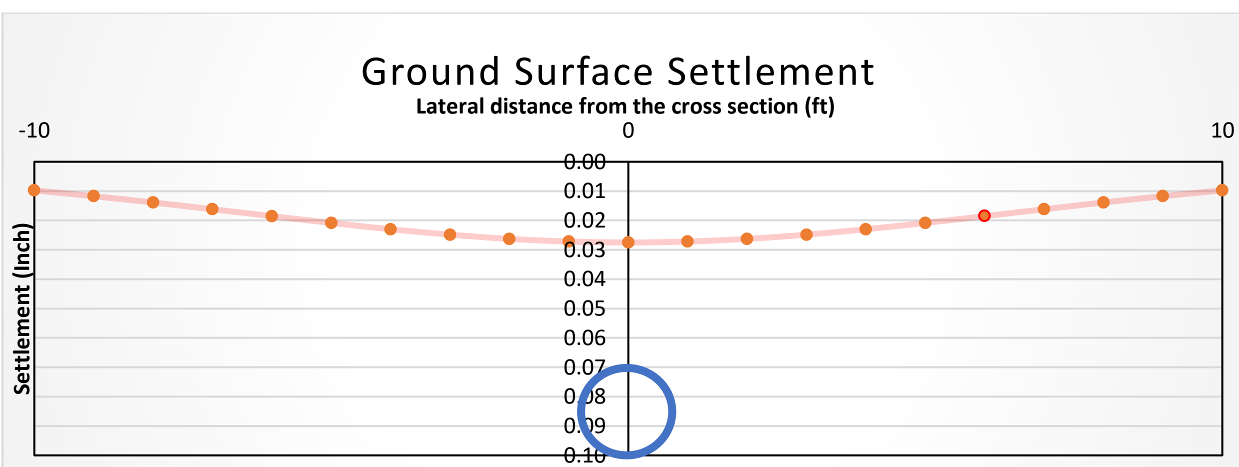
Cross Section 1 at Sta. 18+55



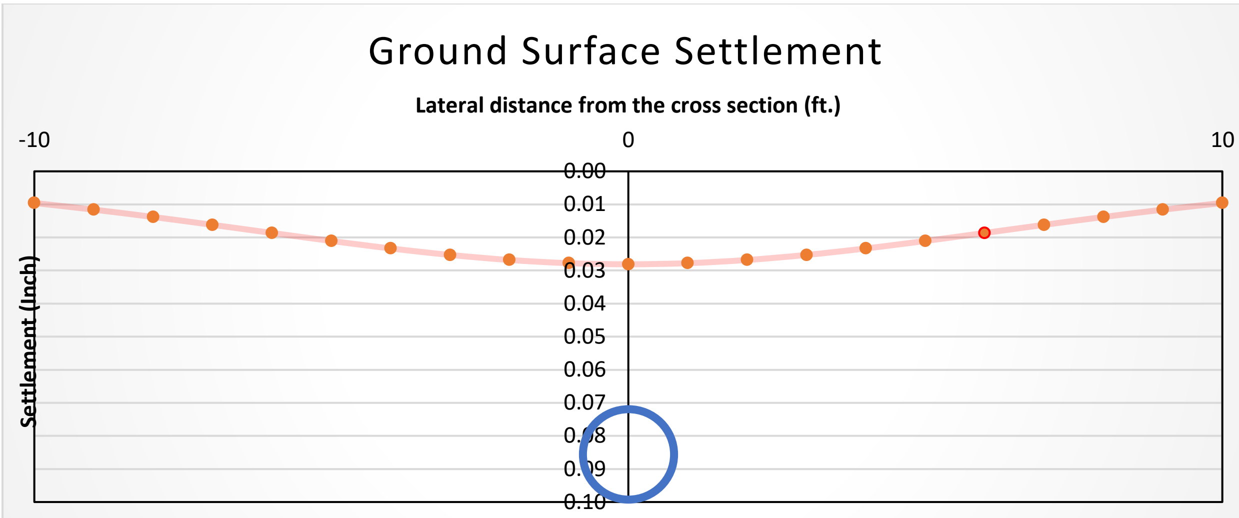
Cross Section 2 at Sta. 18+85



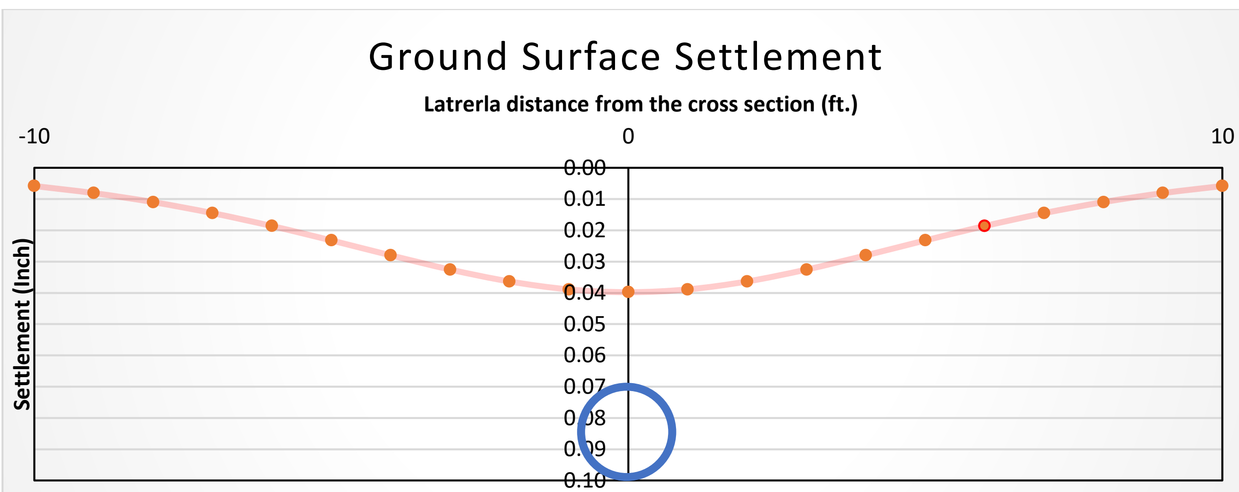
Cross Section 3 at Sta. 19+24



Cross Section 4 at Sta. 19+38



Cross Section 5 at Sta. 19+85



General Notes
USCS Classification Chart

GENERAL NOTES

SAMPLE IDENTIFICATION

The Unified Soil Classification System (USCS), AASHTO 1988 and ASTM designations D2487 and D-2488 are used to identify the encountered materials unless otherwise noted. Coarse-grained soils are defined as having more than 50% of their dry weight retained on a #200 sieve (0.075mm); they are described as: boulders, cobbles, gravel or sand. Fine-grained soils have less than 50% of their dry weight retained on a #200 sieve; they are defined as silts or clay depending on their Atterberg Limit attributes. Major constituents may be added as modifiers and minor constituents may be added according to the relative proportions based on grain size.

DRILLING AND SAMPLING SYMBOLS

SFA: Solid Flight Auger - typically 4" diameter flights, except where noted.
HSA: Hollow Stem Auger - typically 3¼" or 4¼ I.D. openings, except where noted.
M.R.: Mud Rotary - Uses a rotary head with Bentonite or Polymer Slurry
R.C.: Diamond Bit Core Sampler
H.A.: Hand Auger
P.A.: Power Auger - Handheld motorized auger

SS: Split-Spoon - 1 3/8" I.D., 2" O.D., except where noted.
ST: Shelby Tube - 3" O.D., except where noted.
BS: Bulk Sample
PM: Pressuremeter
