EGRT CONSTRUCTION

EVERGREEN LINE RAPID TRANSIT PROJECT

COMBINED CRIAR / IMP / I&M SUBMISSION

BORED TUNNEL SEGMENT
SECTION 220

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Revision	Date (yy/mm/dd)	Description of Changes	Initials
A	13/08/23	N/A	SS
B	13/10/04	Incorporate comments on Rev A	SS

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1.0 INTRODUCTION

The purpose of this report is to present the combined content of the Bored Tunnel Construction Risk and Impact Assessment Report (CRIAR), Impact Mitigation Plan (IMP) and the Instrumentation & Monitoring (I & M) Plan.. This report identifies and locates the Existing Conditions that may experience adverse impacts due to the Evergreen Line Bored Tunnel segment and evaluates the risk of damage. Based on these findings, measures to mitigate medium to high risks items are presented. This report also describes the planned instrumentation and monitoring program which will provide confirmation that mitigation measures are adequate. This report satisfies the submission requirements outlined in, Schedule 4 Part 1 Article 4 and Schedule 4 Part 2 Article 6 of the Project Agreement (PA) and amended in EGL-0442, the Province's response to DB-C-RFV-0025.

1.1 Scope

This report is intended to evaluate potential damage to the Existing Conditions that may result from undertaking the Works both during construction and throughout the design life of the structure (Bored Tunnel). The areal extent of the Work evaluated is constrained by the Bored Tunnel portals at I/B station 416+790 to 418+736. The potential impacts associated with work conducted by SGJV, including the portal preparation and excavation of the cut and cover tunnels, are described in the North Portal and South Portal CRIARs, (doc. 511326-10000-S2EB-4GCR-0001 & 511326-00000-S2EB-4GCR-0001). The planned mitigation strategies and instrumentation plans are presented in the North and South Portal IMPs (511326-00000-S2SL-4GIM-0002 & 511326-00000-S2SL-4GIM-0001) and I&M plans (511326-00000-S2MD-4GER-0001 & 511326-00000-S2SL-4GMP-0001).

Definitions of some of the terms used in this document which are taken from the PA are given at the end of the document. These terms are indicated in the text capitalization e.g. 'Existing Conditions'.

The evaluations conducted were based on available data including Disclosed Data and information available on municipal websites. More detailed information about the Existing Conditions will be collected during pre-construction surveys but these are not expected to alter the expected impacts.

This report does not address environmental, social and nuisance impacts, and safety which are covered in other documents.

1.2 Zone of Influence

The Zone of Influence, as described in the Project Agreement, constitutes the area containing any Existing Conditions that may potentially be damaged or otherwise adversely impacted due to the Work (see end of the document for the full definition).

As defined by RFV DB-C-IFR-0429 (submitted to the Province concurrent with submittal of this document) which modifies PA Sch. 4 Part 2, Art 6.10.3 (a) (ii), the zone requiring deformation monitoring along the Bored Tunnel section extends:

- laterally out from the tunnel centreline a distance equal to 1.5 times the tunnel depth, for tunnel cover < 35m, and
- laterally 20m out from the tunnel centerline, for tunnel cover > 35m,

where tunnel cover as defined as the distance between the grounds surface and tunnel springline.

The selected Bored Tunnel Zone of Influence (ZoI) coincides with the required settlement monitoring zone, and is shown in Figure 1. The Zone of Influence has been selected based on an evaluation of expected ground deformation above the tunnel. This evaluation is described in more detail in Section 6.0.

This document seeks to identify the Existing Conditions that are mostly likely to be impacted. Due to the extensive number of Existing Conditions in the Zone of Influence, not all Existing Conditions were analyzed in detail, but the most critical were selected and evaluated, as well as representative examples of the remainder of the Existing Conditions.

2.0 PLANNED WORKS

2.1 Permanent Works

As part of the Bored Tunnel, the Permanent Works will include the following items:

- Precast concrete segmental linings, 0.35-meters thick, to serve as both initial and final lining for the entire length of the tunnel, from I/B station 416+790 to 418+736. Details of the lining are provided in ELRT Bored Tunnel Drawings No. 511328-12220-S2JA-43DD-0001 to 0010.
- An invert slab and backfill within the tunnel bore to provide the necessary grade for the two track alignments.
- The plinths and tracks resting on the invert slab.
- A walkway platform between the two trackways, for emergency egress purposes
- A dividing wall to isolate the two trackways, with occasional doorways to provide cross access between tunnels.
- Mechanical, electrical and systems finishes within the tunnel, including lighting, tunnel drainage, and standpipes.

Details for all but the first bullet above are still being worked out by SLCW as part of a separate design package. That being said, of the Permanent Works, only the installation of the segmental lining, as part of the tunnel excavation discussed under Temporary Works, is anticipated to have the potential to cause impacts to Existing Conditions. All other Permanent Works will occur within the lining, and are not anticipated to cause significant impacts.

2.2 Temporary Works

For construction of the Bored Tunnel, the Temporary Works will include the following items:

- Excavation of the tunnel itself by tunnel boring machine (TBM) excavation, including segmental lining installation and tail void grouting. The TBM excavated diameter is anticipated to be just under 10 meters.
- Ground improvement work at the North Portal to aid in the launch of the TBM.

- Assembly of the TBM in the launch pit at the North Portal and subsequent launch.
- Retrieval and subsequent disassembly of the TBM at the retrieval pit at the South Portal.

Of the Temporary Works, the excavation of the tunnel is the main focus of this report, and is anticipated to be the most critical aspect of the work. The remainder of the report discusses anticipated impacts from tunnel excavation. Work within the North and South Portals for TBM launch and disassembly are not anticipated to have significant impacts. Ground improvement work and localized excavation work to create the work pad at the North Portal may have localized impacts around the excavation.

2.3 Construction sequence

For construction of the Bored Tunnels, the following sequence is anticipated to be followed. Note that some minor deviations may occur from this sequence, but they are not anticipated to significantly affect the magnitude of impacts.

1. Construction of the North Portal: Work will include installation of excavation support, excavation of the portal, and installation of a temporary work slab for launching the TBM. This work will be performed by the SGJV, and impacts of the work are covered in a separate CRIAR (Document Number 511326-10000-S2EB-4GCR-0001).

2. Ground Improvement at the North Portal: Work will include excavation of a small pad for the work, and jet grouting soil within the first approximately 15-m of the tunnel excavation.

3. Construction of the South Portal and Ground Improvement: Similar work as the North Portal will be performed at the South Portal. Timing is not as critical for tunneling as the North Portal. This work will be performed by the SGJV, and impacts of the work are covered in a separate CRIAR (Document Number 511326-00000-S2EB-4GCR-0001).

4. Installation of TBM Thrust Frame at the North Portal and Preparation for TBM Launch: Work will include installation of a steel frame anchored to the temporary work slab, to support the initial thrust forces of the TBM as excavation commences, and set-up of the TBM within the portal excavation.

5. TBM assembly: Hoisting of TBM parts into the launch pit.

6. TBM Launch: Work will include the initial (10 to 15 meters) excavation of the tunnel as the TBM breaks out into the ground through the excavation support system of the North Portal.

7. Tunnel Excavation: The TBM will mine in 1.5 meter increments. Excavation will be by an earth pressure balanced tunnel boring machine (EPB-TBM), with spoils removed via an auger to a conveyor belt. For each 1.5 meter cycle, a segmental lining ring will be installed, and tail void grout will be injected behind previously constructed rings to lock the lining in place.

8. TBM Retrieval: Work will include the excavation of the last 10 to 15 meters of the tunnel, break-through into the South Portal through the excavation support system, installation of the last length of rings as the TBM is advanced into the portal excavation, and removal of the TBM from the portal. TBM to be removed with hoisting crane set on cut and cover box section.

9. Tunnel Finishes Installation: Subsequent to tunnel completion, work will include installation of the invert slab and tunnel backfill to bring the invert up to the grade of the trackways; installation of the plinths and rails for each trackway; installation of the walkway platform and dividing wall between the two trackways; and installation of all required mechanical, electrical, and systems components (including jet fans).

3.0 SUBSURFACE CONDITIONS

An interpreted subsurface profile is provided in the Geotechnical Baseline Report (Golder, 2011) based on soil borings drilled during the geotechnical investigation program. This profile is included as Figure 2 in this report. The Geotechnical Design Report- Bored Tunnel structure (Doc No. 511328-12220-S2JA-4GEN-0001 rev A) provides the basis for the design and analyses conducted for the Bored Tunnel combined CRIAR/IMP/I&M report. The geotechnical investigation data used in producing the Geotechnical Design Report is available in the Geotechnical Data Report (Golder Oct 2010, Report No. 08-1411-0115/4000/4240).

3.1 Soil Units

In general, the soil profile along the tunnel alignment consists of variable thicknesses of fill overlying a relatively thin layer of sandy alluvium and weathered surficial soil, overlying dense to very dense soils (glacial till and till-like materials). Due to multiple episodes of glacial advance and retreat in this area, the stratigraphy is expected to be highly variable both laterally and horizontally. The elevation of the contact between pre-glacial, dense to very dense layered silts and sands, and underlying silts and sands with gravel, cobbles, and boulders will also vary. The soils have been consolidated by the weight of the overriding glaciers and are typically very dense or hard.

Soils have been grouped based on their material properties, including results of index and strength tests, and expected behaviour during tunneling. The predominant soil units encountered along the tunnel alignment are described below.

3.1.1 Unit 1: Upper Till

These soils were encountered at relatively shallow depths over the southern part of the tunnel alignment. This glacial till belongs to the Vashon Drift geological formation, which is widely encountered throughout Greater Vancouver. This unit is predominately a well-graded mixture of silt, sand and gravel, with trace amounts of clay (generally less than 10%). Boulders and cobbles are anticipated to be encountered in this unit.

3.1.2 Unit 2: Interlayered Sands, Gravels, and Silts

These soils are encountered along the majority of the tunnel alignment. This unit has been correlated to the Quadra Sand geological formation, and is highly variable in composition. Three sub-units have been identified: a uniform sand with trace to some fines (Unit 2A); a silty

sand/sandy silt with trace to some clay (Unit 2B), and a sand and gravel mixture with trace to some silt (Unit 2C).

3.1.3 Unit 3: Lower Till

This very dense glacial till belongs to the Coquitlam Drift geological formation. These soils are predominately well-graded mixtures of silt, sand and gravel, with trace amounts of clay (less than 10%). Boulders and cobbles are anticipated to be encountered in this unit.

3.1.4 Unit 4: Silty Clay/Clayey Silt

These soils are present only in the northern portion of the alignment, beneath the Lower Till. Unit 4 consists predominantly of silty clay of medium plasticity and with trace sand. Slickensided fractures were observed in soil samples, likely indicative of shearing due to glacial loading and unloading. Sand, silty sand, and silt layers should be expected in this unit. Gravel, cobbles, and boulders are also present in this unit.

3.1.5 Unit 5: Sand/Silt Mixtures and Interlayered Silts

These soils consist predominately of interlayered, non-plastic silts and sandy silts, similar to Unit 2B but generally found at lower elevations.

3.2 Groundwater

Groundwater levels are highly variable due to the steep topography of the upland areas and the complex soil stratigraphy. Groundwater is recharged in the upper slopes and discharged predominately to Burrard Inlet, as well as to a number of the small creeks, through interbedded coarse, granular layers.

Observed piezometric groundwater levels drop off with the slope (and the tunnel alignment) down towards the North Portal. However, the groundwater flow is sometimes confined within more permeable layers, and piezometric levels at greater depths may be higher than those measured in shallower depths. Artesian conditions have not been encountered along the tunnel alignment, but were observed in boreholes at lower elevations to the north of the Port Moody station far from the tunnel alignment.

4.0 EXISTING CONDITIONS

4.1 General

The Bored Tunnel segment is located between the Burquitlam and Port Moody stations. The tunnel alignment passes under Clarke Road from Kemsley Avenue in the South and then turns east to pass under the Charles St. Cul-de-Sac and exits just west of the Barnet Highway. The area is predominantly residential, with some undeveloped forested land.

4.2 Existing Conditions

The following sections identify and provide a brief description of the Existing Conditions that could potentially be impacted by the Works. As shown in Figure 1, a significant number of structures are located within the Zone of Influence (ZOI). As required by the PA Sch. 4, Part 1, Art. 4.4.1, all Existing Conditions within the Zone of Influence will receive a Pre- and Post-Construction Survey.

4.2.1 Buildings

The existing buildings in the tunnel area are predominantly residential buildings with 1 to 3 above ground stories. No buildings are taller than 3 stories. There are many single family dwellings, duplexes and small apartment complexes. These consist mainly of wood-framed homes, possibly with basements. There are also a few larger apartment buildings with longer footprints (up to 100m long). Four commercial buildings were identified including a convenience store, a motel, a set of small retail shops and a used car dealership; these are all 1-2 story buildings. A complete list of buildings to be evaluated for impacts is provided in Appendix A. This list includes all structures within the ZOI, as well as a small number of buildings that are in very close proximity to the ZOI.

4.3 Utilities

Many utilities fall within the ZOI, in particular along Clarke Rd and its cross streets. These include water lines, storm sewers, sanitary sewers, gas lines, and various communication utilities. The utilities are shown in Figure 1. A complete list of utilities crossing or along the tunnel alignment is included in Appendix B.

The available utility drawings show the known utilities, however there may be others not shown. Utility locations must be confirmed prior to commencing work in the vicinity of the portals.

The majority of the utilities being crossed are either small diameter lines (<150mm) that may deform with the ground without significant risk of rupture or leakage, or those that occur along

deeper portions of the tunnel alignment and are not anticipated to be affected by the tunnel. The larger utilities and the areas of shallower tunneling are the main focus of this assessment. There are a very limited number of major utilities within the ZOI. For the purpose of assessing tunnel impacts, major utilities are defined as follows, consistent with past studies on utilities:

- Sanitary sewers with diameter d >600mm
- Water lines with d>400mm
- Storm sewers with d> 900mm
- High pressure gas lines with d>200mm
- All cast iron (CI) utilities (due to brittle joints).

The only large-diameter major utility identified in the bored tunnel segment is the 650mm water main (steel pipe) that crosses Clarke Rd. near Chapman Ave. Other critical utilities include a number of smaller cast-iron water pipes 150-200mm in diameter. These CI pipes run under Charles St, along Clarke Rd. as well as joining Clarke Rd from various cross streets.

The utilities that are closest to the shallow tunnel sections are most at risk of impacts due to tunnel construction. Those to be discussed in more detail include:

At the South Portal,

- 380 mm concrete storm sewer line situated on the north side of Kemsley Avenue and then runs near-parallel to the tunnel along Clarke Road;
- 200 mm concrete sanitary sewer line situated on the south side of Kemsley Avenue;
- 150 mm water line situated on the south side of Kemsley Avenue; and

At the North Portal,

- 150 mm diameter sanitary sewer between Charles Street and Clarke Street;
- 150mm water line at Charles Street cul-de-sac;
- 150mm diameter sanitary sewer at Charles Street cul-de-sac; and

- 200mm concrete storm sewer at Charles Street cul-de-sac.

Additional utilities outside the zones closest to the portals may require special attention. Utility owners will be consulted to identify any specific utilities that may be more sensitive or have additional requirements during construction.

4.4 Roads and sidewalks

The tunnel will for pass under Clarke road for approximately half the alignment (1km). Other roads and streets that fall in the tunnel Zone of Influence include Charles St. at the North end, as well as the many cross-streets along Clarke Road. The cross-streets are: Kelmsley Ave., Thompson Ave., Chapman Ave., Robinson St., Glenayre Dr., Ingersoll Street, Seaview Dr., Mt Royal Dr., Cecile Dr., and Chateau Place.

5.0 PRE-CONSTRUCTION CONDITIONS SURVEYS

In accordance with Schedule 4, Part 1, Article 4.4.1 of the PA, all Existing Conditions within the Zone of Influence will receive a Pre- and Post-Construction Survey. The Pre-Construction Condition Survey is required to be completed by no later than 45 business days prior to the commencement of any excavation, dewatering, tunneling, or other settlement or vibration producing activities as part of the construction. The Pre-Construction Conditions Survey will include all structures in the tunnel Zone of Influence as well as roadways and sidewalks. Pre-Construction Condition Surveys will predominantly take the form of video and photo documentation of existing conditions. There are a couple of additional structures outside the ZOI that will also undergo pre-construction surveys for completeness. These structures have been selected using engineering judgment.

Due to the significant number of utilities within the Zone of Influence, only those utilities where there is the potential for impacts will receive surveys. The ability to conduct these surveys is limited by type and size of conduit. Thus, it may not be feasible to survey even some of those in the higher risk areas. For these situations, monitoring of ground movements (at surface or in boreholes) will be used to determine if impacts have occurred. Utilities recommended for pre-construction surveys prior to and upon completion of tunnel-related work include:

- A 200 mm concrete sanitary sewer line situated on the south side of Kemsley Avenue;
- A 380 mm concrete storm sewer line situated on the north side of Kemsley Avenue;
- Its continuation to the northeast along Clarke Road, a 380 mm concrete storm sewer;
- 200mm concrete storm sewer at Charles Street cul-de-sac;
- 150 mm diameter sanitary sewer between Charles Street and Clarke Street; and
- 150mm diameter sanitary sewer at Charles Street cul-de-sac.

6.0 CONSTRUCTION RISK IMPACT ASSESSMENT (CRIAR)

6.1 Potential construction impacts

In accordance with Sch. 4, Part 1, Article 4.2.2(b)(iii), this section identifies the potential damage and other adverse impacts on the Existing Conditions due to the planned construction activities.

6.1.1 Ground deformation

The method of excavation will impact the ability to control the ground and thus control deformation at the surface. By selecting an EPB-TBM for tunnel excavation, the probability of significant deformation is minimized. EPB-TBMs use the pressure of excavated materials inside the cutterhead to counteract earth pressure around the excavation. As a result, volume loss which is a key factor affecting the magnitude of ground deformation can be significantly reduced.

As described in Section 3.0, the local geology, for the most part, constitutes glacially overridden till-like soils. If excavated using well-controlled face-pressure TBM excavation, these soils are typically not susceptible to significant deformation and ground loss, and thus significant surface settlement is not anticipated. In clean, sand lenses below the groundwater table, risks increase due to a higher potential for flowing ground, but only if face pressures are not well controlled.

Due to the nature of the soils, the method of tunnel excavation, and permanent lining installation as excavation proceeds, it is expected that the majority of ground deformation will occur during tunnel excavation. Once the permanent lining is installed, there is expected to be very little if any additional ground movement. Per Mair and Taylor (1997), larger post-construction settlements are typically only anticipated if soft, compressible clays that experience consolidation-related settlements are present. No such soils are anticipated along the tunnel alignment.

Impacts related to ground deformation include settlement of Existing Facilities, leading to cracking and other damage. To evaluate the severity of impacts the magnitude of ground deformations were analyzed for the tunnel, in particular where the excavation is shallowest. The method of analysis and results are described in Section 6.3. Impacts are expected to be Negligible for the majority of the tunnel alignment due to significant ground cover, as discussed further below.

6.1.2 Other sources of impacts

Other sources of impacts due to tunnel construction include groundwater drawdown from TBM startup and tunnel inflow, and vibration and ground born noise caused by the excavation equipment.

6.1.2.1 Groundwater drawdown

Settlement due to groundwater drawdown is not considered a likely impact due to the nature of the soil. Very dense glacially over-ridden materials are not typically susceptible to consolidation, and will usually only experience small elastic deformations due to increased effective stresses. Investigations did not reveal the presence of any sensitive soils. EPB-TBM excavation will significantly reduce groundwater inflow into the tunnel excavation. Careful monitoring of excavation material volume can provide critical information during excavation to ensure that larger ground losses are avoided or mitigated before significant impacts occur.

Due to the installation of a gasketed segmental lining, only very limited and small magnitude drawdown is expected. Therefore, water levels are expected to return to close to initial conditions following construction.

6.1.2.2 Increased Stress on Underground Structures and Utilities

In the case of tunneling, the increase of stress on underground structures is predominantly related to ground deformations causing strains in buried/underground facilities. In the area of the Bored Tunnel, there are no known significant underground developments (greater than 1 underground story). An evaluation of increased strains in utilities due to ground deformation has been conducted and is presented in Section 6.3.3.

The crane equipment used to assemble and disassemble the TBM will induce significant loads into the ground/structure below. This loading has been considered in the portal shoring designs. No additional stress on underground structures or utilities is expected due to the use of equipment at the surface in the Bored Tunnel segment.

6.1.2.3 Vibration

The equipment used for tunnel excavation will be an EPB-TBM. The TBM creates minimal vibration as the cutterhead is supported by a large main bearing which supports its rotation as it excavates the ground. Excavation-related vibrations are therefore anticipated to be negligible. Vibration is not expected to be a concern for any of the support and ancillary equipment used in the tunnel due to the use of rubber-tired vehicles. On occasion, vibration or noises may be felt by sensitive individuals on the surface and such occurrences will be dealt with on an individual basis. Due to insignificant vibration levels arising from tunnelling operations, damage to overlying Existing Conditions is highly unlikely.

6.1.2.4 Modification of Drainage Patterns

Shallow water supply wells could be impacted in the short term by tunnel excavation. However, based on a review of the BC Water Well Data Base, there are no known shallow water wells in the vicinity of the bored tunnel segment.

The final tunnel lining will be a gasketed segmental lining designed to significantly limit groundwater inflow into the tunnel. Therefore we do not expect modifications of drainage patterns to occur. This is especially true due to the nature of the glacial soils which have variable but often low hydraulic conductivity. No significant changes in groundwater flow patterns are expected.

6.1.2.5 Impacts due to Re-grading/Removal of Slope Support

Based on the current scope of tunneling Work, there will not be any re-grading or modification of existing slopes except for the jet grout pad at the North Portal. The only Existing Condition within close proximity of the excavation is a tennis court, which would have limited potential impacts. The excavation will be supported by soil nails to stabilize the slope during construction.

Surface excavation work at the North and South Portals are covered in their respective CRIARs.

6.2 Ground deformation due to tunneling

6.2.1 Basis of analysis

A settlement analysis was performed for the length of the tunnel alignment to estimate the magnitude of ground deformation. The evaluation relies on the Gaussian distribution to predict ground settlement (Peck 1969). The method evaluates deformation transverse to the tunnel alignment and provides vertical and horizontal settlements, as well as quantifies strain. The transient settlement trough that is created parallel to the tunnel excavation was also evaluated.

Key assumptions for input criteria include the following:

- Volume loss of 0.5%. The volume loss factor was selected on the basis of careful EPB-TBM excavation and the controlled excavation of soils. Controlling ground loss during excavation requires diligent collection and analysis of key parameters during operation, with a well-developed chain of command to assess information and make rapid decisions.
- Trough width factor of 0.5 (k). The trough width factor is based on values in the literature that range between 0.4 and 0.6. Using a k value of 0.5 is appropriate in a setting of mixed soils, as is the case for the Evergreen Line Bored Tunnel segment.

6.2.2 Results of predicted settlements

Settlement, horizontal ground movement, ground slope and horizontal strain can be evaluated based on the ground deformation analysis. These curves vary with depth and thus will vary with stationing along the tunnel alignment. The tunnel depth (measured from springline to ground surface) varies from 18m at the north portal, to 50m at its deepest, to 12m at the South Portal. Figure 3 provides a selection of strain and settlement curves for the range of tunnel depths along the tunnel alignment (z= 12m, 18m, 40m, 50m). An example of a transient settlement trough developing above the TBM longitudinally is shown in Figure 4.

Based on these curves, ground movement contours were defined and plotted along the tunnel alignment, as shown in Figure 5 (vertical) and Figure 6 (horizontal).

6.3 Response of Existing Conditions

6.3.1 Zone of Influence

In order to narrow the scope of analysis and risk evaluation, the Zone of Influence was established to define the area in which impacts are most likely to occur. Based on the predicted settlement curves, potential impacts are only expected within 20m of the tunnel centerline. This 20m offset generally corresponds to 5mm or less of vertical settlement; refer to the example settlement profile for 35m depth in Figure 7 below. Less than 5mm of vertical settlement provides a threshold for where potential impacts occur. This threshold is a conservative value; analysis of various structures and utilities reveal that Negligible effects are expected with settlement values up to 10mm. Thus, for the majority of the tunnel alignment (cover >35m), the ZOI is defined as a 20m lateral offset from the centerline. To account for the additional risks associated with shallow tunneling, the ZOI is widened to 1.5H to 1V where the tunnel cover is less than 35m. This ZOI coincides with the required zone of monitoring specified in the PA, and modified by RFV DB-C-IFR-0429 submitted concurrently with the CRIAR/IMP/I&MP.

Despite the limits of the Zone of Influence identified above, it is recommended that Pre-Construction Condition Surveys include a small number of structures outside the ZOI as shown on Figure 1.

6.3.2 Evaluation of structures

Based on predicted ground movement, existing structures are assigned a potential damage level based on expected strain values (criteria developed by Boscardin and Cording, 1989). Building strains were evaluated based on maximum estimated bending and shear strains due to ground

deformation for a particular location, tunnel depth and building geometry. The damage categories and corresponding strain levels are shown in Table 1 a & b below.

Table 1a: Building Damage Levels

Category of damage	Normal degree of severity	Limiting tensile strain (ϵ_{lim}) (%)
0	Negligible	0 - 0.05
1	Very Slight	0.05 - 0.075
2	Slight	0.075 - 0.15
3	Moderate	0.15 - 0.3
4 to 5	Severe to Very Severe	> 0.3

(After Boscardin and Cording 1989)

Table 1b: Classification of Visible Damage

Class of damage (1)	Description of damage[a] (2)	Approximate width[b] of cracks, mm (3)
Negligible	Hairline cracks	<0.1
Very Slight	Fine cracks easily treated during normal redecoration. Perhaps isolated slight fracture in building. Cracks in exterior brickwork visible upon close inspection.	<1
Slight	Cracks easily filled. Re-decoration probably required. Several slight fractures inside building. Exterior cracks visible, some re-pointing may be required for weathertightness. Doors and windows may stick slightly.	<5
Moderate	Cracks may require cutting out and patching. Recurrent cracks can be masked by suitable linings. Tuck-pointing and possibly replacement of a small amount of exterior brickwork may be required. Doors and windows sticking. Utility service may be interrupted. Weathertightness often impaired.	5 to 15 or several cracks > 3 mm
Severe	Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and door frames distorted, floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams. Utility service disrupted.	15 to 25 also depends on number of cracks
Very Severe	Major repair required involving partial or complete re-construction. Beams lose bearing, walls lean badly and require shoring. Windows broken by distortion. Danger of instability.	usually >25 depends on number of cracks

[a]Location of damage in the building or structure must be considered when classifying degree of damage.

[b]Crack width is only one aspect of damage and should not be used on alone as a direct measure of it.

Note: Modified from Burland et al. (1977)

(Boscardin and Cording 1989)

A preliminary check for a common building geometry was conducted and it was revealed that for depth, z, greater than 25m, effects are expected to be negligible. Based on this finding, the critical buildings were identified, which are those closest to the portals where the tunnel is most shallow. The evaluation for these particular buildings is based on their specific geometry and location relative to the tunnel. Of all the buildings in the Zone of Influence, only 8 are expected to experience greater than negligible aesthetic damage. These are summarized in Table 2 below.

Table 2: Summary of Existing Structures Exceeding Negligible Effects

Structure	Damage Category
1860 Charles St	Very Slight
1870 Charles St	Very Slight
1814-1816 View St	Very Slight
661 Clarke Rd	Very Slight
707 Clarke Rd	Very Slight
663/665 Harrison Ave.	Very Slight
647 Kemsley	Slight
661 Clarke (rear lane building).	Slight

The remaining 41 buildings evaluated for effects are expected to experience Negligible effects. Figure 1 summarizes these results showing expected damage level for each building in the Zone of Influence. The relative risk of these structures and proposed mitigation measures are covered further in Section 6.4 & Section 7.

6.3.3 Evaluation of buried utilities

6.3.3.1 Methodology

The buried utilities identified in Section 4.3 as the most susceptible to tunnel construction were evaluated for strain due to ground deformation. Each utility is evaluated as per O'Rourke & Trautmann (1982) for three modes of failure: joint pull-apart, joint rotation and tensile strain. The utilities assessed include cast-iron, concrete and asbestos cement pipes. Other types of utilities are typically less sensitive to ground deformations than these types. The maximum allowable values for the modes of failure vary with pipe type. A Critical Impact Ratio is identified for each utility, as discussed in more detail below.

For simplicity as well as a degree of conservatism, these evaluations consider utilities as running perpendicular to the tunnel alignment (the worst-case), even though some cross the alignment obliquely. Based on currently available information, the vertical alignment of utilities is usually unknown and therefore depths of utilities are assumed based upon typical installation depths.

6.3.3.2 Criteria selection

The Critical Impact Ratio (CIR) is defined as the assumed allowable level divided by the calculated level for each mode of failure. The pull-apart evaluation conservatively compares maximum lateral movement above the tunnel, $S(x)_{max}$, to the allowable pull-apart criteria. The joint rotation evaluation compares theta, a relative rotation angle across the joint based on maximum vertical displacement, to the allowable joint rotation criteria. The tensile strain evaluation calculates maximum bending strain and maximum lateral strain in the pipe. The sum of the strains is compared against the allowable tensile strain. The allowable values for each mode of failure are provided in Table 3. The allowable values employed in the analysis represent conservative values supported by past tunneling in proximity to underground utilities. However, consultation with the appropriate utility owners will be required to confirm the suitability of these values.

Table 3: Utility Allowable Strain Criteria

Mode of failure	Allowable Value	Type of pipe
Joint Pull-Apart	10mm	Concrete and asbestos cement
	5mm	Cast iron
Joint Rotation	0.25 deg	All
Tensile failure	200 microstrain	All

The criteria used for calculating the CIR are based on values recommended in the literature, past experience and engineering judgment. The CIR is explained in more detail in Table 4. It is important to note that due to simplifications made in this evaluation and the conservatism in selecting allowable values, the numerical value of the CIR should not be used in the same fashion as a factor of safety. Rather, the CIR should be considered as a measure to determine susceptibility of the utilities to tunneling impacts.

Table 4: Interpretation of CIR

Critical Impact Ratio (CIR)	Assessment of potential effects
Ratio < 1	Utility likely to be impacted, mitigation/protection measures should be considered
1< Ratio < 1.5 (or 2 for Cast Iron)	Utility may be susceptible to impacts, additional monitoring recommended, and contingency mitigation plans should be developed
Ratio >1.5 (or 2 for Cast Iron)	Utility should not be significantly impacted

6.3.4 Anticipated impacts and recommended response

Based on the methodology described in Section 6.3.3, the seven critical utilities identified in Section 4.3 were evaluated for susceptibility to impacts. The results are summarized below in Table 5. Based on these findings, engineering judgment and practicality, a response action is recommended for each. The proposed mitigation/protection measures are addressed in Section 7. Utilities crossing the Bored Tunnel alignment where there is greater ground cover (i.e. farther from the portals) were found to have CIR > 2. With CIR>2, impacts are not expected and mitigation measures or specific utility monitoring is not necessary. Anticipated impacts and proposed mitigation strategies will be presented to utilities owners for their input and agreement.

Table 5: Expected Utility Impacts

Station	Description	Critical Impact Ratio	Response
North Portal			
418+705	150mm asbestos cement sanitary sewer	>1.5	Impacts not expected. Monitor to confirm deformation within expected range.
418+675	150mm cast iron water main	1< Ratio < 2	Utility may be susceptible to impacts. Monitoring recommended to assess utility deformation. Contingency mitigation plan developed.
418+640	150 mm unknown material Sanitary Sewer	>1.5	Impacts not expected. Monitor to confirm deformation within expected range.
418+640	200mm concrete storm sewer	>1.5	Impacts not expected. Monitor to confirm deformation within expected range.
South Portal			
416+795	150mm water main, cast iron	Ratio < 1	Utility likely to be impacted. Mitigation/protection measures should be considered.
416+795	200mm concrete sanitary sewer	Ratio < 1	Utility likely to be impacted. Mitigation/protection measures should be considered.
416+808	380mm concrete storm sewer	Ratio < 1	Utility likely to be impacted. Mitigation/protection measures should be considered.

6.4 Construction Risk Evaluation

Table 6 identifies the key Bored Tunnel construction impacts and their associated risks. For the purpose of this evaluation:

RISK = [Probability] X [Consequence]

where,

Probability is the likelihood that the potential construction impact could occur, and

Consequence is the resulting effect or to impact to the Existing Condition.

Based upon a qualitative assessment of probability and consequence, a level of risk is assigned for each potential impact. The levels of risk are defined as follows:

High: A high level risk exists, and mitigation measures will likely be required. These will be addressed in detail in the Impact Mitigation Plan and likely require mitigation measures.

Medium: A medium level risk exists and mitigation measures will likely not be required but detailed monitoring will be necessary as a precautionary measure. Medium level risks must be further considered in the Impact Mitigation Plan.

Low: The potential risk is low if normal construction practices are adopted. Instrumentation and mitigation are not required, but either may be undertaken by the Primary Constructor as a due diligence measure.

Due to the large number of Existing Conditions, they have been placed into groups with Existing Conditions with similar risk assessments.

To summarize, several Low risk and "Low to Medium" risk items were identified. However, only a small number of Medium risk items and no High risk items were identified.

Table 6: Summary of Construction Risk- Bored Tunnel Segment

(See End of Report)

7.0 IMPACT MITIGATION PLAN (IMP)

7.1 General

The Impact Mitigation Plan describes the measures that will be employed to minimize or avoid impacts to Existing Conditions in the vicinity of the Bored Tunnel Works. Impact mitigation strategies have been identified for all Existing Conditions that were deemed vulnerable to damage in the Construction Risk Impact Assessment (Section 6). These strategies include temporary and permanent measures that will be carried out to prevent, minimize or resolve damage to the Existing Condition. The Bored Tunnel Impact Mitigation Plan is submitted in accordance with Sched. 4, Part 1, Article 4.3.1 and also meets the requirements of Article 4.2.2 (b) (v) & (vi). Instrumentation and monitoring are covered in Section 8 as part of the Instrumentation and Monitoring (I&M) Plan for potentially vulnerable Existing Conditions identified in Section 6.

7.2 Proposed Methods

Based on the risk assessment in the CRIAR, it was found that there are no high risk items. Thus the mitigation strategies presented rely primarily on an observational approach with appropriate response, rather than costly and potentially unnecessary preventative measures. This approach upholds the protection of Existing Conditions while remaining practical. The observational approach will be sustained by various forms of monitoring as well as TBM performance tracking. Action Levels will be used to evaluate these indicators.

In addition to supporting an observational approach with a monitoring plan, several mitigation measures were considered for implementation. The measures and brief discussion of why they were or were not selected are listed below:

- Restoration: One of the selected mitigation methods if deemed necessary after construction and if monitoring and post-construction surveys indicate unacceptable impacts. Restoration is discussed in more detail in this section.

- Ground improvement: One of the selected methods for reducing potential impacts at the tunnel portals. Improving the ground enhances the TBM performance and reduces ground movement.

- Relocation: Not selected, as most utilities with anticipated impacts cross above the tunnels, and thus would be difficult to relocate without still being with the Zone of Influence of the tunnels.

- Modification: Based upon the Low to Medium risks for Existing Conditions, it was deemed more economical to perform restoration if damage occurs rather than proactive, and potentially expensive, modification. Also, similar to Relocation, modified Existing Conditions would still be within the Zone of Influence, and thus still susceptible to impacts.

- Reconstruction: Impacts to Existing Conditions are not anticipated to be severe, and thus reconstruction is not anticipated to be required.

- Decommissioning or abandoning: For buildings, anticipated impacts are not severe enough to warrant abandonment of facilities. For utilities, it was assumed that decommissioning and abandonment were not practical options, and based upon Low to Medium Risk, were not warranted.

A combination of ground improvement and restoration, using an observational approach, was selected amongst the available mitigation methods, as discussed in more detail in this section. Monitoring will be used to check performance, as discussed below and in more detail in Section 8. Detailed mitigation measures, addressed by specific potential impact, are describe in Section 7.3.

In order to limit mitigation effort, various types of monitoring will be used during construction. Monitoring enables the contractor to specifically identify sources or areas of concern, to respond more quickly to these concerns, as well as to "learn-on-the-job" and reduce impacts through construction techniques which cater to specific project conditions. Monitoring is to include:

- Monitoring of utilities prior to, during and after construction to assess and manage construction impacts. Establish thresholds and appropriate responses to Action Levels, working in collaboration with the owners of the utilities.

- Monitoring surface movement and movement of existing structures prior to, during and after construction to assess and manage construction impacts. Establish thresholds and appropriate responses to Action Levels.

- Monitoring deformation at depth using extensometers to detect potential sources of significant deformation before it propagates to surface. Extensometers can be placed ahead of crossing beneath critical buildings and utilities to provide an early indication of how well ground deformations are being controlled by TBM excavation, and provide time for adjustments if needed.

- Continuously monitoring volume of excavated material during tunnel excavation to identify zones of over-excavation and remediate condition quickly.
- Monitoring face pressures during excavation and between excavation cycles, to verify that required face pressures are being maintained at all times. Monitoring other TBM related measures, such as line and grade, TBM thrust and torque, and other parameters, to gauge control of TBM excavation.
- Verification of volume of grout to fill the annular space and required pressures, and confirmation of proper segment installation to ensure water-tightness.

7.3 Risk Specific Impact Mitigation

Building on the risks described above in the CRIAR, this section identifies the specific mitigation measure for each risk identified as a Medium risk. Table 6 includes some discussion of mitigation measures, which is further discussed in this section. No High risks were identified in the CRIAR. Any additional mitigation strategies deemed necessary during construction are viewed as beyond the latitude of the IMP. These added measures will be presented to the Province via a supplemental document.

7.3.1 Geology Risks

Three specific hazards were identified in Table 6 related to geology that pose Medium overall risks. Geological risks are largely mitigated by design of the TBM for these occurrences. Specific measures for encountering boulders include inclusion of disc cutters on the cutterhead, heavily reinforced rippers, and grizzly bars on openings to limit the size of boulder fragments entering the screw conveyor. For encountering unexpected soil types and potential for flooding the tunnel, the TBM has been designed as an earth pressure balanced machine (EPBM) for mixed ground conditions with a closed bulkhead, and frequent sampling and analysis of soils will be performed to allow quick changes in soil conditioning or support pressures, as identified in daily meetings during TBM excavation.

7.3.2 Design Risks

Six specific hazards were identified in Table 6 related to design that pose Medium overall risks. Design risks are largely mitigated by logistics and close communication. For design and construction of the TBM, close coordination with the supplier of the TBM has been on-going since early on in the design process, and issues that come up are quickly resolved. For traffic impacts at Barnett Highway due to jet grouting and TBM assembly, dedicated personnel has been assigned to

avoid interruptions, and logistics of the site have been optimized. For storage and assembly of the TBM, the project area and assembly process has been optimized, including the use of special systems to add in the efficiency. For segmental lining handling, all equipment involved in the handling of segments will be carefully inspected and maintained, and systems will be in place to avoid having personnel under loads during lifting. For operations in restricted work areas, due to lack of sufficient work areas, construction activities can be optimized, and if necessary, additional work areas can be secured.

7.3.3 Operational Risks

Six specific hazards were identified in Table 6 related to operations that pose Medium overall risks. Operational risks are largely mitigated by careful monitoring of production, and selection of qualified personnel. Specific measures for lack of supervision during excavation or incorrect TBM operator instructions will be the continuous presence of a shift engineer throughout excavation, daily tool box and weekly summary meetings to discuss status, carefully written procedures for excavation (Tunnel Excavation Plan), and clear communications protocols and chain of command. For TBM labour issues, specific mitigation measures are careful selection of personnel, making sure key personnel are experienced and qualified, and providing appropriate production bonuses and incentives. For spoil handling and potential for getting muck-bound, possible mitigation measures include increasing on-site muck storage capacity, increasing truck flow by optimizing logistics, and identifying alternatives for muck disposal, including short-term storage at alternative sites. For failure of the TBM guidance of data monitoring system, mitigation measures include having a shift engineer present throughout construction, carefully monitoring the ground surface for movements, clear communications protocol, and prompt availability of spare parts to perform repairs. For TBM extraction and disassembly, mitigation measures include optimizing the disassembly process, and designing the TBM for ease of disassembly.

7.3.4 TBM Excavation Risks

Three specific hazards were identified in Table 6 specific to TBM excavation that pose Medium overall risks. TBM excavation risks are largely mitigated by the TBM monitoring system, in conjunction with a clear chain-of-command to react to conditions as they are encountered. This chain-of-command will be fully developed in construction submittals to TBM excavation, but is anticipated to start with in-tunnel personnel (TBM operators, shift supervisors, and shift engineers), with communications to on-site personnel (Project Manager and in-office staff) and the Engineer of Record as necessary. Specific measures for risks at the North Portal during TBM launch can be mitigated by careful design and coordination. For over-excavation risks, mitigating measures are continuous monitoring of TBM excavation parameters, daily tool box meetings and detailed

instructions for operators, and continuous control of TBM face pressures, and excavated weights, including comparison to anticipated weights. For poor segmental ring build quality, mitigating measures include careful control of TBM excavation and segment installation, daily tool box meetings and detailed instructions for operators, and tail void grouting per requirements.

7.4 Site Specific Impact Mitigation

Building on the risk specific mitigation measures described above, this section identifies the specific mitigation measure for each potentially impacted Existing Condition identified by analysis and described in the CRIAR. Any additional mitigation strategies deemed necessary during construction are viewed as beyond the latitude of the IMP. These added measures will be presented to the Province via a supplemental document.

7.4.1 Existing Buildings

Key structures have been identified in the CRIAR. The highest risk structures reside close to the tunnel portals. The mitigation measures presented below are applicable to all structures vulnerable to impacts (i.e. within the ZOI) and will be implemented throughout the tunnel construction period.

Table 7: Impacts and Proposed Monitoring and Mitigation Measures for Existing Buildings

Potential Impact	Proposed Monitoring and Mitigation Measures
Ground deformation leads to the settlement of building. May lead to cracking of plastered surfaces of walls and enlargement of existing cracks, aesthetic in nature.	Monitor deformation of adjacent structures during construction with structure settlement points, and monitor subsurface deformations ahead of the TBM advance using extensometers. Establish and adhere to Action Levels and corresponding responses. Action Levels are to be defined such that minor damage is detected and work is adjusted or potentially halted prior to more significant damage occurring. Monitoring of excavation indicators, such as face pressure, excavation volumes, and other TBM related parameters, to monitor effectiveness of ground control. Perform visual inspections on a regular basis in proximity of current tunneling activities. Proper filling of the tail void with grout following tunnel excavation with required grout pressures and volumes.

7.4.2 Utilities

The impacts and corresponding mitigation measures have been identified for existing utilities within the Tunnel Zone of Influence and are presented below. Due to the special needs of some utility owners, it may be determined through consultation that additional mitigation measures are necessary. These needs will be addressed and met outside the Impact Mitigation Plan.

Table 8: Impacts and Proposed Monitoring and Mitigation Measures for Existing Utilities

Potential Impact	Proposed Monitoring and Mitigation Measures
Ground deformation leads to the settlement of utilities overlying or in proximity to tunneling. Settlement causes damage in the form of cracks, leaks at joints, and similar impacts.	Monitor surface settlement points in proximity to key utilities during construction, and monitor subsurface deformations ahead of the TBM advance using extensometers. Monitor most critical utilities directly with utility settlement points. Establish and adhere to Action Levels and corresponding responses. Action Levels are defined such that minor damage is detected and work is adjusted or potentially halted prior to more significant damage occurring. Monitoring of excavation indicators, such as face pressure, excavation volumes, and other TBM related parameters, to monitor effectiveness of ground control. Proper filling of the tail void with grout following tunnel excavation with required grout pressures and volumes.

7.4.3 Roads & sidewalks

The following impacts and corresponding mitigation measures have been identified for existing roads and sidewalks within the Tunnel Zone of Influence.

Table 9: Impacts and Proposed Monitoring and Mitigation Measures for Existing Roads and Sidewalks

Potential Impact	Proposed Monitoring and Mitigation Measures
Ground deformation leads to the settlement of road and sidewalks. May lead to cracking, bulging and deformations of asphalt/concrete.	Monitor surface settlement points. Perform visual inspections on a regular basis in proximity of current tunneling activities. Establish and adhere to Action Levels and corresponding responses. Action Levels are defined such that minor damage is detected and work is adjusted or potentially halted prior to more significant damage occurring. Monitoring of excavation indicators, such as face pressure, excavation volumes, and other TBM related parameters, to monitor effectiveness of ground control. Proper filling of the tail void with grout following tunnel excavation with required grout pressures and volumes.

7.5 Contingency Measures

In addition to the mitigation measures described above, the contractor may select to implement contingency measures. The use of such contingency measures may be appropriate when faced with poor ground performance or if new information reveals Existing Conditions to be more vulnerable the previously expected. Contingency measures may include continuous mining (24/7) to limit downtime between mining cycles; bentonite injection around the TBM; and void filling capabilities (from both the tunnel and ground surface). Careful monitoring will inform the contractor when

contingency measures may be required. Contingency strategies will be developed and implemented on an as-needed basis.

7.6 Unavoidable Damage Caused

7.6.1 Nature and Extent of Unavoidable Damage

Based on the analysis conducted, there may be some unavoidable damage due to the Work despite compliance with Good Industry Practice as discussed in this report. The impact is expected to be minor and may include aesthetic damage to buildings and minor cracking or leakage through joint openings of utilities. Minor cracking of sidewalks and roadways is also possible. The extent of this damage is expected to be confined to a limited area around the portals where the tunnel is shallowest. In the case of buildings, damage could include cracks forming in plastered surfaces of walls and enlargement of existing cracks. No impairment of the stability of buildings or their components is expected.

7.6.2 Proposed Steps and Measures to Repair the Damage

Should damage occur to Existing Conditions, restoration measures will be taken to repair damage to a state equivalent to that which existed prior to the damage or impact in accordance with PA Sched 4, Part 1, Article 4.3.2. The Province will be notified of all such damage and proposed remediation. Any permits or consents required to complete the design and construction of the works will be obtained from the relevant authorities. Approval will also be obtained from the owner of the Existing Condition.

7.7 Stakeholder Agreement

As required by Schedule 4, Part 1, Article 4.3.1, the Contractor will use “all reasonable efforts to obtain the written approval of the owner of applicable Existing Conditions” to the contents of the Impact Mitigation Plan. Stakeholder approval of planned mitigation and monitoring will be obtained by a consultation process, currently in progress.

8.0 INSTRUMENTATION AND MONITORING (I & M) PLAN

The requirements of Schedule 4, Part 2, Article 6.10.7 as well as Schedule 4, Part 1, Article 4.2.2 (b) (vii) are fully addressed in the Instrumentation & Monitoring (I & M) Plan presented in this section. The I & M Plan addresses the instrument installation, baseline readings, frequency of readings, Action Levels, data collection methodology and response plans.

8.1 General

The planned instrumentation and monitoring satisfies the scope outlined in Schedule 4, Part 2, Article 6.10.1. The monitoring of the geotechnical and hydrogeological aspects of Bored Tunnel Work will meet the following needs:

(i) "Verify the Primary Contractor's compliance with the requirements of this Agreement, including this Schedule;

(ii) Verify the parameters, assumptions and analyses developed and used by the Primary Contractor in:

A. The Design and Construction of the Work; and

B. The ground improvements as described by the Primary Contractor in the Construction Risk and Impact Assessment Report prepared in accordance with Article 4 [Existing Conditions], Part 1 of Schedule 4, and Ground Improvement Plan;

(iii) Permit the Primary Contractor to control the Construction of the work;

(iv) Detect evidence of any impending failures of any aspects of the work;

(v) Measure the impact, if any, of each of the Work and the Evergreen Line, once operational, on existing Conditions within the Zone of Influence;

(vi) Provide evidence to assist with the handling of Construction-related damage claims made by third parties" (PA Sch4, P2, 6.10.1).

The proposed instrumentation will serve to provide early warning of ground movement and measure the impact, if any, on Existing conditions. The instrumentation for the Bored Tunnel segment will be temporary installations and will be removed/decommissioned following project completion. The proposed instrumentation is to include:

- Ground settlement monitoring with arrays of surface settlement points as well as structure settlement points;
- Ground deformation above the tunnel crown with multi-point borehole extensometers;
- Utility settlement points to monitor movement of buried utilities;
- Piezometers in existing wells in proximity to the tunnel; and
- In tunnel monitoring of TBM and lining performance.

Based on the findings of the CRIAR, vibration due to tunneling work is not anticipated to be a likely source of impacts. Vibration monitoring will only be conducted on an as-needed basis on select structures in response to public concern or requests. If required, monitoring of structures will be carried out using a triaxial geophone and a recording device. The devices will be placed inside the structure where applicable and accessible. If access to the property is not available, the devices will be placed adjacent to the building, closest to the tunnel alignment.

Figure 8 shows instrumentation layout for geotechnical instrumentation for the Bored Tunnel segment (Drawing Nos. 511328-12220-S2JA-4GDD-0001, 1001 to 1006, and 4001 and 4002).

8.2 Geotechnical instrumentation-Types and characteristics

This section introduces the various types of instruments, describes their characteristics and how they will be used in the Bored Tunnel instrumentation and monitoring program. The planned locations for each instrument type are shown in Figure 8. The exact location of each instrument is to be determined in the field based on accessibility, ease of installation, and avoidance of conflicts. All the necessary permits and permissions will be obtained prior to the installation of instruments, targets, boreholes or other instrumentation. As required by Sched 4, Part 2, Art 6.10.6 (a) (v) the actual instrument location will be submitted to the Province's Representative before monitoring begins and no later than 10 Business Days after the completion of installation of the applicable instrument.

As stated in Sched. 4, Part 2, Article 6.10.8 of the PA, an Instrumentation & Monitoring Report will be generated which will include: instruments installed and specific location, initial monitoring schedule for baseline readings, instrument specifications and manuals, and calibration documentation.