CPT-U: Cone Penetrometer Testing with Pore-Pressure Readings

SOIL PROPERTY SYMBOLS

N: Standard "N" penetration: Blows per foot of a 140 pound hammer falling 30 inches on a 2-inch O.D. Split-Spoon.
N_{60}: A "N" penetration value corrected to an equivalent 60% hammer energy transfer efficiency (ETR)
Q_u: Unconfined compressive strength, TSF
Q_p: Pocket penetrometer value, unconfined compressive strength, TSF
w%: Moisture/water content, %
LL: Liquid Limit, %
PL: Plastic Limit, %
PI: Plasticity Index = (LL-PL),%
DD: Dry unit weight, pcf
▼,▽,▼: Apparent groundwater level at time noted

RELATIVE DENSITY OF COARSE-GRAINED SOILS

Relative Density	N - Blows/foot
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	50 - 80
Extremely Dense	80+

ANGULARITY OF COARSE-GRAINED PARTICLES

Description	Criteria
Angular:	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular:	Particles are similar to angular description, but have rounded edges
Subrounded:	Particles have nearly plane sides, but have well-rounded corners and edges
Rounded:	Particles have smoothly curved sides and no edges

GRAIN-SIZE TERMINOLOGY

Component	Size Range
Boulders:	Over 300 mm (>12 in.)
Cobbles:	75 mm to 300 mm (3 in. to 12 in.)
Coarse-Grained Gravel:	19 mm to 75 mm (¾ in. to 3 in.)
Fine-Grained Gravel:	4.75 mm to 19 mm (No.4 to ¾ in.)
Coarse-Grained Sand:	2 mm to 4.75 mm (No.10 to No.4)
Medium-Grained Sand:	0.42 mm to 2 mm (No.40 to No.10)
Fine-Grained Sand:	0.075 mm to 0.42 mm (No. 200 to No.40)
Silt:	0.002 mm to 0.075 mm
Clay:	<0.002 mm