8.2.1 Settlement points- Surface, structures, and utilities

Settlement points will be installed along road surfaces and sidewalks to evaluate settlement due to tunneling. The program makes use of cross-streets to locate an array of surface settlement points approximately perpendicular to the tunnel alignment to provide a settlement profile. This array provides a more complete picture of ground deformation and enables the instrumentation specialist to compare the magnitude and shape of the settlement curve to expected values. These points will take the form of a target or steel rebar installed and grouted into the ground.

Settlement points will be placed on Existing Conditions (structures and utilities) to monitor the ground movement as well as assess any impacts to the structures. On buildings, these will be placed in the form of pins or targets, as shown on the details in Figure 8. Utility settlement points will consist of a vacuum-excavated hole down to the utility, and a fiberglass bar affixed to the utility that can be read from the ground surface, as shown on the details in Figure 8. Alternative utility settlement points may also be considered, such as shallow single point extensometers directly adjacent to utilities to be monitored. Utility monitoring will be conducted with agreement of utility owners.

A list of structures receiving settlement points is provided in Appendix 1. Most buildings will receive 4 points to characterize movement, however, for some larger structures additional points are required. Buildings requiring 8 points are shown on the instrumentation layout (Figure 8).

Settlement points are typically monitored manually by survey teams. Use of automated total stations is not anticipated to be used.

8.2.2 Multipoint borehole extensometers (MPBXs)

Multipoint borehole extensometers will be installed in boreholes and are used to measure the ground movement at different distances above the tunnel crown. These will be installed at several locations along the tunnel alignments, including critical areas with reduced ground cover near the portals. The extensometer measurements help determine the amount of soil loss at the tunnel face and distribution of ground movements with depth. These instruments can provide early detection of ground movements ahead of the tunneling face and at depth, allowing time to implement mitigation strategies prior to movements reaching the ground surface. MPBXs will be connected to data loggers for continuous data monitoring.

8.2.3 Groundwater monitoring

Vibrating Wire (VW) piezometers installed in existing wells will be used to measure groundwater levels and hydrostatic pressures potentially impacted by tunneling. No new wells are planned for installation. Several of the existing wells have multi-level piezometers allowing for monitoring in different aquifers. The VW piezometers will be connected to data loggers for continuous data monitoring.

8.2.4 Visual monitoring

Visual monitoring will be completed during normal site inspection by the Engineer of Record. Visual monitoring is to include visual inspection of asphalt, curbs, sidewalks and buildings. Any changes to the existing conditions will be documented, monitored and reported to the SSJV for assessment by the pre-construction assessors.

8.3 Instrument calibration

Calibration of the instrumentation needs to follow guidelines outlined in Schedule 4, Part 1, Article 6.10.10. Detailed instrumentation specification and instrumentation calibration data will be included in the Instrumentation and Monitoring Report.

8.4 Instrument accuracy

Accuracy of instrumentation relative to Action Levels discussed in Section 8.9 is critical to the success of a geotechnical instrumentation system. Inaccuracy of readings can lead to both not detecting movements in excess of Action Levels, and false alarms where actual readings are less than the Action Levels. Accuracy varies for each type of instrumentation used, with better accuracy achievable for vibrating wire instruments (extensometers and piezometers). Table 10 provides a general overview of the accuracy of each type of instrument. More detail on accuracy of each instrument will be submitted as part of the instrumentation product data construction submittal.

Table 10: Instrumentation Accuracy

Instrument Type	Typical Specified Accuracy	Measurement Accuracy (in mm)
Optical (Manual) Survey	N/A	+/- 2
MPBX	+/- 0.1% F.S. (vibrating wire)	+/- 0.15 for 150-mm range
	+/- 0.25% F.S. (potentiometer)	+/- 0.375 for 150-mm range
Piezometer (Vibrating Wire-type)	+/- 0.1% F.S.	+/- ~100 for 1 MPa range

8.5 Instrument installation

Instrumentation will be installed following industry accepted installation procedures and accepted practices and manufacturer's recommendations. The installation of instrumentation will be coordinated with construction work in order to provide sufficient time to collect baseline readings. Baseline readings will be addressed further in Section 8.8.1.

8.6 Replacing instrumentation

Schedule 4, Part 1, Article 6.10.8 (b) specifies that if instrumentation is moved or requires repair or replacement the Instrumentation Specialist (or their designee) will contact the Province within 24 hours of damage, and within 5 business days of any decision to repair, replace or move the instrumentation and prior to actually replacing, repairing or moving. SSJV will contact the Province in writing and explain the following in the event of damage and required replacement, repair or movement:

- The type and location of the instrument that needs to be replaced, repaired or moved;

- The reason why the instrument needs to be replaced, repaired or moved;
- The intended timeline;
- When an instrument is replaced, the contractor will provide the type, as-built location and calibration sheets of the new instrument and the date in which it was replaced and became operational;
- When an instrument is repaired, SSJV will provide the date in which the instrument was back in operational and the calibration sheets; and
- When an instrument is moved, SSJV will provide as-built location and calibration sheets and the date in which the instrument moved and became operational.

8.7 In tunnel monitoring

In addition to geotechnical instrumentation at the surface, in tunneling monitoring will assist in early detection of ground deformation that has the potential to propagate to the ground surface.

8.7.1 TBM performance

The contractor will be required to monitor TBM performance to provide the earliest possible warning of an over-excavation event. TBM monitoring will occur continuously during tunnel excavation. TBM performance monitoring should include, but is not limited to, the following:

- Face pressure and its distribution in the excavation chamber as indicated by total pressure (EPB) sensors located in the TBM main bulkhead.
- Weight of material excavated during and after each excavation advance taken from the conveyor scales.
- Volume and pressure of tail void grout injection as measured in the grout reservoir and at the grout injection point, respectively.

As discussed above, a chain-of-command will be set up in construction submittals to review TBM performance monitoring data, and to act accordingly.

8.7.2 Monitoring within the Constructed Works

Convergence points will be installed on the precast tunnel lining to measure the lining deflections or distortions. Optical targets will be installed in an array at tunnel cross sections along the alignment for convergence measurement purposes. Convergence point arrays will be installed approximately every 25 rings (or 37.5m).

8.8 Geotechnical Instrumentation- Data collection and data management

Monitoring of the geotechnical instruments described in Section 8.2 will be completed in order to provide early warning for increased ground movement, and to measure the impact, if any, on Existing Conditions. The procedures and requirements for monitoring are documented in the following sections.

8.8.1 Baseline Readings

As stated in Sched. 4, Part 2, Article 6.10.8 of PA, the procedure for baseline readings and an initial schedule of monitoring to collect the baseline readings will be described to the Province's representative in the Instrumentation & Monitoring Report.

Baseline values will be established for the piezometers, extensometers and settlement monitoring points (surface, structure and utility points) following installation. Baseline readings will be taken no later than one week after the installation of the instrumentation. A minimum of three baseline readings will be collected and will be completed at least one week prior to the start of construction. The baseline for visual monitoring will be findings of the pre-construction surveys of structures, utilities, and roadways.

8.8.2 Monitoring Frequency

The monitoring frequency for geotechnical instrumentation varies during the tunnel construction period based on the proximity of the instrument to the tunnel face/working area. TBM performance parameters are monitored at the tunnel face and thus will be continually monitored throughout TBM operation.

Schedule A provides the monitoring schedule for settlement points, in close proximity to the portals. Schedule B provides the monitoring schedule for settlement points above the remainder of the tunnel. Schedule C provides the monitoring schedule for extensometers and piezometers. Schedule D provides the monitoring schedule for in tunnel convergence monitoring. Schedule E provides the monitoring schedule for visual inspection. Measurement frequency is subject to change should Action Levels thresholds be approached or breached. The measurement frequency

may be increased as judged necessary by the SSJV. For clarity, the following reading definitions are provided:

Daily readings: readings performed each day Monday through Friday regardless of construction activity. Daily readings shall also be taken each day on which excavation occurs on Saturday and Sunday.

Weekly readings: Readings performed on average every 7 days, with at least 6 and no more than 8 days between successive readings.

Note: Any specified distance between instrument and TBM is defined as the horizontal distance between the TBM face and the instrument.

Schedule A- For settlement points within 50m of portals

1. Obtain baseline readings as described in Section 8.8.1, prior to commencement of tunneling-related activities.
2. Read instrument daily when ground improvement and/or dewatering occurs within 50m of the instrument. Continue daily readings until SSJV tunnel preparation work is complete.
3. Read instrument weekly after tunnel preparation work is complete. After 1 month of weekly readings the reading frequency may be reduced to monthly as judged by the SSJV.
4. Monthly readings shall be performed thereafter until tunneling operations begin nearby (either launch or retrieval), after which the monitoring schedules in Step 5 or 6 below apply.
5. For TBM launch (North Portal instruments):
    a. Read instrument daily for 3 days prior to TBM launch.
    b. Read instrument once per shift when excavation commences and continue readings at once per shift until TBM is greater than 25m from instrument.
    c. Continue with daily readings until TBM is greater than 100m beyond the instrument.
    d. Obtain weekly readings until TBM is greater than 300m beyond instrument.
    e. Monthly readings shall be performed thereafter until Total Completion Date or until three subsequent readings indicate less than 3-mm variation in movements.
6. For TBM retrieval (South Portal instruments):
    a. Obtain weekly readings when the TBM is less than 300m from instrument.
    b. Read instrument daily when TBM is less than 100m from instrument.

c. Read instrument once per shift when TBM is less than 25m from instrument.
d. Continue readings once per shift until the TBM tail shield is fully exposed.
e. Continue with weekly readings for 1 month after TBM tail shield is fully exposed.
f. Monthly readings shall be performed thereafter until Total Completion Date or until three subsequent readings indicate less than 3-mm variation in movements.

Schedule B- For settlement points above tunnel

1. Obtain baseline readings as described in Section 8.8.1.
2. Obtain weekly readings where the tunnel face is within 300m of the applicable instrument.
3. Begin daily readings when the TBM is within 100m of the instrument.
4. Obtain 1 reading per shift where the tunnel face is within 25m of the instrument.
5. Return to daily readings once the tunnel face is greater than 25m from instrument.
6. Return to weekly readings once the tunnel is greater than 100m instrument.
7. Return to monthly readings once the tunnel is greater than 300m from instrument.
8. Continue with monthly readings thereafter until Total Completion Date or until three subsequent readings indicate less than 3-mm variation in movements.

Schedule C- For extensometers & piezometers

1. Obtain baseline readings as described in Section 8.8.1.
2. Read instrument hourly starting at least 1 month prior to the TBM reaching the instrument. Continue with hourly readings for at least 1 month after the TBM has passed the instrument.
3. Read instrument daily for 1 month after hourly readings are complete.
4. Read instrument weekly thereafter until Total Completion Date or until three subsequent readings indicate less than 2-mm variation in movements for extensometers, and 0.5-m variation for piezometers.
5. Read surface monitoring point associated with extensometer in accordance with Schedule B.

Schedule D- For in tunnel convergence points

1. Obtain initial readings following tunnel lining installation and Tail Void Grouting and installation of survey points, within 5 shifts of liner installation.
2. Obtain weekly measurements for the first two months following initial reading.
3. Obtain monthly measurements until Total Completion Date or until three subsequent readings indicate less than 2-mm variation in movements.

Schedule E- Visual inspection of structures, roadways etc.

1. Obtain baselines from pre-construction surveys.

2. Perform visual inspection weekly when tunnel work (tunnel face or portal preparation by SSJV) is within 100m of applicable Existing Condition.
3. Begin visual inspections daily when tunnel work is within 50m of applicable Existing Condition.
4. Return to weekly visual inspections once the tunnel work is greater than 50m from applicable Existing Condition.
5. Perform monthly visual inspections once the tunnel work is greater than 100m from applicable Existing Condition.
6. Continue with monthly visual inspections thereafter until Total Completion Date or until directed to stop by the resident engineer.

8.8.3 Data Management and Availability

Piezometer and extensometer data will be collected remotely and uploaded directly to the Vista Data Vision (VDV) data management site. Settlement points and convergence points will be surveyed and data also uploaded to VDV online site. As required by Sched 4, Part 2, Article 6.10.6 of the PA, all data collected will made available online within 48 hours of being acquired. The exception to the above is data collected from instrumentation installed in the Bored Tunnel which must be made available to the Province's Representative within four hours of the time of measurement [Sch 4, Part 2, 6.10.7 (b) (ii)]. Access to the data will be provided to the designer, Engineer of Record, SSJV and the Province's Representative.

8.9 Action Levels

Each instrument, or group of instruments, is assigned two Action Levels based upon allowable movement/instrument response. Table 11 provides Action Levels for the planned geotechnical instrumentation. The Action Levels help to identify areas or sources of concern and provide the contractor the opportunity to remediate the situation before significant damage occurs. These Action Level values are based on allowable movements for buildings and utilities, published codes, industry local practice and previous experience. Only limits on vertical deformations (settlement), rather than vertical and horizontal) are given for the following reasons: for tunneling-induced deformations, both vertical and horizontal deformations typically occur concurrently (horizontal deformations are not usually seen without associated vertical deformations); and accuracy of monitoring horizontal deformations makes it difficult to obtain consistent measurements based upon recent experience on similar projects.

For the Action Levels, the following definitions are used:

- Amber: Intermediate level at which additional measures are implemented, per Table 12.
- Red: Maximum level at which impacts are anticipated, and at which further additional measures are implemented, per Table 12.

Table 11: Action Levels

	Action Level	
Instrument	Amber	**Red**
Surface or structure settlement points (mm)	10-20	>20
Utility settlement points, Cast Iron (mm)	5-15	>15
Utility settlement points, Utilities other than Cast Iron (mm)	10-20	>20
Piezometer water levels (m/day)	2-5	>5
MPBX – anchor closest to tunnel (mm)	25-50	>50
MPBX – second anchor closest to tunnel (mm)	20-40	>40
MPBX – third anchor closest to tunnel (mm)	15-30	>30
MPBX – other anchors in proximity to ground surface (mm)	Same as Surface Settlement Points	
Convergence points (mm)	10-20	>20

8.10 Remedial Responses

Remedial responses appropriate for each type of monitoring and Action Level are presented in Table 12 below. As a response to all instances of Amber and Red Action Levels, the cause of threshold exceedance will be investigated and current excavation methods and mitigation strategies will be re-evaluated.

Table 12- Monitoring Action Levels and Responses

Instrumentation	Amber Action Level		Red Action Level	
	Observation	Remedial Response	Observation	Remedial Response
Visual inspection- Existing Structure	New cracks appear in structure walls/roof/ foundation. Existing cracks increasing in width.	• Notify SSJV Site Superintendent and Instrumentation Specialist. • Double frequency of visual inspections for structures in question and those in close proximity. Compare to any other available data for instrumentation in vicinity of observations. • Identify source of movements, and implement corrective actions and/or mitigation measures if conditions worsen.	New cracks observed with width >3mm and longer than 1m in structure walls/roof/ foundation. Unevenness, bulging or distortion of structure.	• Immediately notify SSJV Site Superintendent and Instrumentation Specialist. • Stop construction if conditions are safe to do so. SSJV Superintendent to notify the Province and other Stakeholders. • Designer contacted to assess conditions and determine an appropriate course of action prior to recommencing work.
Visual inspection- Roadways & sidewalks	New cracks in pavement, curbs or sidewalks. Existing cracks increasing in width. Unevenness, bulging and distortion in pavement.		New cracks observed with width >3mm and longer than 1m in pavement, curbs or sidewalk Unevenness, bulging and distortion in pavement that could impact traffic.	
Settlement points (Structure, utility, surface)	See Table 11	• Notify SSJV Site Superintendent and Instrumentation Specialist. • Confirm results by redoing survey. • • Increase frequency of monitoring to once a shift if not already. • Identify source of movements, and implement corrective actions and/or mitigation measures if movements increase.	See Table 11	
Multipoint borehole extensometer	See Table 11	• Notify SSJV Site Superintendent and Instrumentation Specialist. • Manually check instrumentation on site. •	See Table 11	

		• Increase frequency of monitoring to hourly if not already. • Identify source of movements, and implement corrective actions and/or mitigation measures if movements increase.		
Piezometer	See Table 11	• Notify SSJV Site Superintendent and Instrumentation Specialist. • Manually check instrumentation on site. • • Increase frequency of monitoring to hourly if not already. • Identify source of groundwater drawdown, and implement corrective actions and/or mitigation measures if conditions worsen.	See Table 11	
Convergence monitoring	See Table 11	• Notify SSJV Site Superintendent and Instrumentation Specialist. • Confirm results by redoing survey. • • Double frequency of monitoring. • Identify source of movements, and implement corrective actions and/or mitigation measures if movements increase.	See Table 11	• Immediately notify SSJV Site Superintendent and Instrumentation specialist. • Designer contacted to assess conditions and determine an appropriate course of action.
TBM performance	Variations in expected weight of material, face pressure and grout take, values to be developed as part of the Tunnel Excavation Plan.	• Notify SSJV Site Superintendent. • Review anomalous data in conjunction with other available boring data to identify source of variation. • Increase frequency of data review by resident engineer. • Explore corrective measures related with TBM operations.	Significant variations in expected weight of material, face pressure and grout take, values to be developed as part of the Tunnel Excavation Plan.	• Immediately notify SSJV Site Superintendent. • Designer contacted to assess conditions and determine an appropriate course of action, including modifying TBM operations. • Zones with poor TBM performance indicators to be assessed to evaluate if modification/treatment is required.

8.10.1 Notification

As shown in Table 12, a key aspect of the remedial responses is the notification of the proper individuals. If a threshold is reached during construction and the data is collected remotely, an automatic email alert will be sent immediately from the VDV program to the appropriate personnel. If a threshold is reached during a manual data collection, the technician who collected the data will notify the Instrumentation Specialist (or their Designee) and the crews on site. The Instrumentation Specialist (or their designee) will then contact the site superintendent verbally to advise that the threshold has been met.

8.11 Decommissioning

Instrumentation will remain in place and monitored until Total Completion or until deemed no longer necessary by the Instrumentation Specialist. The Engineer of Record will determine which, if any, instrumentation will be left in place after Total Completion. All other instrumentation will be removed before Total Completion.

9.0 CLOSURE

If you have any questions or comments, please contact the undersigned.

Sincerely,

Jacobs Associates Canada Corp.

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10/14/13

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DEFINITIONS FROM THE PROJECT AGREEMENT

"**Design**" means:

a) The production of the compendium of drawings, plans, specifications, calculations and other material produced by or on behalf of the Primary Contractor to calculate and define the Construction necessary to carry out and complete the Work in accordance with the Design-Build Requirements and the other provisions of this Agreement, including the preparation of all reports, design drawings, construction drawings and Records Documentation;

b) The performance of all project management, quality management, environmental management, communications management and other management services and activities required to be performed or carried out by the Primary Contractor for the carrying out of the foregoing;

c) the supply by the Primary Contractor of all Plant, Construction Plant, other property and workers for the carrying out of the foregoing; and

d) All other work, services and activities to be provided by the Primary Contractor in respect of the foregoing, all as set out and described in and in accordance with this Agreement, including the Design-Build Requirements and the Design and Construction Certification Procedures.

"**Disclosed Data**" means: any and all information, data, reports and documents from time to time disclosed, provided or made available by the Province or its representatives or any other person on behalf of the Province to the Primary Contractor or its representatives or to any Subcontractor or its representatives or any Proponent Team Member of the Preferred Proponent (as both such terms are defined in the Request for Proposals) in connection with or pertaining to the Project, the Work, the Site, the Project Infrastructure, the requirements of any Governmental Authority, traffic records, or any obligations undertaken by the Primary Contractor under this Agreement, and whether disclosed, provided or made available before, on or after the Effective Date, and including:

a) Any Design Data provided or made available by or on behalf of the Province;

b) The Reference Documents;

c) Any and all plans, drawings, materials, books, records, files, correspondence, studies, tests, test results, test data, certificates, investigations, samples, surveys, reports, statements, documents, facts, information, projections and traffic information (including any of the foregoing stored electronically or on computer-related media);

d) Any and all information relating to Contamination;

a) The Borehole and Test Pit Log Data, the Geotechnical Baseline Report and any other information, data, reports and documents relating to geological conditions provided or made available by or on behalf of the Province;
b) The data, reports and documents referred to in this Agreement including in any Schedule;
c) Any of the foregoing provided in connection with the Request for Qualifications and/or the Request for Proposals; and
d) Anything contained or referred to in the Data Room.

"**Effective Date**" means: [**Date of financial close**]

"**Existing Conditions**" means:
a) All Existing Facilities; and
b) Any natural geographic feature existing at the Effective Date.

"**Existing Facilities**" means:
a) Any building, structure, utility, roadway or other thing built or constructed on, in, under or over land or water; and
b) Any man-made alteration to a natural geographic feature, existing at the Effective Date.

"**Work**" means: all work and activities of or required of the Primary Contractor and the Subcontractors in connection with the performance of any obligations of the Primary Contractor under this Agreement including, without limitation, the Design, the Construction and the Reinstatement Work.

"**Zone of Influence**" has the meaning given in Article 4.2.1(c) [Construction Risk and Impact Assessment] of Part 1.

Article 4.2.1(c) states:

As part of its risk and impact assessment, the Primary Contractor shall define the area (the "**Zone of Influence**") containing any Existing Conditions that may potentially be damaged or otherwise adversely impacted, directly or indirectly:

I. By the performance, provision and carrying out of the Work; or
II. Over the design life of each of the components of the Evergreen Line, arising from or as a result of the Design, the Work, or the use of the Evergreen Line in accordance with or as anticipated by this Agreement.

REFERENCES

Boscardin, M., and Cording, E. 1989. Building Response to Excavation-Induced Settlement. J. Geotech. Engrg., 115(1), 1–21.

Evergreen Line Rapid Transit Project Agreement, Schedule 4, Part 2, Articles 4 [Structures], 5 [Seismic] & 6 [Geotechechnical]

Evergreen Line Rapid Transit Project Agreement, Schedule 4, Part 1, Articles 4 [Existing Conditions]

Mair, R. J. and Taylor, R. N., 1997. "Bored tunneling in the urban environment". In *14th International Conference on Soil Mechanics and Foundation Engineering*, Germany; 2353-2385.

O'Rourke, T. D., and Trautmann, C. H. 1982. "Buried pipeline response to tunnel ground movements" Europipe 82 Conf., Basel, Switzerland, paper 1.

Peck, R. B. 1969. "Deep excavations and tunneling in soft ground". In *Proceedings, 7th International Conference on Soil Mechanics and Foundation Engineering*, Mexico City; 225-290.

Kind of Risk	Work activity	Hazard (scenario)	Impact	Mitigation Measures	Probability	Consequence	Risk
Geology							
	TBM Excavation	Boulder(s)	Slower TBM production or stoppage, possible intervention to break boulder, damage to cutters	TBM cutterhead design for mixed ground, equipped with disc cutters and heavily reinforced rippers in addition to grizzly bars in cutterhead openings to prevent large boulder fragments from fouling screw conveyor	**Medium**	**Medium**	**Medium**
	TBM Excavation	Unexpected soil type	Slower TBM production or stoppage, ground settlements, loss of time on schedule	TBM designed for mixed ground conditions with closed bulkhead, sampling and analysis of the changed condition with subsequent adjustment of the soil conditioning parameters and/or support pressure. Daily tool box meeting with instruction to TBM operator and heading Engineers and increased TBM data monitoring	**Medium**	**Medium**	**Medium**
	TBM Excavation	Hydraulic connection – Tunnel flood	Slower TBM production or stoppage, ground settlements, loss of time on schedule	TBM designed for mixed ground conditions with closed bulkhead for work below the ground water table, analysis of the changed condition with adjustment of the conditioning parameters including the use of hydrophilic polymer. Daily tool box meeting with instruction to TBM operator and heading Engineers and increased TBM data monitoring	**Low**	**High**	**Medium**
Design							
	Design - construction TBM	Delays in coordinating the design and providing approval. Problems with manufacturing and transportation. Difficulty of adherence to contract specifications and operation.	Time lost on schedule	Control, supervision and coordination with suppliers. Client/Customer to step-in avoiding potential delays	**Medium**	**Medium**	**Medium**
	Jet- grouting	Traffic on site (Barnet highway)	Interruption of flows incoming / outgoing and delay of the production process (congestion or accident). Loss time in schedule	Optimization of logistics, provide dedicated personnel	**Medium**	**Low**	**Medium**
	Storage - TBM assembly	Lack of suitable space for container storage and positioning of crane . Inappropriate transportation and or delivery of equipment and consumables.	Time lost on schedule	Optimize project area and assembly steps. Research alternative solutions and special systems. Optimize crane and assembly logistics.	**Medium**	**Medium**	**Medium**

Kind of Risk	Work activity	Hazard (scenario)	Impact	Mitigation Measures	Probability	Consequence	Risk
	TBM assembly	Traffic on site (Barnet highway)	Interruption of flows incoming / outgoing and delay of the production process (congestion or accident). Loss time in schedule	Optimization of logistics, provide dedicated personnel	**Medium**	**Medium**	**Medium**
	Segmental lining production	Segmental ring quality issues, nonconformity in size and/or quality of tunnel lining due to inexperienced fabricator	Slower TBM production or stoppage	Improved segment design. Continuous supervision and quality control during the production process, coordination with pre-casting subcontractor. Certifications required.	**Medium**	**Low**	**Low**
	Segmental lining handling	Failure of lifting gear resulting in segment(s) falling	Time lost on schedule, safety problems	Work within crane capacity at all times, perform regular inspection and maintenance of segment crane / forklift /other lifting gear. Use only approved lifting gear for segments and implement colour code system to visually control lifting gear.	**Low**	**Medium**	**Medium**
	Pre-excavation preparation	Difficulty in reaching/maintaining optimal operational conditions	Time lost on schedule, over-consumption of ground conditioning materials, over-excavation, extra injection of tail void grout, ground settlement	Convene a task force to review and recommend improvements, perform additional tests, improve design. Technical designers available during assembly and support from TBM Manufacturer	**Low**	**Low**	**Low**
	Operation in restricted work areas	Lack sufficient area or space to operate efficiently and productively.	Interference of construction activities, impact on safety. Time lost on schedule	Optimize activities by using alternative solutions and possibly securing additional work areas.	**Low**	**Medium**	**Medium**
Operational							
	Pre-excavation preparation	Material delivery delays	Slower TBM production or stoppage	Quantities monitoring, scheduled plant maintenance, check availability of spare parts and materials.	**Low**	**Low**	**Low**
	TBM Excavation	Lack of supervision	Slower TBM production or stoppage	Continuous presence of shift engineer during excavation. Daily tool box meetings. Procedure for instruction to TBM operator from TBM manager/Monitoring Engineer/TBM Engineer. Weekly review meeting of TBM parameters	**Low**	**Medium**	**Medium**
	TBM Excavation	Lack of personnel	Slower TBM production or stoppage	Back-up supervisors and TBM operators. Duty and holiday roster revised and approved by TBM Manager and Project Manager.	**Low**	**Low**	**Low**

Kind of Risk	Work activity	Hazard (scenario)	Impact	Mitigation Measures	Probability	Consequence	Risk
	TBM labour	Local labour could underperform. Unattractive working conditions, salaries and bonuses.	Work delay	Careful personnel selection in advance of works. Place experienced personnel in key positions and provide appropriate production bonuses and incentives.	Low/High	Low	Medium/ Low
	TBM Excavation	Incorrect TBM operator instructions	Slower TBM production or stoppage	Continuous presence of shift engineer during excavation. Tunnel Excavation Plan instructions prepared and posted in operators cabin in English. No variance from instructions unless given by TBM Manager/Monitoring Engineer/TBM Engineer.	Low	Medium	Medium
	Segments storage	Segment availability due to difficulties during transport or heavy traffic.	Time lost on schedule. Slower TBM production or stoppage due to segment delivery delay.	Possible requirement for double-handling, locate alternative segment staging areas.	Medium	Low	Low
	Spoil handling	Muck bound situation	TBM delay or stoppage	Increase muck storage capacity on site, increase the flow of spoil trucks by optimizing logistics, identification of a second short-range area with possible double-handling of the spoil.	Medium	Medium	Medium
	Construction activity	Interruption of, telephone, internet, services	Time lost on schedule	Provide appropriate cable protection for communications cables and have spare parts and qualified personnel ready to repair if required	Low	Low	Low
	Construction activity	Interruption of utilities, waste water	Time lost on schedule	Provide appropriate pipeline protection for utilities spare parts and qualified personnel ready to repair if required	Low	Medium	Low
	TBM Excavation	Failure of TBM guidance and/or data monitoring	TBM out of alignment, surface settlement	Constant presence of shift engineer during excavation, 24 hours surface monitoring, surface/TBM communication. Prompt availability of spares to carry out repair.	Low	Medium	Medium
	Disassembly-extraction TBM	Lack suitable space for storage pieces and positioning lifting group.	Time lost on schedule	Optimize disassembly of the TBM. Design TBM for ease of assembly and disassembly.	Medium	Medium	Medium
TBM Excavation							

Kind of Risk	Work activity	Hazard (scenario)	Impact	Mitigation Measures	Probability	Consequence	Risk
	TBM Excavation	Injury to personnel and damage to structures at launch site as a result of instability (North Portal). Inappropriate design parameters or unknown geotechnical conditions.	Time lost on schedule	Design carried out by competent professionals using appropriate design parameters with adequate factors of safety.	**Low**	**Medium**	**Medium**
	TBM Excavation	Highly abrasive soil results in high primary wear to tools and secondary wear to cuttinghead. Frequent replacement of primary cutting tools.	Unacceptable ground movements. damage to structures, roadway and utilities, TBM delays	Regular cutter head inspection, addition of lubricating polymers for ground conditioning, perform quartz content and SAT analysis of muck.	**Medium**	**Low**	**Low**
	TBM Excavation	Injury to personnel and damage to overlying structures as a result of instability or failure of the tunnel lining	Time lost on schedule	Regular maintenance of equipment, quality control at segment precasting factory, proper execution of segmental lining erection through use of a written method statement, effective planning and supervision.	**Low**	**Medium**	**Low**
	TBM Excavation	Problems with tail void grouting	Water infiltration, ground settlements	Supervision of operators and attention to TBM data Monitoring, carry out regular plant maintenance, prompt availability of spare parts, limit forward advance rate to maintain constant grouting pressure in accordance with Tunnel Excavation Plan. Continuous batching of grout to ensure . Clear instruction to TBM operator if zone of over-excavation will require extra grout.	**Low**	**Low**	**Low**
	TBM Excavation	Over-excavation	Additional tail void grouting, ground settlements, excessive face pressure	TBM continuous control. Daily tool box meeting / instruction to TBM operator by Monitoring and TBM Engineers. Continuous control of face pressure and excavated weight with comparison to theoretical.	**Low**	**High**	**Medium**
	TBM Excavation	Poor segmental ring build quality	Ground settlements, excessive lipping and/or stepping of tunnel lining, excessive ovalization, high ground water inflow. Safety issue	Continuous control of TBM guidance system and TBM position versus alignment. Daily tool box meeting / instruction to TBM operator by Monitoring and TBM Engineers. Tail void grouting according to plan	**Low**	**Medium**	**Medium**

Kind of Risk	Work activity	Hazard (scenario)	Impact	Mitigation Measures	Probability	Consequence	Risk
	Construction activity	Noise and dust from TBM	Health and safety problems result in stoppage of TBM operations	Provide noise enclosures for equipment and ensure proper ventilation of working areas and sprinklers if dusty conditions develop.	Low	Medium	Low
	TBM Excavation	Long term TBM stoppage .	Increase in volume loss, surface settlement, TBM trapped	Regular TBM maintenance, maintenance of face pressure at or above ambient.	Low	Medium	Low
Equipment Break Down							
	TBM Excavation	Interruption of power feed to TBM transformer, Grouting plant, Continuous Conveyor, Conditioning plant: mechanical and electrical failure.	Stop in critical area and TBM in stand by. TBM delay	Perform scheduled maintenance, provide prompt availability of spare parts and repair, perform regular review of TBM data to detect TBM faults.	Low	Low	Low
	TBM Excavation	Segment vehicle accident	TBM stoppage	Daily toolbox meeting and safety briefing for all rubber-tired vehicle operators. Operators perform vehicle circle/safety check prior to operation of their vehicle. Perform regular maintenance and ensure all safety related equipment is functioning before use.	Low	Medium	Low
Environmental							
	TBM Excavation	Sensible vibration or noise felt by residents along the alignment	Nuisance to local community and schools. Cracks on existing structures	Provide vibration sensors, and public relations and outreach with the local community.	Med/Low	Low	Low
	TBM Excavation	Noise and dust adjacent to tunnel portal	Nuisance to local community	Provide noise barriers, "white noise machines", water spray for dust suppression. public relations and outreach with the local community	Low	Low	Low
	TBM Excavation	Groundwater pollution due to the use of soil conditioners	Nuisance to local community and wildlife, TBM stoppage	Use waterproof barrier systems and proper storage procedures for all TBM consumables, use non-toxic, biodegradable soil conditioners	Low	Medium	Low
	Disassembly-extraction TBM	Inclement, wet weather	Flooding of the tunnel during TBM disassembly (completed Tunnel). Time lost on schedule	Tunnel is self draining. Use water barrier systems and pumps. Prepare for inclement weather.	Low	Medium	Low

APPENDIX A: LIST OF STRUCTURES TO BE MONITORED

Structure also falling under North & South Portal CRIAR scope

Note: ID numbers were assigned arbitrarily for Jacobs Associates tracking

ID	Approx Station Ref	Building address	Parcel #	Municipality	Type of structure	Above ground Stories
1	416+830	647 Kemsley Ave	4060263	Coquitlam	Residence	2
2	416+840	661 Clarke Rd (2 bldgs.)	4060262	Coquitlam	Residence	1.5
3	416+875	707 Clarke Rd	4060260	Coquitlam	Residence	2.5
4	416+900	663 & 665 Harrison Ave	4060251	Coquitlam	Residence	2
5	416+925	711 & 713 Clarke Rd	4060250	Coquitlam	Residence	2
6	416+940	715 & 717 Clarke Rd	4060376	Coquitlam	Residence	2
7	416+955	719 & 721 Clarke Rd	4060375	Coquitlam	Residence	2
60	416+960	720 Clarke Rd	4060545	Coquitlam	Residence	2
8	416+980	723 & 725 Clarke Rd	4110356	Coquitlam	Residence	2
9	417+000	727 &729 Clarke Rd	4110270	Coquitlam	Residence	2
61	417+000	730 Clarke Rd	4060374	Coquitlam	Motel	2
10	417+025	731 & 733 Clarke Rd	4110272	Coquitlam	Residence	2
11	417+040	735 Clarke Rd	4110137	Coquitlam	Residence	2
62	417+045	736 Clarke Rd	4060373	Coquitlam	Residence	2
12	417+055	680 Thompson Ave	4110340	Coquitlam	Residence	2
63	417+070	736 Clarke Rd	4060373	Coquitlam	Residence	2
64	417+140	932 Robinson	4110001	Coquitlam	Residence	3
13	417+145	751 Clarke Rd	4110275	Coquitlam	Residence	2.5
16	417+225	685 & 687 Chapman Ave	4110012	Coquitlam	Residence	2
67	417+240	955 Robinson St	4110265	Coquitlam	Residence	2
18	417+250	765 & 767 Clarke Rd	4110191	Coquitlam	Residence	2
19	417+270	769 &771 Clarke Rd	4110013	Coquitlam	Residence	2
20	417+290	773 & 775 Clarke Rd	4110190	Coquitlam	Residence	2
21	417+315	783 Clarke Rd & 881 Glena	4110277	Coquitlam	Residence	2
24	417+360	789 Clarke Rd	4110135	Coquitlam	Commercial	1
27	417+445	901 Clarke rd		Port Moody	Residence	3
29	417+540	907 Clarke Rd		Port Moody	Residence	3
84	417+580	900 Clarke Rd		Coquitlam	Residence	3
85	417+640	910,912,914,916 Clarke Rd		Port Moody	Commercial	1
33	417+650	201/203 Seaview Dr		Port Moody	Residence	2
94	417+850	53 Mount Royal Dr		Port Moody	Residence	1
44	417+955	1005- 1033 Clarke Rd		Port Moody	Residence	2.5
45	417+980	1005- 1033 Clarke Rd		Port Moody	Residence	2.5
47	418+050	1031-1053 Cecile Dr		Port Moody	Residence	2.5
49	418+150	1050 Cecile Dr		Port Moody	Residence	2.5
102	418+270	1102-1124 Chateau Pl		Port Moody	Residence	2

51	418+280	1130 Cecile Pl		Port Moody	Residence	2.5
52	418+360	1126-1184 Chateau Pl		Port Moody	Residence	2
105	418+550	1895 Charles St		Port Moody	Residence	2
106	418+580	1885 Charles St		Port Moody	Residence	1.5
107	418+595	1875 Charles St		Port Moody	Residence	1.5
55	418+610	1865 Charles St		Port Moody	Residence	1.5
56	418+630	1855 Charles St		Port Moody	Residence	2
57	418+650	1845 Charles St		Port Moody	Residence	2
108	418+665	1880 Charles St		Port Moody	Residence	2
58	418+675	1850 Charles St		Port Moody	Residence	1 to 2
109	418+690	1870 Charles St		Port Moody	Residence	1
110	418+695	1860 Charles St		Port Moody	Residence	1
59	418+720	1814-1816 View St		Port Moody	Residence	2

Total: 50 existing structures (2 buildings at 661 Clarke Rd)

APPENDIX B: UTILITY INVENTORY ALONG BORED TUNNEL ALIGNMENT

NOTE: Utility summary list is for information only and not to be relied upon for construction. All utility locations must be verified in the field. The utility inventory may or may not constitute a complete list.

LRT CHAINAGE (start)	LRT CHAINAGE (end)	UTILITY TYPE	PIPE SIZE (mm)	ORIENTATION (II) or (+) to alignment	HORIZONTAL OFFSET (if II) (m)	TOP OF TUN. ELEV	Ground surface ELEV	CLEARANCE (tunnel to ground surface) (m)
418+706	418+693	Sanitary	150	+		13.0	35.0	22.0
418+675	418+650	Water	150	+		14.0	38.0	24.0
418+665	418+635	Gas	60	+		15.0	41.0	26.0
418+665	418+665	HYDRO		+		15.0	41.0	26.0
418+640	418+640	HYDRO		+		15.0	43.0	28.0
418+665	418+640	HYDRO		II	0	15.0	41.0	26.0
418+670	418+660	Telephone		+		14.0	38.0	24.0
418+640	418+635	Telephone		+		15.0	43.0	28.0
418+640	418+635	Storm	200	+		15.0	43.0	28.0
418+640	418+635	Sanitary	150	+		15.0	43.0	28.0
418+615	418+615	HYDRO		+		15.0	47.0	32.0
418+615	418+615	Telephone		+		15.0	47.0	32.0
418+535	418+520	Sanitary	200	+		20.0	56.0	36.0
418+485	418+485	Storm	200	+		25.0	57.0	32.0
418+468	418+468	Telephone		+		28.0	56.0	28.0
418+355	418+348	Storm	300	+		35.0	78.0	43.0
418+310	418+300	Hydro		+		38.0	80.0	42.0
418+280	418+280	Water	150	+		40.0	88.0	48.0
418+235	418+235	Sanitary	150	+		35.0	80.0	45.0
418+245	418+225	Water	200	+		42.0	88.0	46.0
418+165	418+163	Water	150	+		46.0	82.0	36.0
418+163	418+161	Water	250	+		47.0	81.0	34.0
418+162	418+158	Sanitary	200	+		47.0	81.0	34.0
418+132	418+130	Gas	26	+		48.0	81.0	33.0
418+075	418+075	Telephone		+		52.0	84.0	32.0
418+075	418+075	Hydro		+		52.0	84.0	32.0
418+075	418+075	Hydro		+		52.0	84.0	32.0
418+062	418+060	Gas		+		52.0	85.0	33.0
418+055	418+055	Storm	250	+		53.0	86.0	33.0
418+050	418+050	Sanitary	200	+		53.0	87.0	34.0
418+000	417+998	Telephone		+		56.0	91.0	35.0
417+996	417+995	Telephone		+		57.0	91.0	34.0
417+993	417+990	Telephone		+		58.0	92.0	34.0
417+990	417+898	Water	150	+		58.0	93.0	35.0
417+960	417+950	Gas		II	10 to 0	59.0	94.0	35.0
417+888	417+888	Sanitary	200	+		63.0	102.0	39.0
417+828	417+828	Gas	114	+		67.0	107.0	40.0
417+825	417+825	Storm	450	+		67.0	107.5	40.5
417+810	417+810	Water	200	+		68.0	109.0	41.0
417+807	417+807	Telephone		+		68.0	109.0	41.0
417+807	417+804	Hydro		+		68.0	109.0	41.0
417+795	417+788	Telephone		+		60.0	110.0	50.0
417+694	417+688	Telephone		+		75.0	118.0	43.0
417+688	417+685	Telephone		+		75.0	118.0	43.0
417+680	417+680	Gas	60	+		76.0	119.0	43.0
417+680	417+480	Sanitary	200	II	10 to 0	76.0	119.0	43.0
417+677	417+672	Telephone		+		76.0	120.0	44.0
417+674	417+674	Storm	600	+		76.0	120.0	44.0
417+672	417+672	Water		+		76.0	140.0	64.0
417+625	417+010	Telephone		II	10 to 0	78.0	123.0	45.0
417+600	417+600	Hydro		+		80.0	124.0	44.0
417+571	417+571	Hydro		+		80.0	125.0	45.0
417+570	417+570	Hydro		+		80.0	124.0	44.0
417+540	417+540	Hydro		+		81.0	125.0	44.0
417+532	417+530	Storm		+		82.0	125.0	43.0
417+515	417+510	Storm	300	+		82.0	125.0	43.0
417+500	417+500	Storm	600	+		82.5	125.0	42.5
417+500	417+400	Storm	450	II	0	85.5	127.5	42.0
417+490	417+485	Hydro		+		83.0	125.0	42.0

NOTE: Utility summary list is for information only and not to be relied upon for construction. All utility locations must be verified in the field. The utility inventory may or may not constitute a complete list.

LRT CHAINAGE (start)	LRT CHAINAGE (end)	UTILITY TYPE	PIPE SIZE (mm)	ORIENTATION (II) or (+) to alignment	HORIZONTAL OFFSET (if II) (m)	TOP OF TUN. ELEV	Ground surface ELEV	CLEARANCE (tunnel to ground surface) (m)
417+400	417+330	Storm	375/380	II	0	88.2	127.5	39.3
417+438	417+438	Hydro		+		87.0	128.0	41.0
417+350	417+200	Water	650	II	5	91.0	128.2	37.2
417+340	417+340	Sanitary	200	+		87.0	128.0	41.0
417+325	417+000	Telephone		II	10 to 0	88.0	128.0	40.0
417+283	417+283	Sanitary	200	+		88.0	128.0	40.0
417+275	417+270	Hydro		+		89.0	128.0	39.0
417+270	417+270	Gas	60	+		89.0	128.0	39.0
417+245	417+240	Hydro		+		90.0	128.0	38.0
417+244	417+238	Telephone		+		90.0	128.0	38.0
417+230	417+230	Telephone		+		90.0	128.0	38.0
417+230	417+230	Gas	168	+		90.0	128.0	38.0
417+210	417+210	Hydro		+		91.0	128.0	37.0
417+208	417+200	Telephone		+		91.0	128.0	37.0
417+200	417+200	Telephone		+		91.0	129.0	38.0
417+200	417+195	Telephone		+		91.0	129.0	38.0
417+200	417+200	Water	650	+		91.0	128.2	37.2
417+198	417+198	Water	150	+		91.0	129.0	38.0
417+185	417+185	Gas	60	+		92.0	129.0	37.0
417+170	417+165	Hydro		+		92.0	128.0	36.0
417+165	417+160	Hydro		+		93.0	128.0	35.0
417+125	417+125	Hydro		+		93.0	128.0	35.0
417+090	417+085	Hydro		+		94.0	128.0	34.0
417+082	417+082	HYDRO		+		95.0	127.0	32.0
417+075	417+075	Gas	60	+		95.0	127.0	32.0
417+075	417+075	Water	150	+		95.0	127.0	32.0
417+072	417+072	Telephone		+		95.0	127.0	32.0
417+070	417+070	Telephone		+		95.0	127.0	32.0
-	416+920	Gas	26-42	II	0	98.0	123.0	25.0
416+865	416+860	HYDRO		+		101.0	122.0	21.0
416+830	416+826	HYDRO		+		102.0	120.0	18.0
416+825	416+822	Telephone		+		103.0	120.0	17.0
416+822	416+820	Telephone		+		103.0	120.0	17.0
416+900	416+808	Storm	375	II	10 to 0	99.0	123.0	24.0
416+880	417+190	Storm	300	II	15 to 0	100.0	123.0	23.0
416+822	416+818	Telephone		+		103.0	119.0	16.0
416+820	416+816	Telephone		+		104.0	119.0	15.0
416+817	416+808	HYDRO		+		104.0	119.0	15.0
416+817	416+808	Storm	450	+		104.0	119.0	15.0
416+817	416+808	Storm	380	+		104.0	119.0	15.0
-	416+805	Sanitary	200	II	20 to 0	104.0	119.0	15.0
416+805	416+795	Gas	60	+		105.0	119.0	14.0
416+805	416+795	Water	150	+		105.0	119.0	14.0
416+805	416+795	Sanitary	200	+		105.0	119.0	14.0
-	416+790	Electrical		II	10 to 0	105.0	118.0	13.0
-	416+790	Water	100	II	10 to 0	105.0	118.0	13.0
-	416+790	Gas	168	II	10 to 0	105.0	118.0	13.0
-	416+790	Storm	200	II	20 to 0	105.0	118.0	13.0
-	416+790	Water	200	II	20 to 0	105.0	118.0	13.0
-	416+790	Telephone		II	20 to 0	105.0	118.0	13.0
-	416+790	HYDRO		II	20 to 0	105.0	118.0	13.0
-	416+790	HYDRO		II	20 to 0	105.0	118.0	13.0
-	416+790	Electrical		II	20 to 0	105.0	118.0	13.0

150 CAST IRON WATER MAIN
200 CONCRETE SANITARY SEWER
380 CONCRETE STORM SEWER

BORED TUNNEL EXTENTS

TUNNEL ZONE OF INFLUENCE AND ZONE OF SETTLEMENT MONITORING

LIMIT OF BORED TUNNEL

TUNNEL TRANSITION | BORED TUNNEL

STA 416+790

BORED TU

MATCHLINE – CONTINUED ON DWG. NO. B
I/B STA. 417+160

416+780 416+800 416+820 416+840 416+860 416+880 416+900 416+920 416+940 416+960 416+980 417+000 417+020 417+040 417+060 417+080 417+100 417+120 417+140 417+160

PLAN
SCALE 1:500

EXPECTED IMPACTS – DAMAGE CLASS

- SLIGHT
- VERY SLIGHT
- NEGLIGIBLE

KEY PLAN

DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET
EGL-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A	1	1	P.J.

PROFESSIONAL SEAL

1800 – 1075 West Georgia Street
Vancouver, B. C.
Canada. V6E 3C9

SNC-LAVALIN Constructors Pacific

JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500
0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT
ANTICIPATED IMPACTS TO EXISTING FACILITIES
SHEET A
FROM STA 416+790 TO STA 417+160

PROVINCE CONTRACT No. 03902
SUB-CONSULTANT No. 1
DRAWING No. A

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PREVIOUS TO —

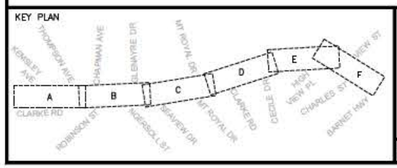
PLAN

SCALE 1:500

EXPECTED IMPACTS – DAMAGE CLASS

- SLIGHT
- VERY SLIGHT
- NEGLIGIBLE

KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET
EGL-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A			P.J.

PROFESSIONAL SEAL

SNC·LAVALIN Constructors Pacific
1800 – 1075 West Georgia Street
Vancouver, B. C.
Canada. V6E 3C9

JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500

0 25

SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

ANTICIPATED IMPACTS TO EXISTING FACILITIES

FIGURE B

FROM STA 417+160 TO STA 417+500

PROVINCE CONTRACT No. 03902	SUB-CONSULTANT No.
DRAWING No. FIGURE 1	A

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PREVIOUS TO —

LAYOUT: 1002
PLOT DATE: 2013-10-04 1:15 PM LILLY, DAVID
FILE LOCATION: L:\14459.1 EVERGREEN LINE RAPID TRANSIT PROJECT\CADD\DOCUMENT\FIGURES\IMPACT TO EX FAC\511328-12220-52JA-40DD-1002.DWG

BLDG'S DEMO'D

TUNNEL ZONE OF INFLUENCE AND ZONE OF SETTLEMENT MONITORING

LIMIT OF BORED TUNNEL

MATCHLINE – CONTINUED ON DWG. NO. B
I/B STA. 417+500

MATCHLINE – CONTINUED ON DWG. NO. D
I/B STA. 417+840

CLARKE ROAD

MT ROYAL DRIVE

SEAVIEW DRIVE

417+480 417+500 417+520 417+540 417+560 417+580 417+600 417+620 417+640 417+660 417+680 417+700 417+720 417+740 417+760 417+780 417+800 417+820 417+840

PLAN

SCALE 1:500

EXPECTED IMPACTS – DAMAGE CLASS

- SLIGHT
- VERY SLIGHT
- NEGLIGIBLE

LAYOUT: 1003
PLOT DATE: 2013-10-04 1:17 PM LILLY, DAVID
FILE LOCATION: I:\14459.1 EVERGREEN LINE RAPID TRANSIT PROJECT\CADD\DOCUMENT\FIGURES\IMPACT TO EX FAC\511328-12220-52JA-40DD-1003.DWG

KEY PLAN

DESIGNED S. FEKETE 2013-08-23 DATE
DRAWN P. JACOBCHUK 2013-08-23 DATE
CHECKED S. SWARTZ 2013-08-23 DATE
APPROVED A. MCGLENN 2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET
EDL-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A			PJ.