PARTICLE SHAPE

Description	Criteria
Flat:	Particles with width/thickness ratio > 3
Elongated:	Particles with length/width ratio > 3
Flat & Elongated:	Particles meet criteria for both flat and elongated

RELATIVE PROPORTIONS OF FINES

Descriptive Term	% Dry Weight
Trace:	< 5%
With:	5% to 12%
Modifier:	>12%

GENERAL NOTES
(Continued)

CONSISTENCY OF FINE-GRAINED SOILS

Q_U - TSF	N - Blows/foot	Consistency
0 - 0.25	0 - 2	Very Soft
0.25 - 0.50	2 - 4	Soft
0.50 - 1.00	4 - 8	Firm (Medium Stiff)
1.00 - 2.00	8 - 15	Stiff
2.00 - 4.00	15 - 30	Very Stiff
4.00 - 8.00	30 - 50	Hard
8.00+	50+	Very Hard

MOISTURE CONDITION DESCRIPTION

Description	Criteria
Dry:	Absence of moisture, dusty, dry to the touch
Moist:	Damp but no visible water
Wet:	Visible free water, usually soil is below water table

RELATIVE PROPORTIONS OF SAND AND GRAVEL

Descriptive Term	% Dry Weight
Trace:	< 15%
With:	15% to 30%
Modifier:	>30%

STRUCTURE DESCRIPTION

Description	Criteria
Stratified:	Alternating layers of varying material or color with layers at least ¼-inch (6 mm) thick
Laminated:	Alternating layers of varying material or color with layers less than ¼-inch (6 mm) thick
Fissured:	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided:	Fracture planes appear polished or glossy, sometimes striated

Description	Criteria
Blocky:	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed:	Inclusion of small pockets of different soils
Layer:	Inclusion greater than 3 inches thick (75 mm)
Seam:	Inclusion 1/8-inch to 3 inches (3 to 75 mm) thick extending through the sample
Parting:	Inclusion less than 1/8-inch (3 mm) thick

SCALE OF RELATIVE ROCK HARDNESS

Q_U - TSF	Consistency
2.5 - 10	Extremely Soft
10 - 50	Very Soft
50 - 250	Soft
250 - 525	Medium Hard
525 - 1,050	Moderately Hard
1,050 - 2,600	Hard
>2,600	Very Hard

ROCK BEDDING THICKNESSES

Description	Criteria
Very Thick Bedded	Greater than 3-foot (>1.0 m)
Thick Bedded	1-foot to 3-foot (0.3 m to 1.0 m)
Medium Bedded	4-inch to 1-foot (0.1 m to 0.3 m)
Thin Bedded	1¼-inch to 4-inch (30 mm to 100 mm)
Very Thin Bedded	½-inch to 1¼-inch (10 mm to 30 mm)
Thickly Laminated	1/8-inch to ½-inch (3 mm to 10 mm)
Thinly Laminated	1/8-inch or less "paper thin" (<3 mm)

ROCK VOIDS

Voids	Void Diameter
Pit	<6 mm (<0.25 in)
Vug	6 mm to 50 mm (0.25 in to 2 in)
Cavity	50 mm to 600 mm (2 in to 24 in)
Cave	>600 mm (>24 in)

GRAIN-SIZED TERMINOLOGY
(Typically Sedimentary Rock)

Component	Size Range
Very Coarse Grained	>4.76 mm
Coarse Grained	2.0 mm - 4.76 mm
Medium Grained	0.42 mm - 2.0 mm
Fine Grained	0.075 mm - 0.42 mm
Very Fine Grained	<0.075 mm

ROCK QUALITY DESCRIPTION

Rock Mass Description	RQD Value
Excellent	90 -100
Good	75 - 90
Fair	50 - 75
Poor	25 -50
Very Poor	Less than 25

DEGREE OF WEATHERING

Slightly Weathered:	Rock generally fresh, joints stained and discoloration extends into rock up to 25 mm (1 in), open joints may contain clay, core rings under hammer impact.
Weathered:	Rock mass is decomposed 50% or less, significant portions of the rock show discoloration and weathering effects, cores cannot be broken by hand or scraped by knife.
Highly Weathered:	Rock mass is more than 50% decomposed, complete discoloration of rock fabric, core may be extremely broken and gives clunk sound when struck by hammer, may be shaved with a knife.

USCS SOIL CLASSIFICATION CHART

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SAND, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

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