PROFESSIONAL SEAL

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Vancouver, B. C.
Canada. V6E 3C9

SNC-LAVALIN Constructors Pacific

JV LOGO SSJV

DESIGNER JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500

0 25

SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

ANTICIPATED IMPACTS TO EXISTING FACILITIES

FIGURE C

FROM STA 417+500 TO STA 417+840

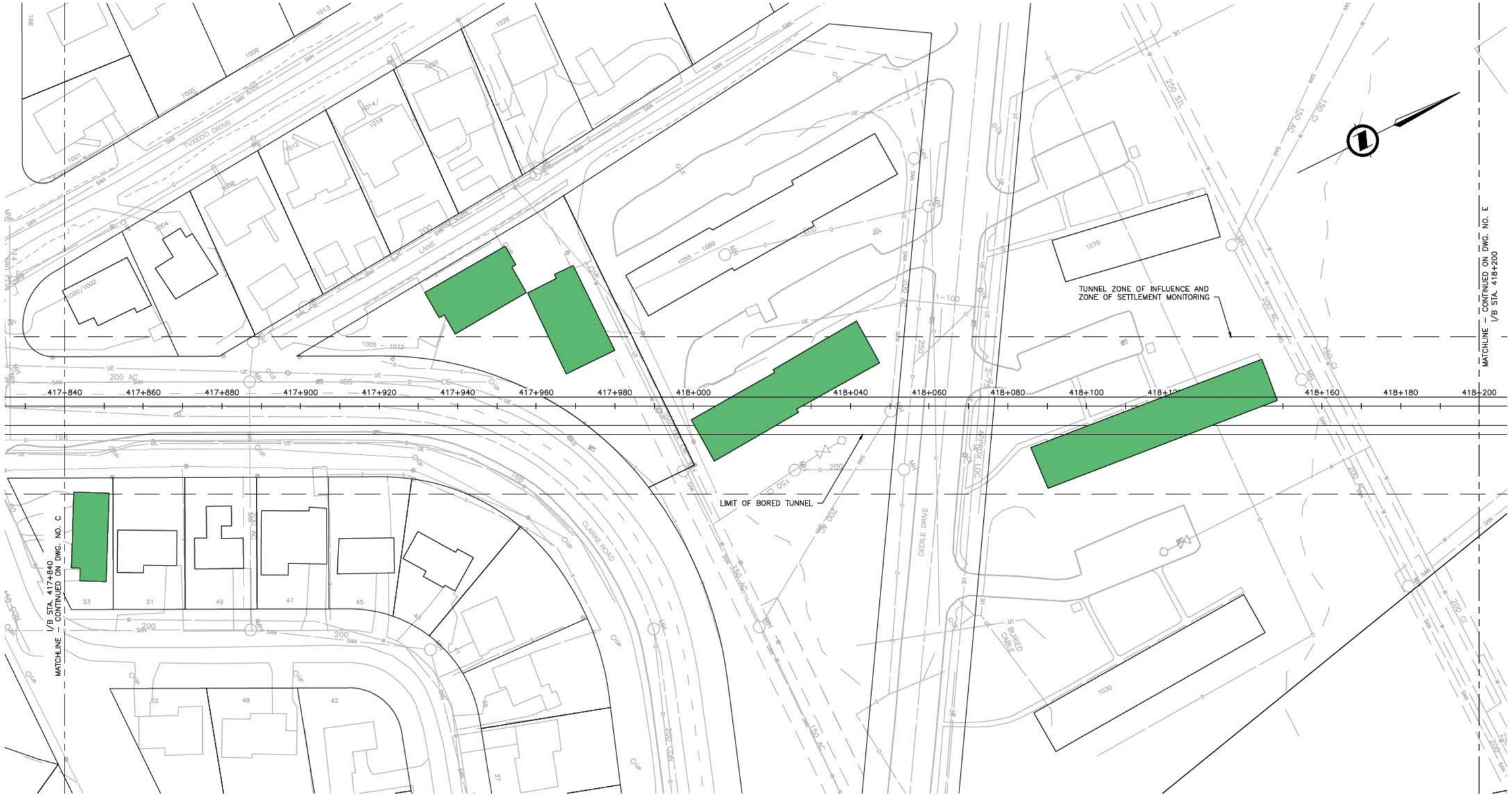
PROVINCE CONTRACT No. 03902

SUB-CONSULTANT No.

DRAWING No. FIGURE 1

A

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PREVIOUS TO —



PLAN
SCALE 1:500

EXPECTED IMPACTS – DAMAGE CLASS

- SLIGHT
- VERY SLIGHT
- NEGLIGIBLE

LAYOUT: 1004
PLOT DATE: 2013-10-04 1:20 PM LILIY, DAVID
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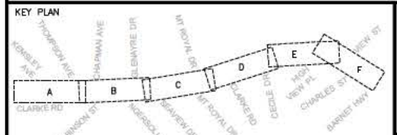
KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET EGL-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A			P.J.

PROFESSIONAL SEAL

1800 – 1075 West Georgia Street
Vancouver, B. C.
Canada. V6E 3C9

SNC·LAVALIN Constructors Pacific

JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500
0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT
ANTICIPATED IMPACTS TO EXISTING FACILITIES
FIGURE D
FROM STA 417+840 TO STA 418+200

PROVINCE CONTRACT No.	SUB-CONSULTANT No.
03902	
DRAWING No.	
FIGURE 1	A

JRA-2015-00011
Page 65

SUPERCEDES PRINTS OF THIS DRAWING WITH LETTERS PREVIOUS TO —

PLAN
SCALE 1:500

EXPECTED IMPACTS – DAMAGE CLASS

- SLIGHT
- VERY SLIGHT
- NEGLIGIBLE

LAYOUT: 1005
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FILE LOCATION: I:\1459.1 EVERGREEN LINE RAPID TRANSIT PROJECT\CADD\DOCUMENT\FIGURES\IMPACT TO EX FAC\511328-1220-52JA-4GDD-1005.DWG

KEY PLAN

DESIGNED	S. FEKETE 2013-08-23 DATE
DRAWN	P. JACOBCHUK 2013-08-23 DATE
CHECKED	S. SWARTZ 2013-08-23 DATE
APPROVED	A. MCGLENN 2013-08-23 DATE

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REVISIONS

REV	DATE	DESCRIPTION	BY
A			PJ.

PROFESSIONAL SEAL

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Vancouver, B. C.
Canada. V6E 3C9

SNC·LAVALIN Constructors Pacific

JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

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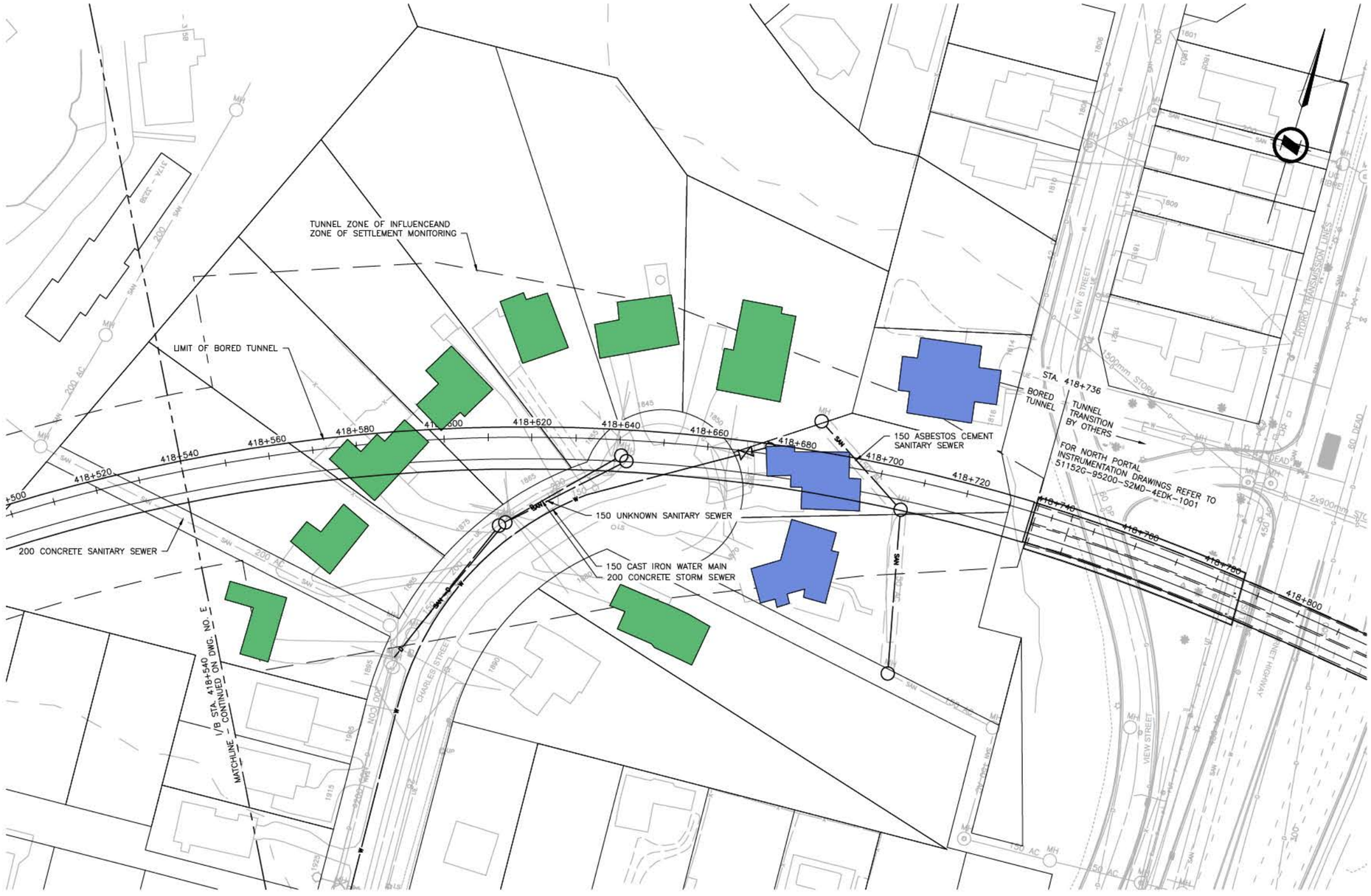
SCALE 1:500
0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT
ANTICIPATED IMPACTS TO EXISTING FACILITIES
FIGURE E
FROM STA 418+200 TO STA 418+540

PROVINCE CONTRACT No. 03902
SUB-CONSULTANT No.
DRAWING No. FIGURE E
A

SUPERCEDES PRINTS OF THIS DRAWING WITH LETTERS PREVIOUS TO

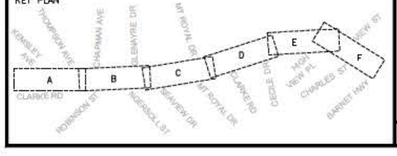


PLAN
SCALE 1:500

EXPECTED IMPACTS – DAMAGE CLASS

- SLIGHT
- VERY SLIGHT
- NEGLIGIBLE

KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET
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REVISIONS

REV	DATE	DESCRIPTION	BY
A			P.J.

PROFESSIONAL SEAL

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SNC·LAVALIN
Constructors Pacific

JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES
Engineers/Consultants

EGRT CONSTRUCTION

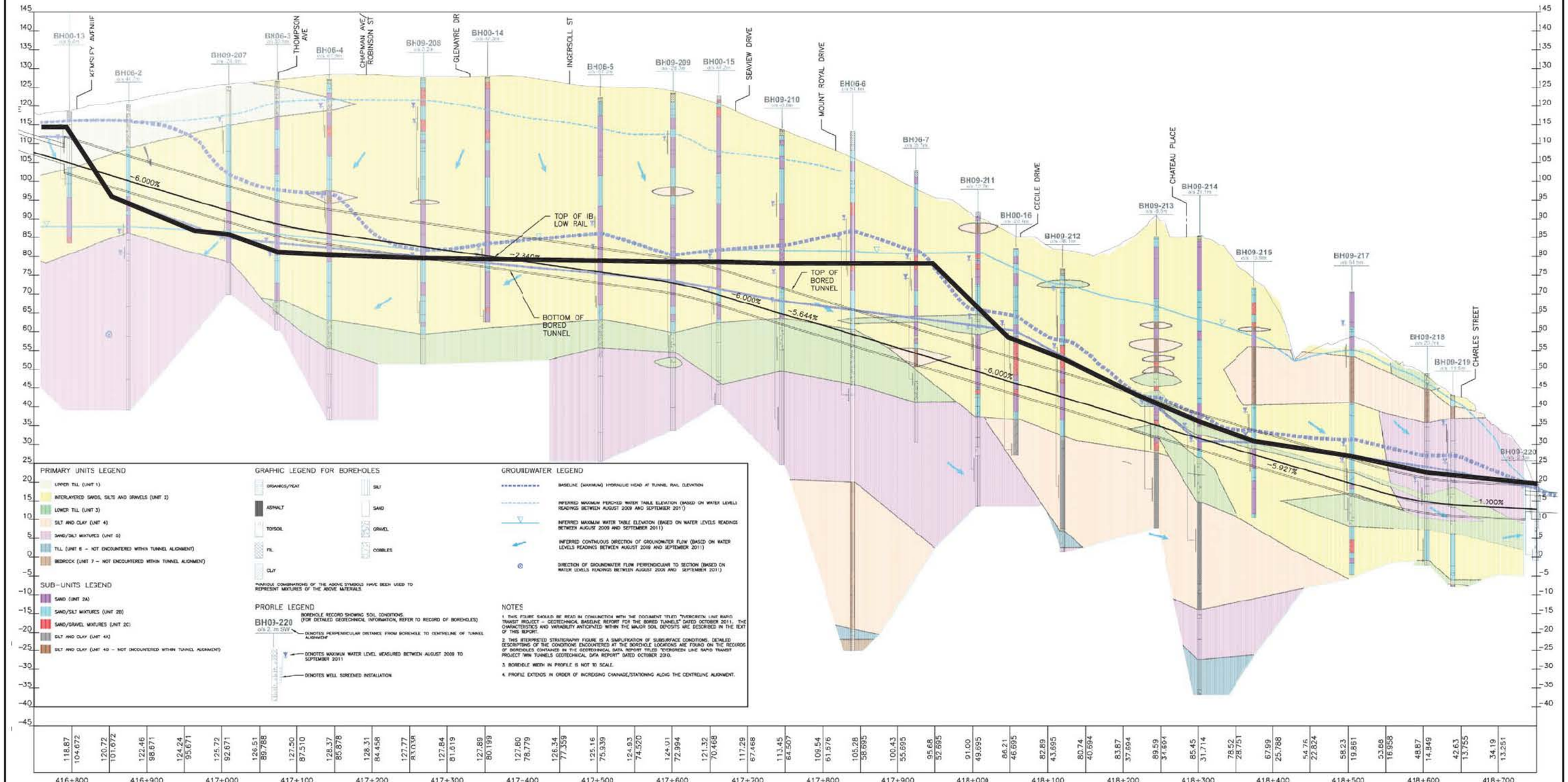
BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500
0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT
ANTICIPATED IMPACTS TO EXISTING FACILITIES
FIGURE F
FROM STA 418+540 TO STA 418+736

PROVINCE CONTRACT No. 03902
SUB-CONSULTANT No.
DRAWING No. FIGURE F
A

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PREVIOUS TO —



DESIGN PIEZOMETRIC LEVEL

NOTES:

1. THE DESIGN PIEZOMETRIC LEVEL IS OVERLAIN ON A SUBSURFACE PROFILE TAKEN FROM THE DOCUMENT TITLED "EVERGREEN LINE RAPID TRANSIT PROJECT - GEOTECHNICAL BASELINE REPORT FOR THE BORED TUNNELS" DATED OCTOBER 2011. THE BORED TUNNEL ALIGNMENT SHOWN IS FROM DRAWING NO.511325-10200-S2SL-40DD-1029, REV. A DATED JANUARY 13TH, 2013.

PROJECT # 4459.1

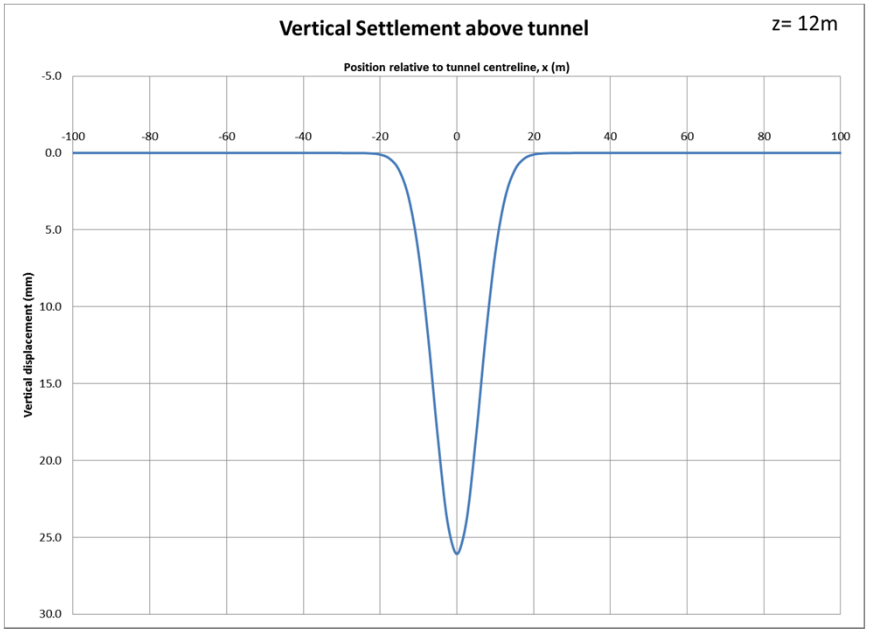
JACOBS ASSOCIATES
Engineers/Consultants

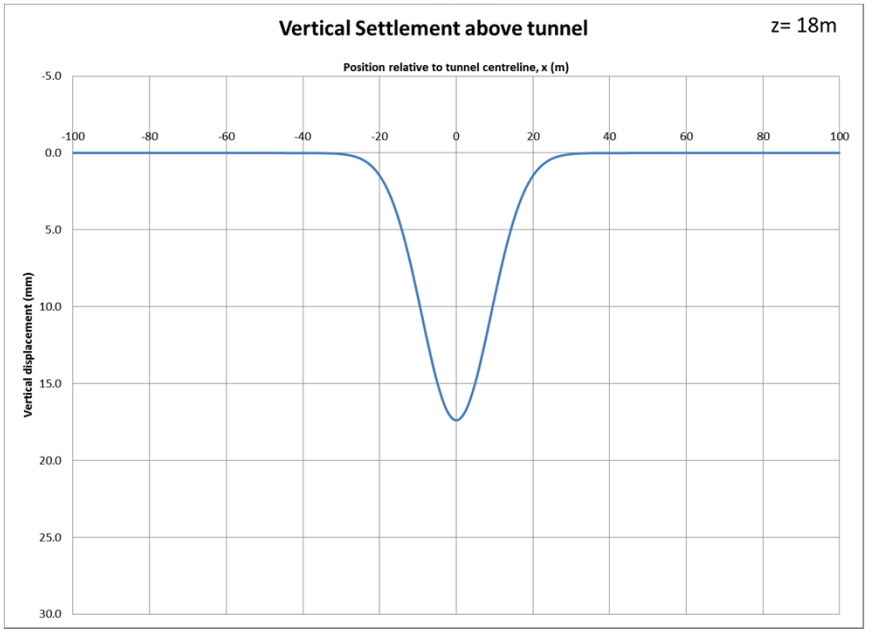
EVERGREEN LINE
RAPID TRANSIT PROJECT

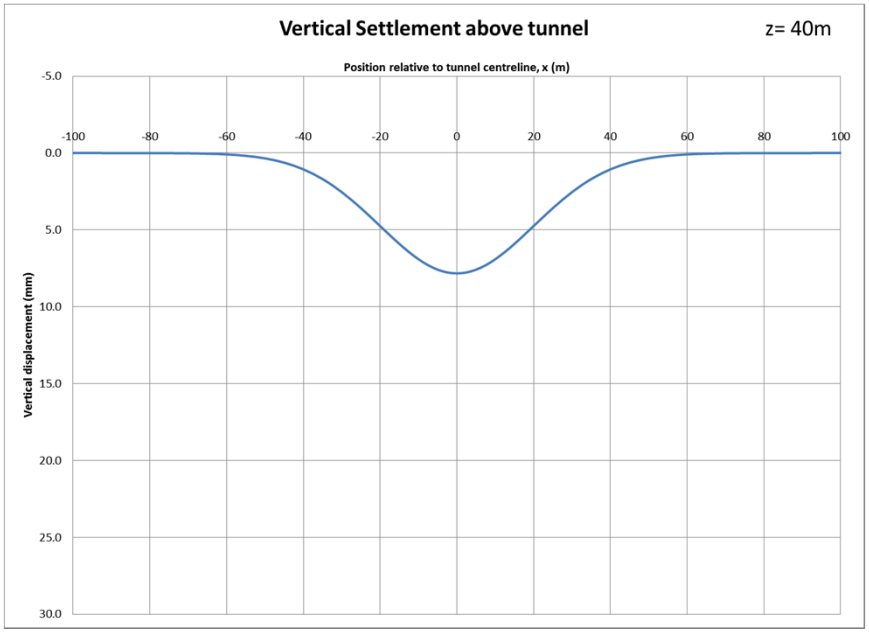
MAY 2013

BORED TUNNEL PROFILE
FIGURE 1

Figure 3a: Vertical Settlement, Sz(x)







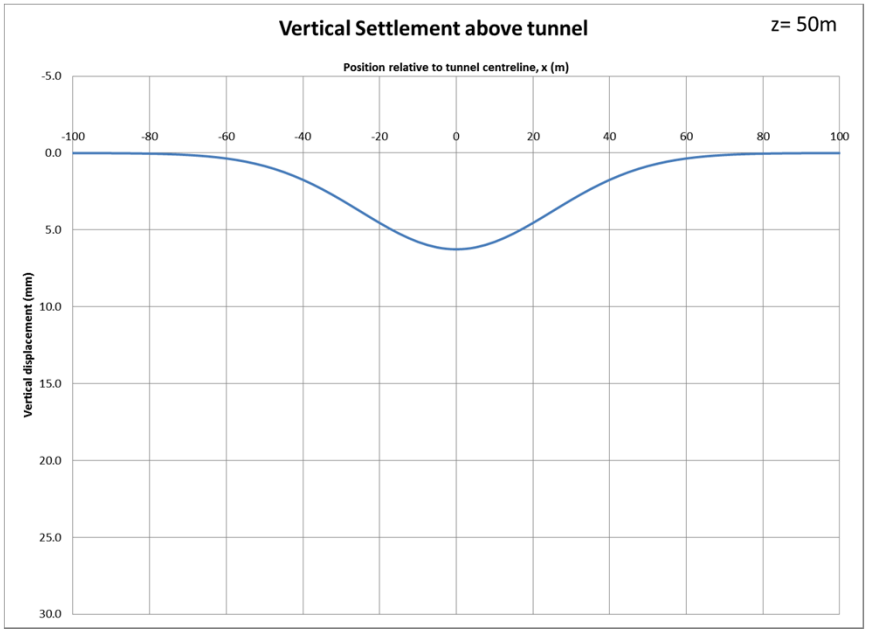
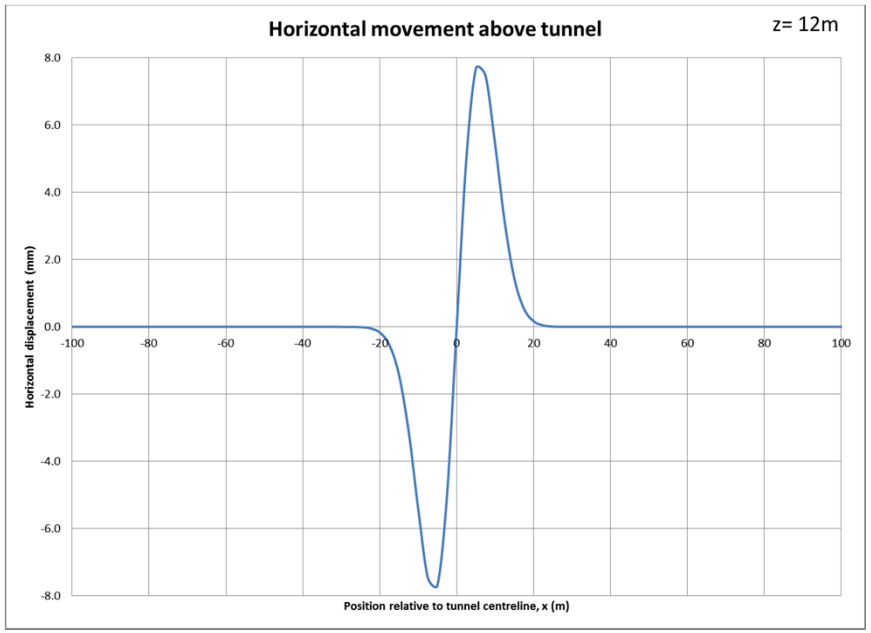
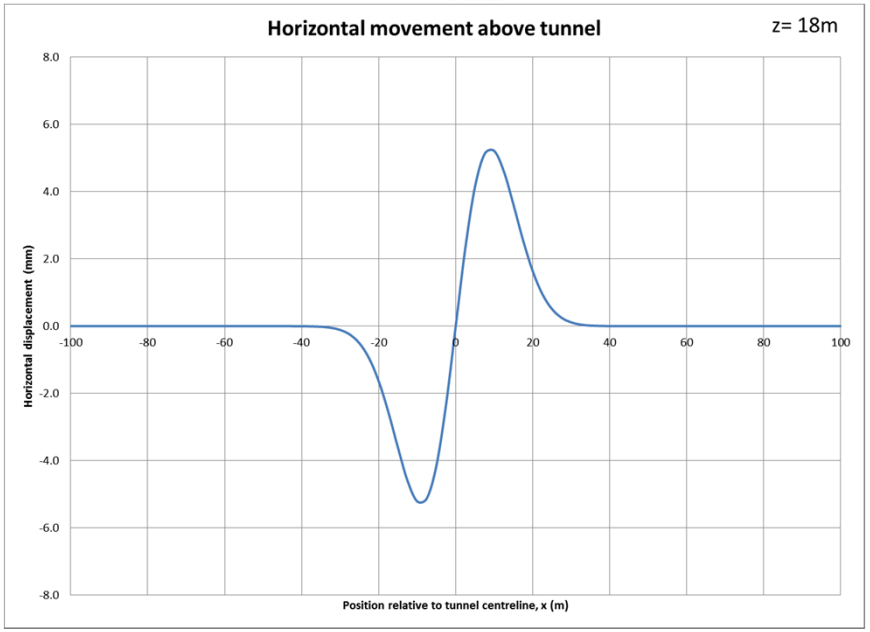
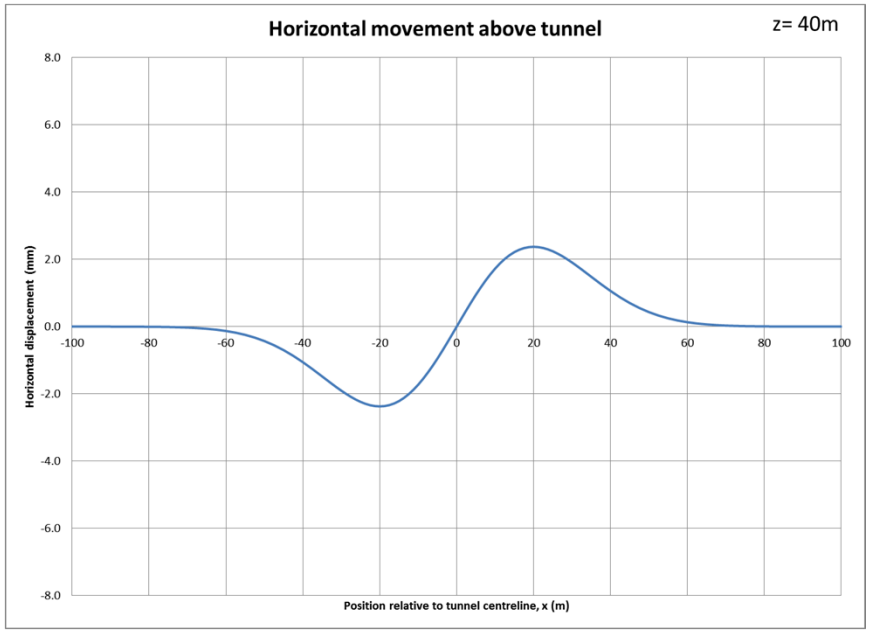


Figure 3b: Horizontal Movement, Sx(x)







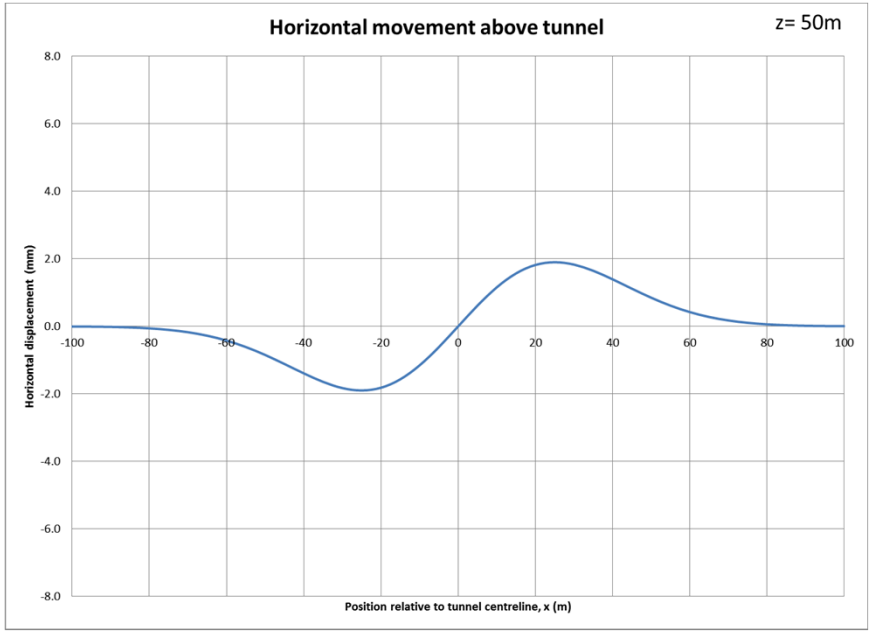
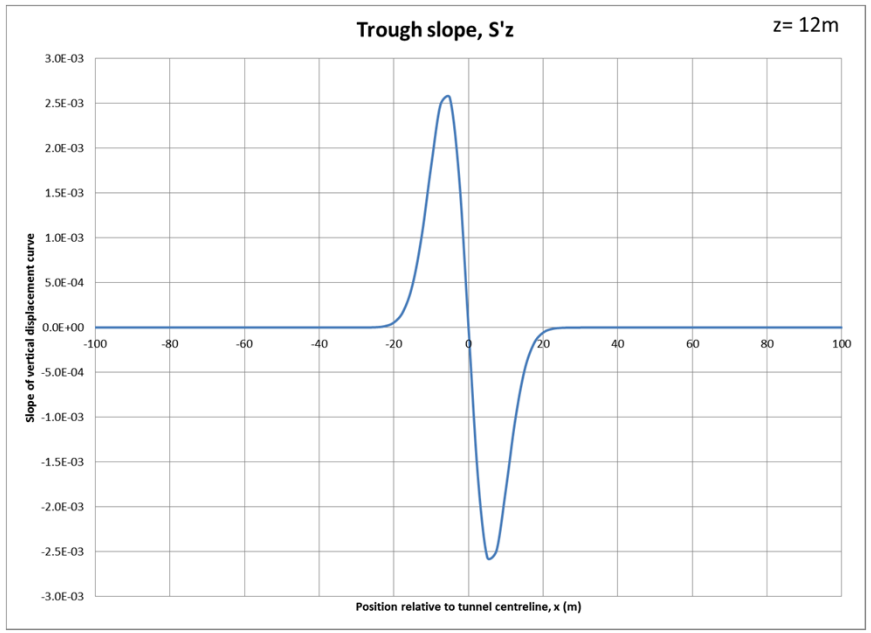
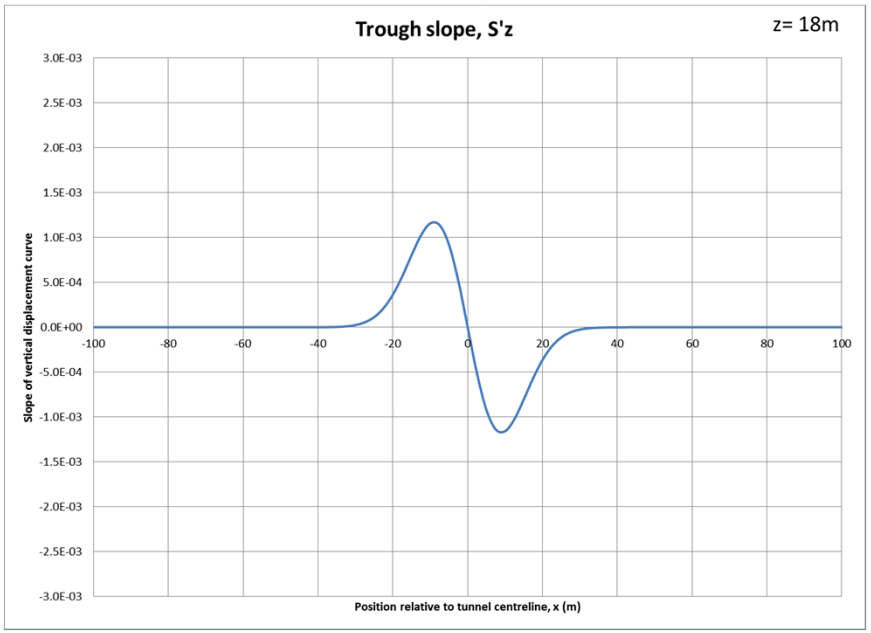
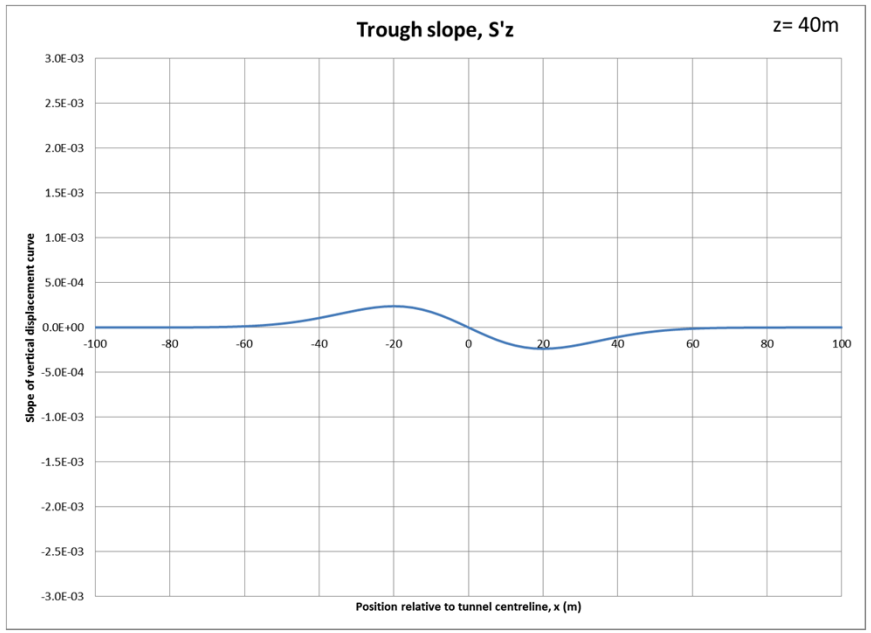


Figure 3c: Trough Slope, Sz'(x)







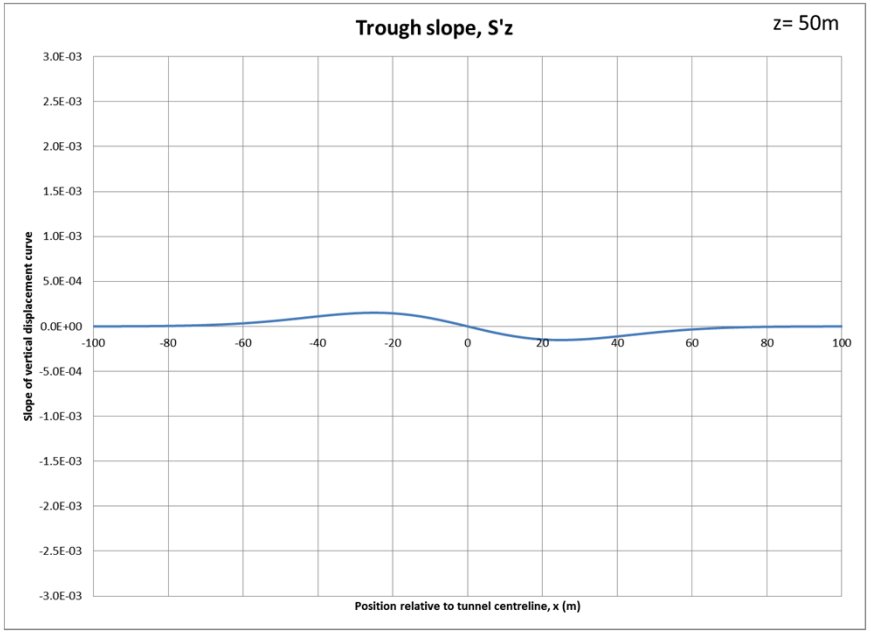
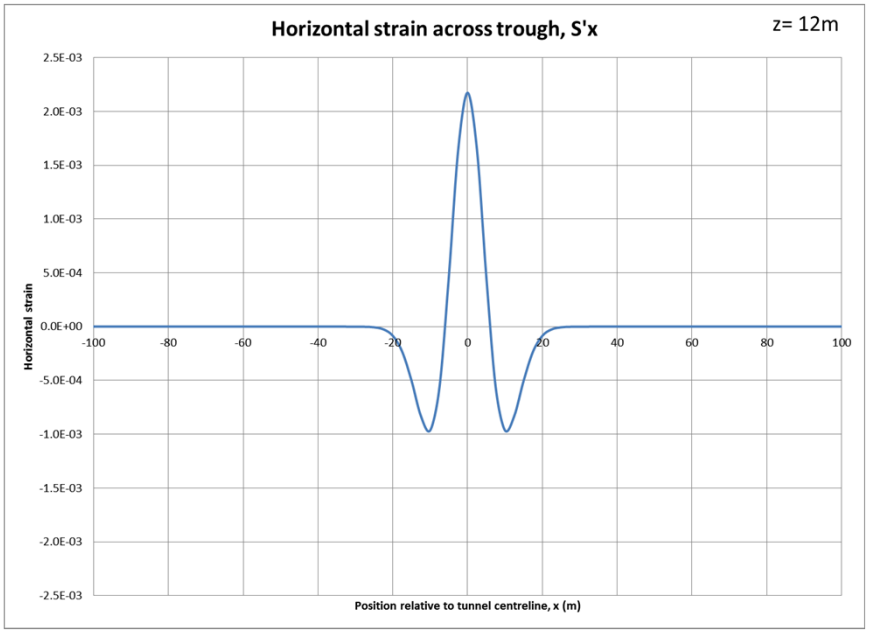
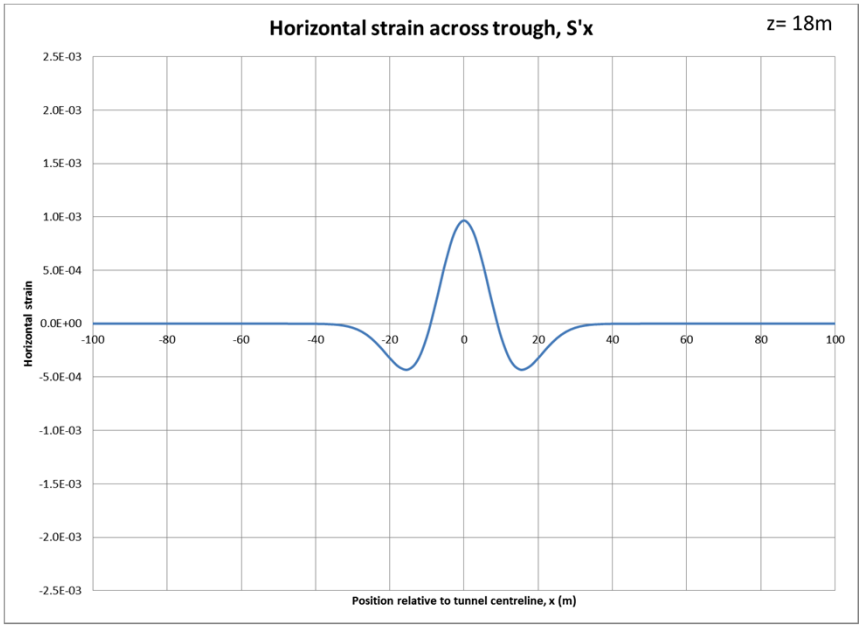
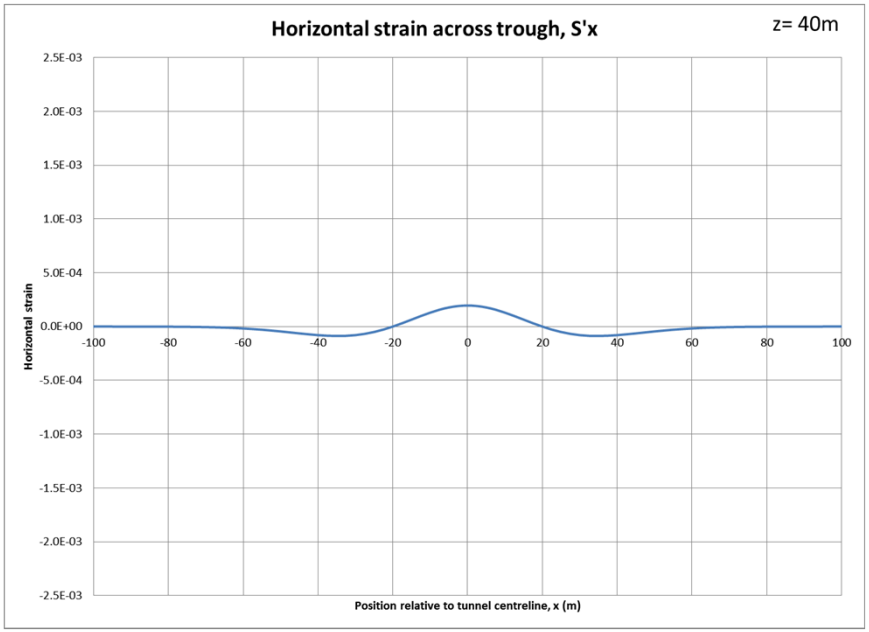
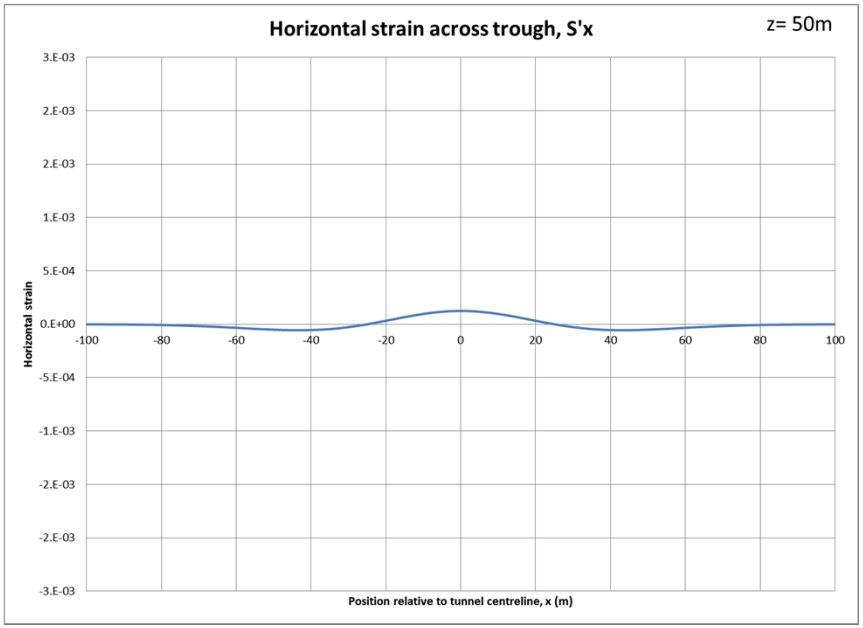


Figure 3d: Horizontal Strain, Sx'(x)



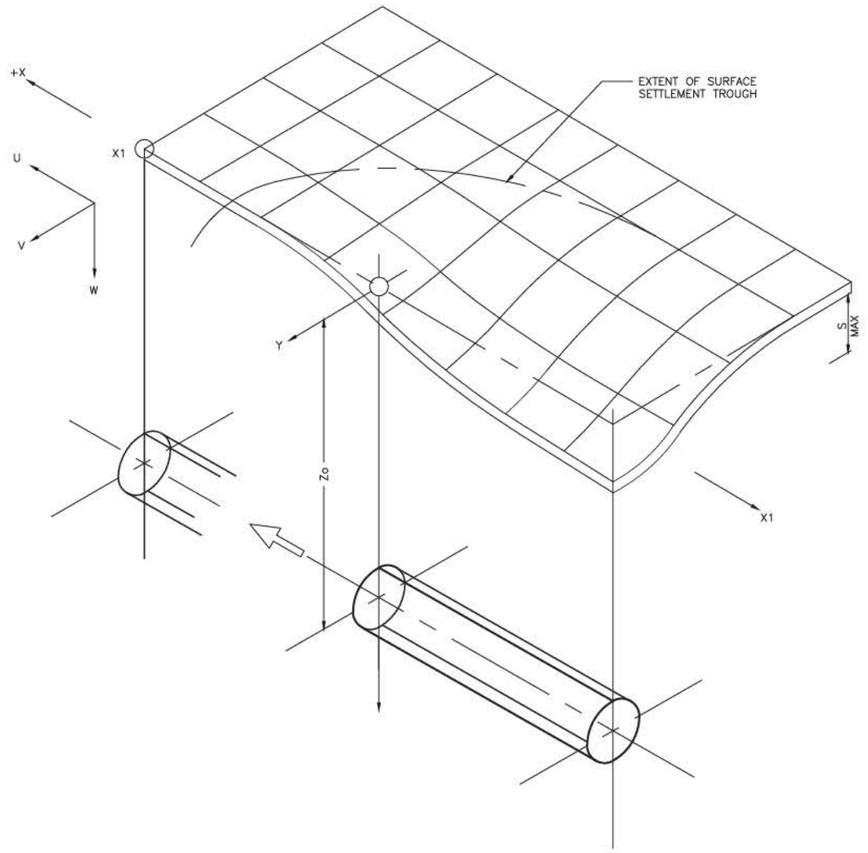






NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS NOTED OTHERWISE.



SETTLEMENT ABOVE ADVANCING TUNNEL HEADING

SCALE 1:500

KEY PLAN

DESIGNED	S. FEKETE	2013-07-10 DATE
DRAWN	P. JACOBCHUK	2013-07-10 DATE
CHECKED	S. SWARTZ	2013-07-10 DATE
APPROVED	A. MCGLENN	2013-07-10 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET EDL-TITLEBLOCK.dwg

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A			P.J.

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SNC·LAVALIN
Constructors Pacific
JV LOGO
SSJV
DESIGNER

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500

0 25

SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

SETTLEMENT CONTOURS

SHEET A

LONGITUDINAL SETTLEMENT AS TUNNEL ADVANCES

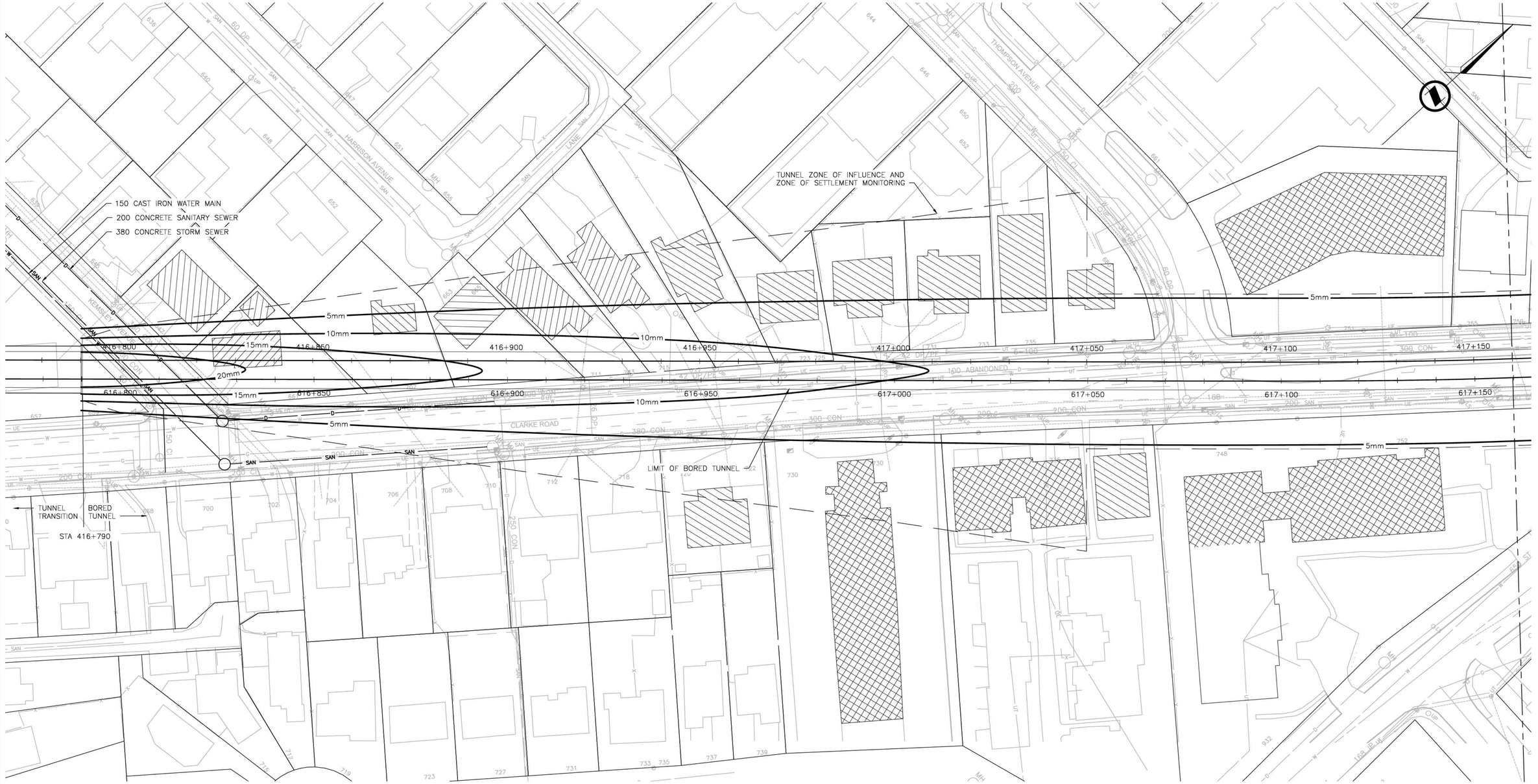
PROVINCE CONTRACT No. 03902

SUB-CONSULTANT No.

DRAWING No. FIGURE 4

A

SUPERCEDES PRINTS OF THIS SHEET WITH LETTERS PREVIOUS TO —



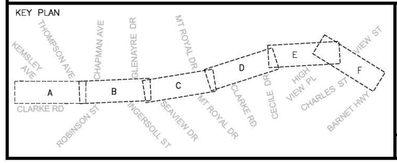
SETTLEMENT CONTOURS PLAN

SCALE 1:500

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS

KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

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DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500

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SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

SETTLEMENT CONTOURS
SHEET A
FROM STA 416+790 TO STA 417+160

PROVINCE CONTRACT No. 03902

SUB-CONSULTANT No.

DRAWING No. FIGURE 5 B

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PRIOR TO

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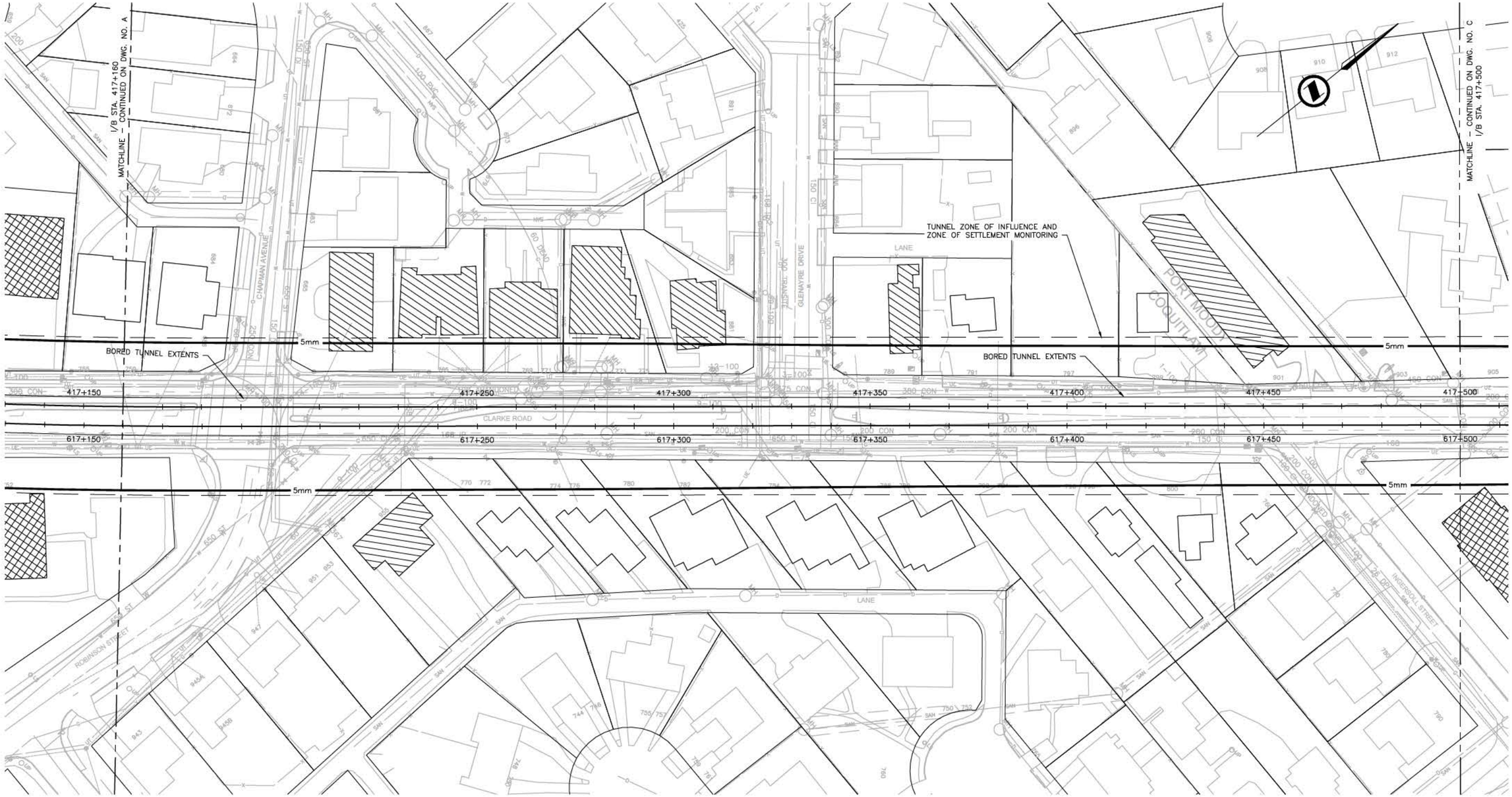
FILE LOCATION: I:\459.1 EVERGREEN LINE RAPID TRANSIT PROJECT\CADD\DOCUMENT\FIGURES\GRND MVMNT\511328-12220-32JA-405D-1001.DWG



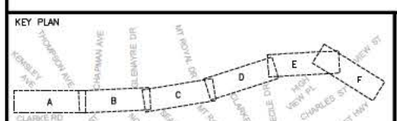
SETTLEMENT CONTOURS PLAN

SCALE 1:500

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS

KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

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JV LOGO: SSJV

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BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500

0 25

SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

SETTLEMENT CONTOURS
SHEET B
FROM STA 417+160 TO STA 417+500

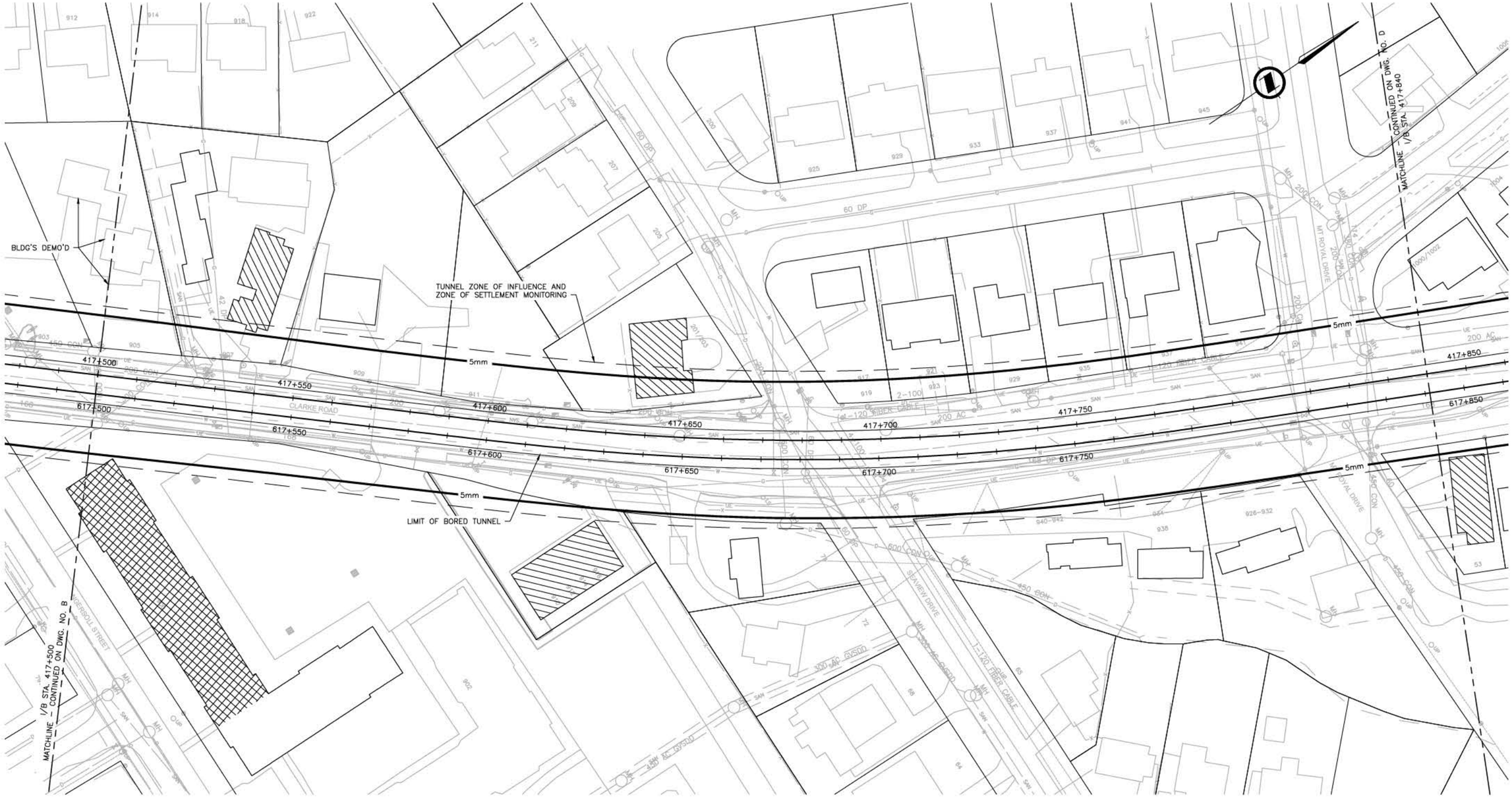
PROVINCE CONTRACT No. 03902

SUB-CONSULTANT No.

DRAWING No. FIGURE 5

A

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PREVIOUS TO —



SETTLEMENT CONTOURS PLAN

SCALE 1:500

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS

KEY PLAN

DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

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JV LOGO: SSJV

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Ministry of Transportation and Infrastructure

SCALE 1:500

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SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

SETTLEMENT CONTOURS

SHEET C

FROM STA 417+500 TO STA 417+840

PROVINCE CONTRACT No. 03902

SUB-CONSULTANT No.

DRAWING No. FIGURE 5

A

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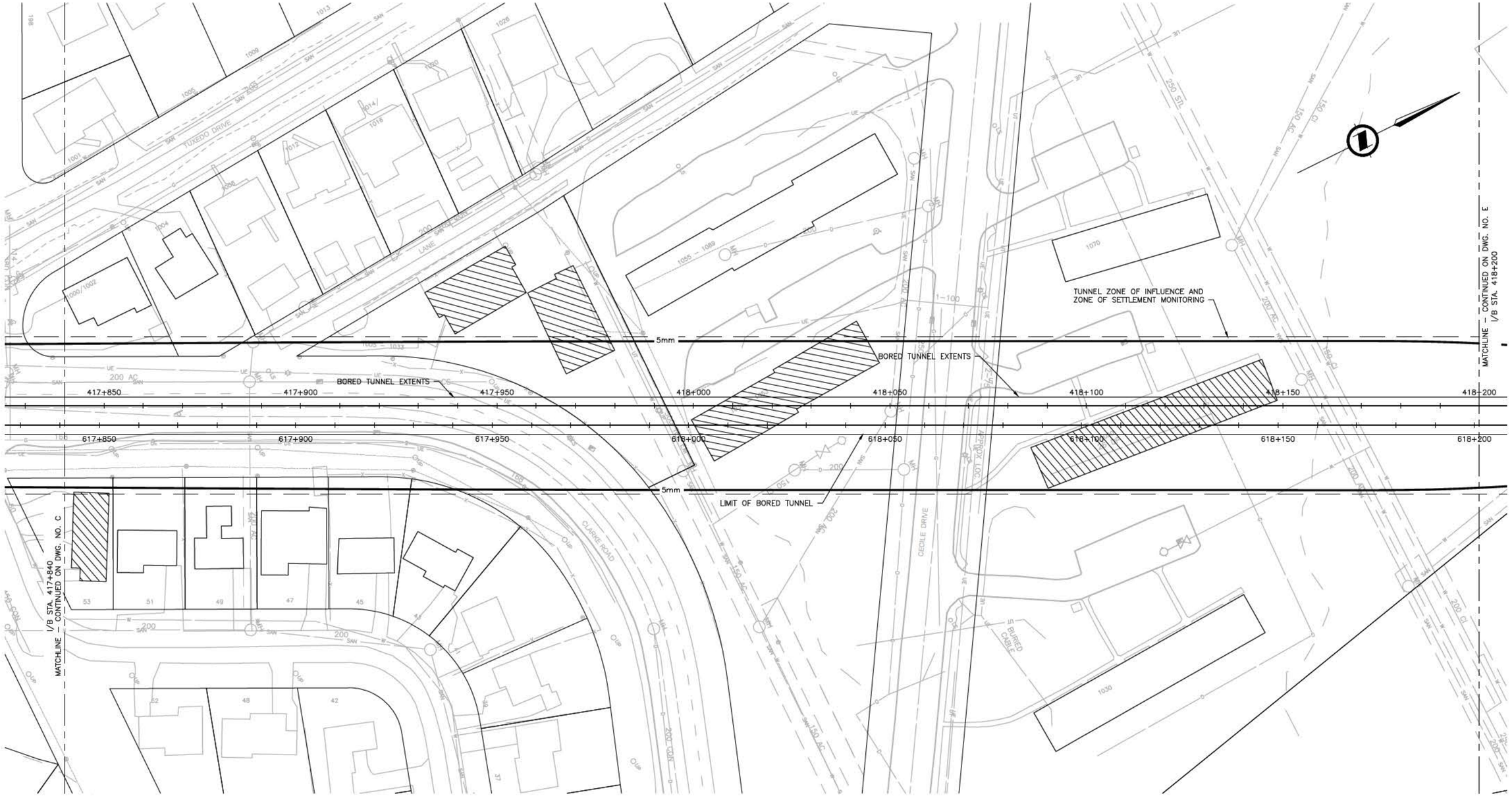

SETTLEMENT CONTOURS PLAN

SCALE 1:500

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS

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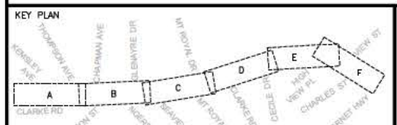

DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

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SNC·LAVALIN Constructors Pacific

JV LOGO: SSJV

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EGRT CONSTRUCTION

British Columbia Ministry of Transportation and Infrastructure

SCALE 1:500

SCALE BAR 0 25

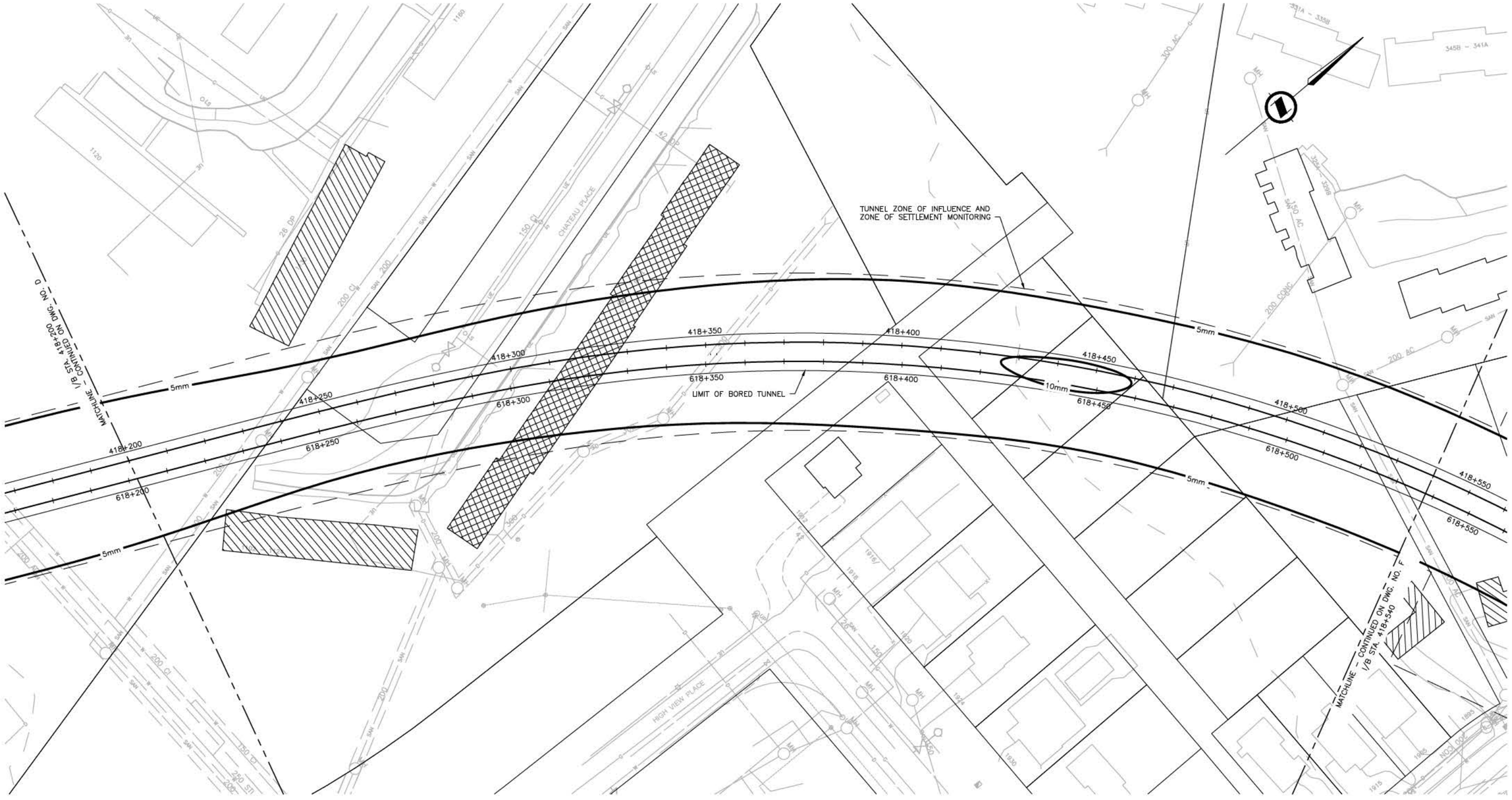
EVERGREEN LINE RAPID TRANSIT PROJECT

SETTLEMENT CONTOURS
SHEET D
FROM STA 417+840 TO STA 418+200

PROVINCE CONTRACT No. 03902 | SUB-CONSULTANT No.

DRAWING No. FIGURE 5 | A

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PREVIOUS TO —



SETTLEMENT CONTOURS PLAN

SCALE 1:500

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS

KEY PLAN

DESIGNED S. FEKETE 2013-08-23 DATE
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CHECKED S. SWARTZ 2013-08-23 DATE
APPROVED A. MCGLENN 2013-08-23 DATE

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Canada. V6E 3C9

JV LOGO SSJV

DESIGNER JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500
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SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT
SETTLEMENT CONTOURS
SHEET E
FROM STA 418+200 TO STA 418+540

PROVINCE CONTRACT No. 03902
SUB-CONSULTANT No.
DRAWING No. JRA-2015-00011 A

FIGURE 5

SUPERCEDES PRINTS OF THIS DRAWING WITH LETTERS PREVIOUS TO —

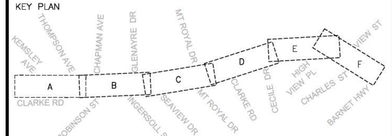
SETTLEMENT CONTOURS PLAN

SCALE 1:500

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS

KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

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DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

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SCALE 1:500

0 25

SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

SETTLEMENT CONTOURS
SHEET F
FROM STA 418+540 TO STA 418+736

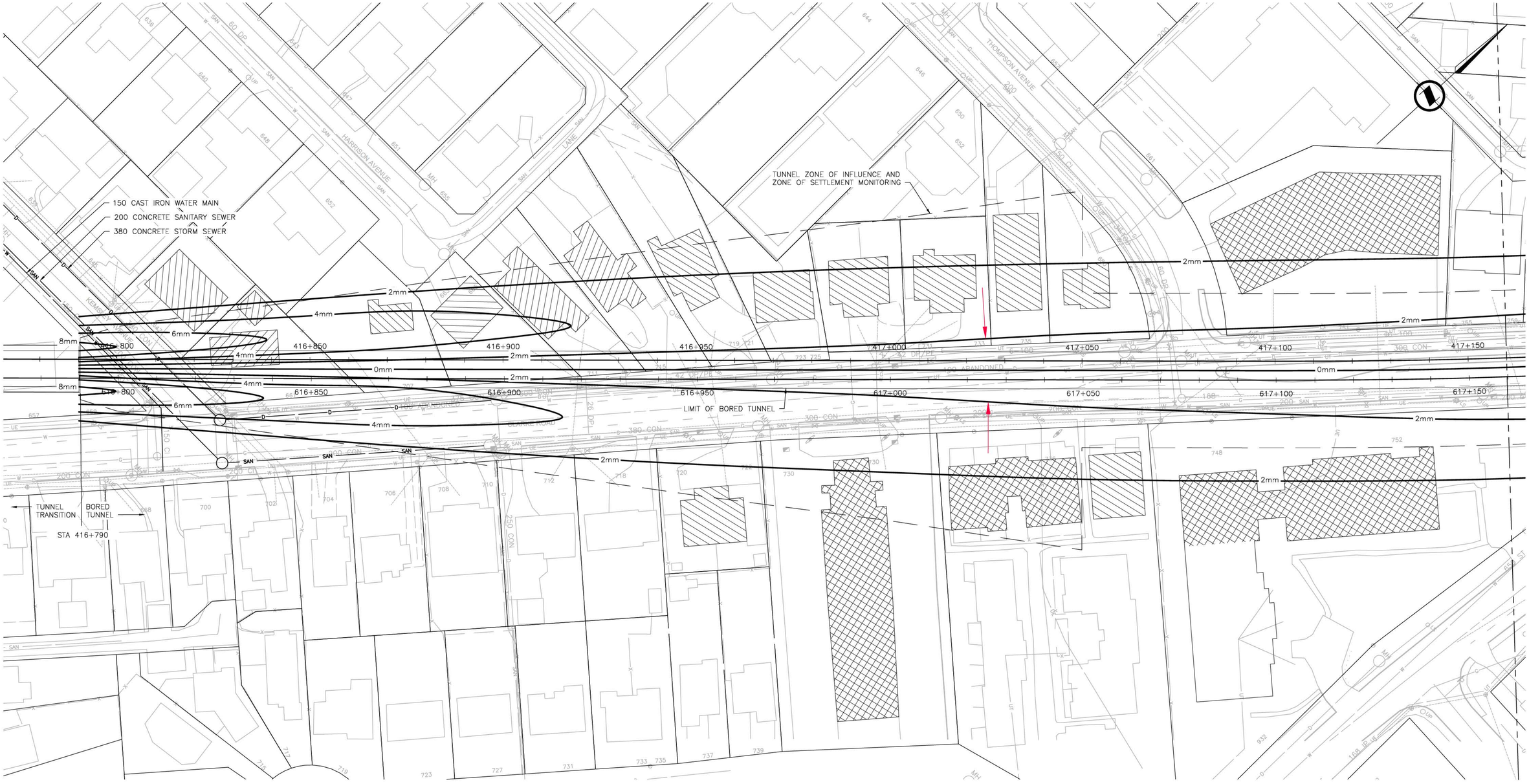
PROVINCE CONTRACT No. 03902
SUB-CONSULTANT No.

DRAWING No. FIGURE 5 B

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PRIOR TO B

TRA-2015-00017
Page 79

LAYOUT: 1006
PLOT DATE: 2013-10-03 11:38 AM LILLY, DAVID
FILE LOCATION: I:\4459.1 EVERGREEN LINE RAPID TRANSIT PROJECT\CADD\DOCUMENT\FIGURES\GRND MWMNT\511328-12220-S2JA-46DD-1006.DWG



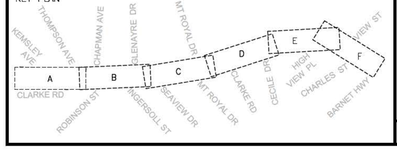
HORIZONTAL MOVEMENT CONTOURS PLAN

SCALE 1:500

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS
2. ← DIRECTION OF HORIZONTAL DISPLACEMENT

KEY PLAN



DESIGNED	S. FEKETE	2013-08-23	DATE
DRAWN	P. JACOBCHUK	2013-08-23	DATE
CHECKED	S. SWARTZ	2013-08-23	DATE
APPROVED	A. MCGLENN	2013-08-23	DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET EGL-TITLEBLOCK.dwg

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B	2013-10-04	REVISED PER COMMENTS	P.J.

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JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

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SCALE 1:500

0 25

SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

HORIZONTAL MOVEMENT CONTOURS SHEET A

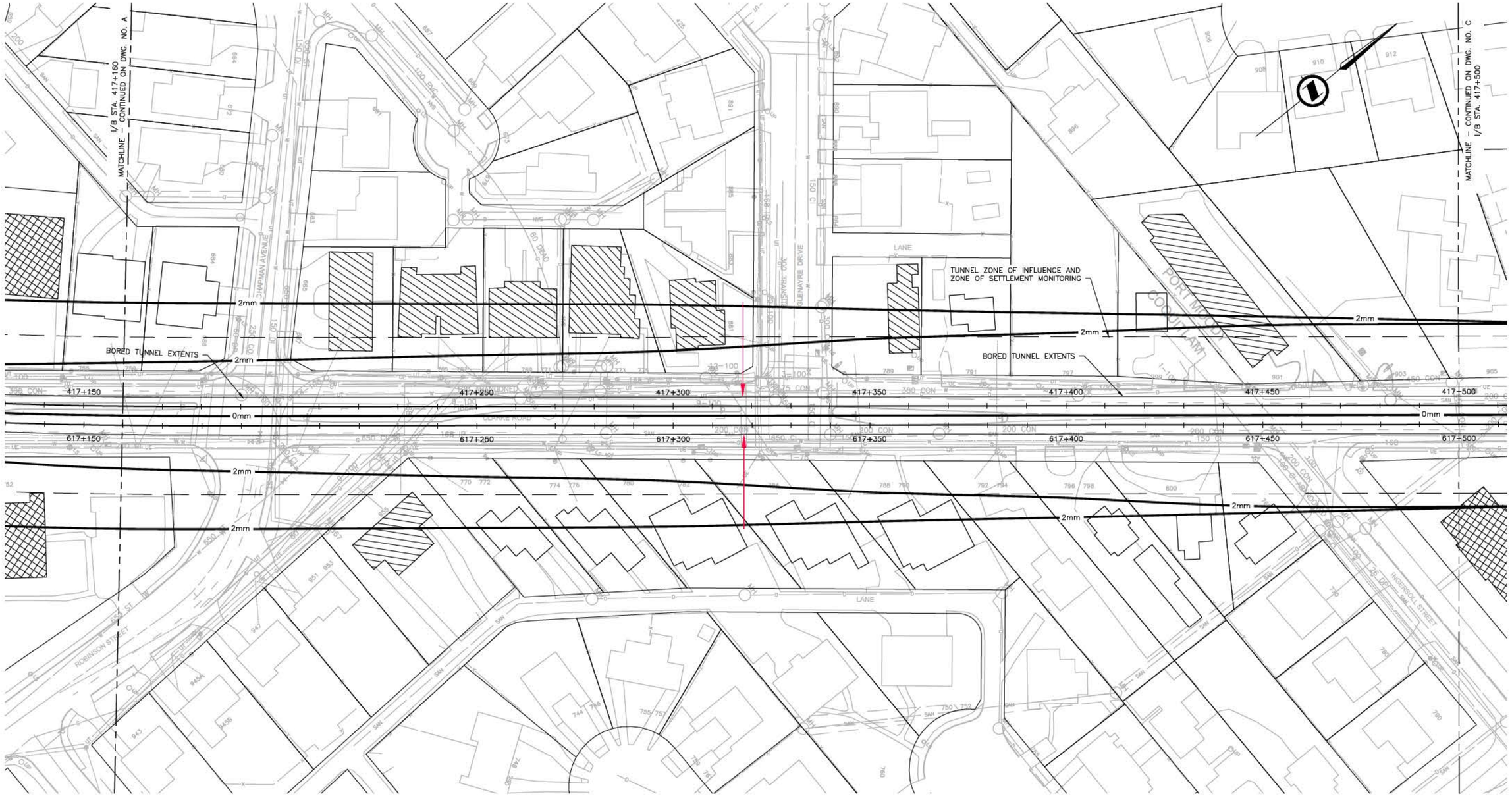
FROM STA 416+790 TO STA 417+160

PROVINCE CONTRACT No. 03902	SUB-CONSULTANT No.
DRAWING No. FIGURE 6	B

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PRIOR TO

TRA-2015-00011

LAYOUT: 1011
PLOT DATE: 2013-10-03 11:41 AM LILLY, DAVID
FILE LOCATION: I:\459.1 EVERGREEN LINE RAPID TRANSIT PROJECT\CAD\DOCUMENT\FIGURES\HORIZONTAL DISPLACEMENT CONTOURS\511328-12220-S2JA-40DD-1011.DWG



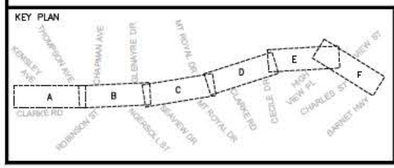
HORIZONTAL MOVEMENT CONTOURS PLAN

SCALE 1:500

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS
2. ← DIRECTION OF HORIZONTAL DISPLACEMENT

KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

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0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

HORIZONTAL MOVEMENT CONTOURS
SHEET B
FROM STA 417+160 TO STA 417+500

PROVINCE CONTRACT No.	SUB–CONSULTANT No.
03902	

DRAWING No. JRA-2015-00011 | A

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PREVIOUS TO —

HORIZONTAL MOVEMENT CONTOURS PLAN

SCALE 1:500

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS
2. ← DIRECTION OF HORIZONTAL DISPLACEMENT

LAYOUT: 1013
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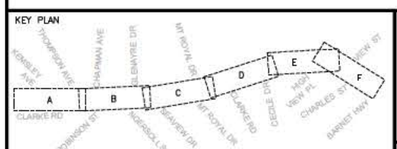

DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

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SSJV
DESIGNER
JACOBS ASSOCIATES
Engineers/Consultants
EGRT CONSTRUCTION
BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:XXX
0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

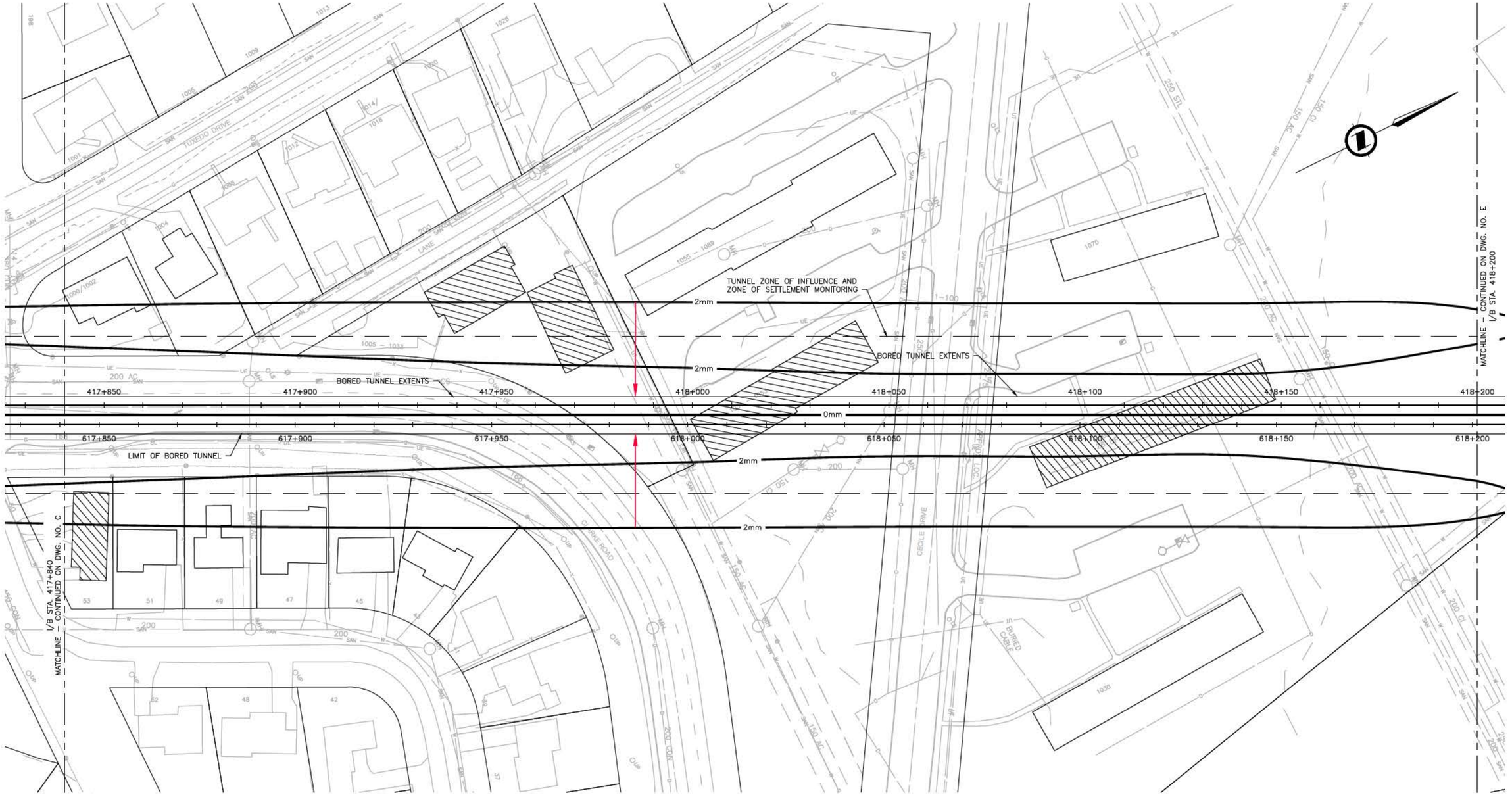
HORIZONTAL MOVEMENT CONTOURS

SHEET C

FROM STA 417+500 TO STA 417+840

PROVINCE CONTRACT No. 03902	SUB-CONSULTANT No.
DRAWING No. JRA-2015-00011	A

SUPERCEDES PRINTS OF THIS SHEET WITH LETTERS PREVIOUS TO —



HORIZONTAL MOVEMENT CONTOURS PLAN

SCALE 1:500

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS
2. DIRECTION OF HORIZONTAL DISPLACEMENT

KEY PLAN

DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

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JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500

0 25

SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

HORIZONTAL MOVEMENT CONTOURS

SHEET D

FROM STA 417+840 TO STA 418+200

PROVINCE CONTRACT No. 03902	SUB-CONSULTANT No.
DRAWING No.	A

FIGURE 6

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PREVIOUS TO —A—

HORIZONTAL MOVEMENT CONTOURS PLAN

SCALE 1:500

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS
2. ← DIRECTION OF HORIZONTAL DISPLACEMENT

LAYOUT: 1015
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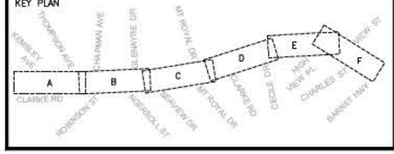
KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET
E2L-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A			P.J.

PROFESSIONAL SEAL

SNC·LAVALIN Constructors Pacific
1800 – 1075 West Georgia Street
Vancouver, B. C.
Canada. V6E 3C9
JV LOGO
SSJV
DESIGNER
JACOBS ASSOCIATES
Engineers/Consultants
EGRT CONSTRUCTION
BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

SCALE 1:500
0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT
HORIZONTAL MOVEMENT CONTOURS
SHEET E
FROM STA 418+200 TO STA 418+540

PROVINCE CONTRACT No. 03902
SUB-CONSULTANT No.
DRAWING No. FIGURE 6 A

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PREVIOUS TO —

HORIZONTAL MOVEMENT CONTOURS PLAN

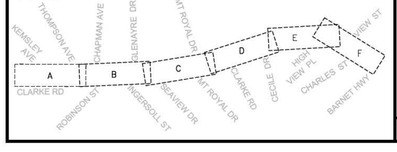
SCALE 1:500

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS
2. ← DIRECTION OF HORIZONTAL DISPLACEMENT

LAYOUT: 1016
PLOT DATE: 2013-10-03 11:43 AM LILLY, DAVID
FILE LOCATION: I:\4459.1 EVERGREEN LINE RAPID TRANSIT PROJECT\CAD\DOCUMENT\FIGURES\HORIZONTAL DISPLACEMENT CONTOURS\511328-12220-S2JA-40DD-1016.DWG

KEY PLAN



DESIGNED	S. FEKETE	2013-08-23
		DATE
DRAWN	P. JACOBCHUK	2013-08-23
		DATE
CHECKED	S. SWARTZ	2013-08-23
		DATE
APPROVED	A. MCGLENN	2013-08-23
		DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET EGL-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A			P.J.
B	2013-10-04	REVISED PER COMMENTS	P.J.

PROFESSIONAL SEAL

1800 – 1075 West Georgia Street
Vancouver, B. C.
Canada, V6E 3C9

SNC·LAVALIN Constructors Pacific

Certified ISO 9001

JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500

SCALE BAR 0 25

EVERGREEN LINE RAPID TRANSIT PROJECT

HORIZONTAL MOVEMENT CONTOURS

SHEET F

FROM STA 418+540 TO STA 418+736

PROVINCE CONTRACT No. 03902

SUB-CONSULTANT No.

DRAWING No. FIGURE 6 B

SUPERCEDES PRINTS OF THIS NUMBER WITH LESSER SUFFIX TRA-2015-00011

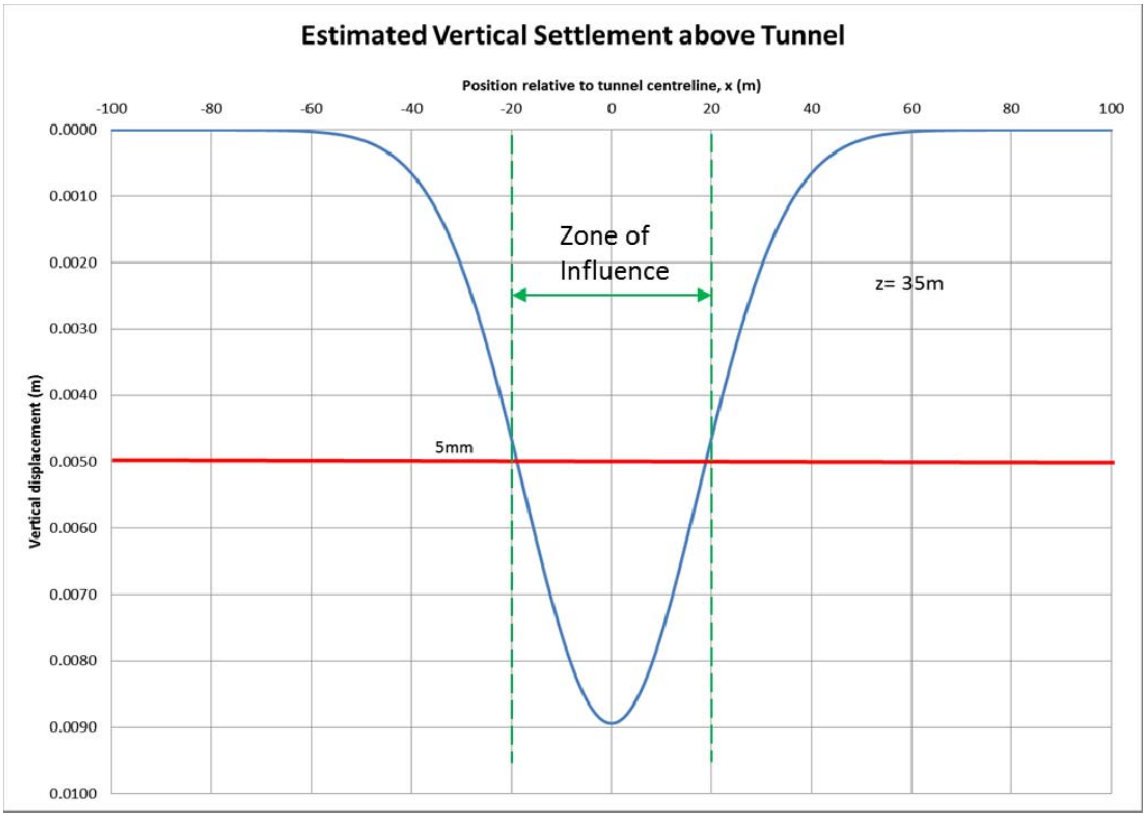
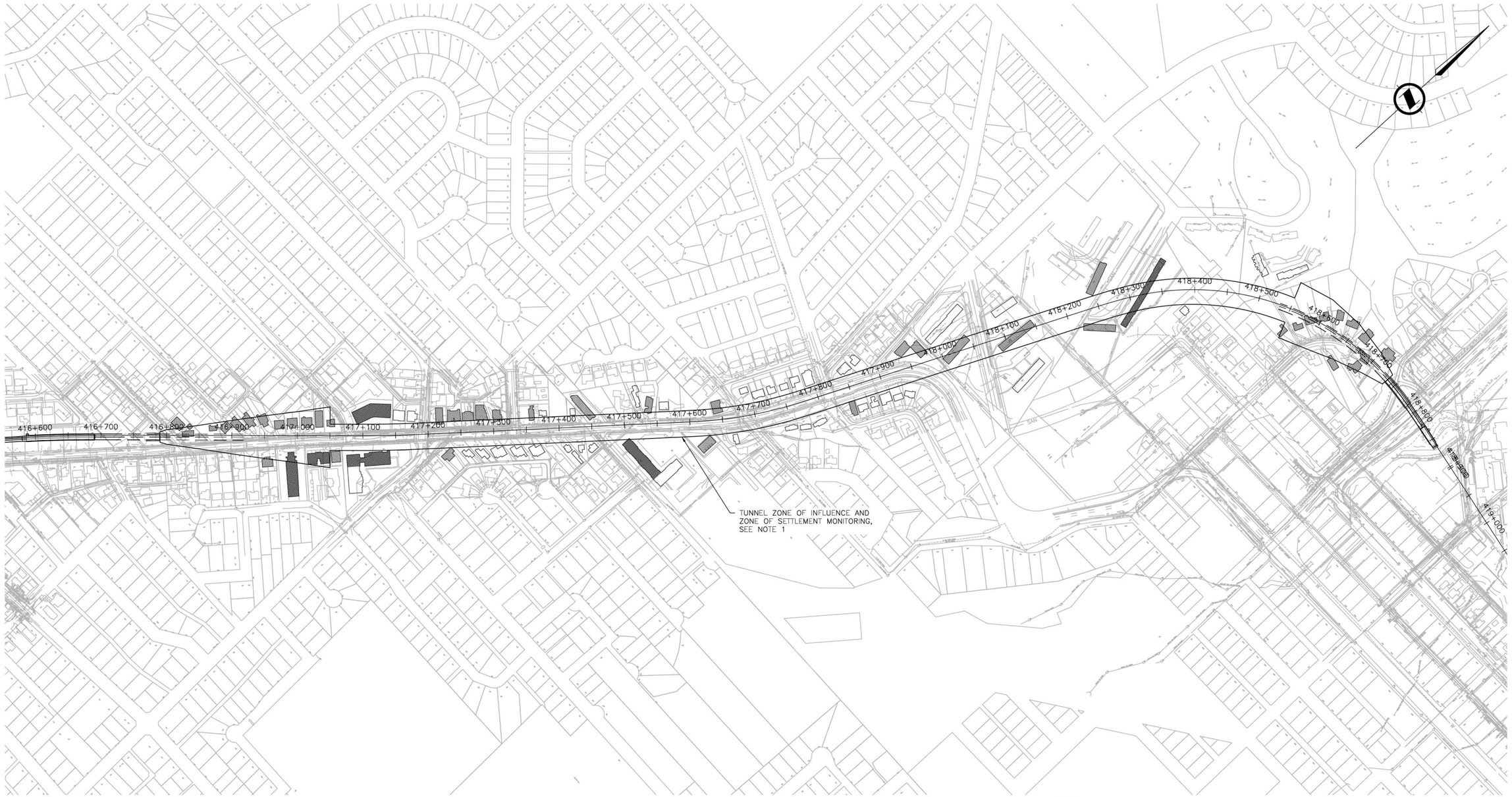


Figure 7- Estimated Vertical Settlement graph, z=35m - showing limits of ZoI where z ≥35m



LEGEND:

EXISTING FACILITIES REQUIRE STRUCTURE SETTLEMENT POINTS

EXISTING FACILITIES WITH LARGER FOOTPRINT, REQUIRE ADDITIONAL SETTLEMENT POINTS

SITEPLAN

SCALE 1:3000

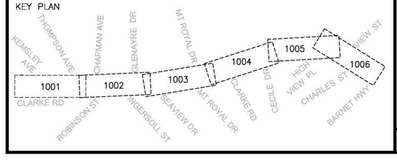
NOTES:

1. ZONE OF SETTLEMENT MONITORING REPRESENTS EXTENT OF AREA REQUIRING INSTRUMENTATION FOR SURFACE SETTLEMENT DEFINED BY 1.5H:1V WHERE V IS DEPTH TO TUNNEL CROWN FROM GROUND SURFACE AND H IS DISTANCE FROM TUNNEL CENTERLINE FOR DEPTHS LESS THAN 35m, AND 20m FROM TUNNEL CENTERLINE FOR DEPTHS GREATER THAN 35m.

ISSUE FOR IDR2

LAYOUT: 0001
PLOT DATE: 2013-10-02 11:43 AM JACOBCHUK, PETER
FILE LOCATION: I:\14459.1 EVERGREEN LINE RAPID TRANSIT PROJECT\CADD\DOCUMENT\CONTRACT DOCS\GEOTECHNICAL INSTRUM

KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET EGL-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A	2013-04-26	ISSUED FOR IDR	P.J.
B	2013-08-23	ISSUED FOR IDR2	P.J.
C	2013-10-04	REVISED PER COMMENTS	P.J.

PROFESSIONAL SEAL

1800 – 1075 West Georgia Street
Vancouver, B. C.
Canada. V6E 3C9

SNC·LAVALIN Constructors Pacific

Certified ISO 9001

JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500

0 25

SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

BORED TUNNEL
GEOTECHNICAL INSTRUMENTATION
SITE PLAN

PROVINCE CONTRACT No. 03902

SUB-CONSULTANT No.

DRAWING No. 511328-12220-S2JA-4GDD-0001 C

SUPERCEDES PRINTS OF THIS NUMBER WITH LESSER SUFFIX LETTER

PLAN
SCALE 1:500

LEGEND:

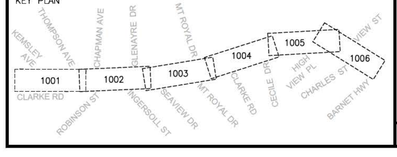
- EXISTING FACILITIES THAT REQUIRE STRUCTURE SETTLEMENT POINTS. (4) POINTS PER FACILITY.
- EXISTING FACILITIES WITH LARGER FOOTPRINT, THAT REQUIRE ADDITIONAL SETTLEMENT POINTS. (8) POINTS PER FACILITY.
- (E) MULTIPOINT BOREHOLE EXTENSOMETER
- SURFACE SETTLEMENT POINT
- EXISTING OBSERVATION WELL WITH PIEZOMETER
- (U) UTILITY SETTLEMENT POINT

NOTES:

1. STATIONING SHOWN IS FOR I/B TRACK ALIGNMENT.
2. BORE HOLES WITH PIEZOMETERS TO BE INCLUDED IN MONITORING PROGRAM: BH09-207, BH06-3, BH00-13
3. BORE HOLES TO BE DECOMMISSIONED PRIOR TO TUNNEL WITHIN 100m: BH00-13.

ISSUE FOR IDR2

KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET
EGL-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A	2013-04-26	ISSUED FOR IDR	P.J.
B	2013-08-23	ISSUED FOR IDR2	P.J.
C	2013-10-04	REVISED PER COMMENTS	P.J.

PROFESSIONAL SEAL

1800 - 1075 West Georgia Street
Vancouver, B. C.
Canada. V6E 3C9
SNC·LAVALIN Constructors Pacific
JV LOGO
SSJV
DESIGNER
JACOBS ASSOCIATES
Engineers/Consultants

EGRT CONSTRUCTION
BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

SCALE 1:500
0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT
BORED TUNNEL
GEOTECHNICAL INSTRUMENTATION PLAN
FROM STA 416+790 TO STA 417+160

PROVINCE CONTRACT No. 03902	SUB-CONSULTANT No.
DRAWING No. 511328-12220-S2JA-4GDD-1001	C

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PREVIOUS TO

PLAN
SCALE 1:500

LEGEND:

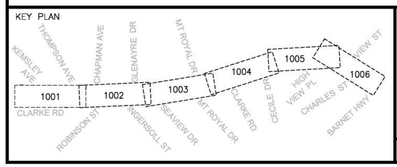
- EXISTING FACILITIES THAT REQUIRE STRUCTURE SETTLEMENT POINTS. (4) POINTS PER FACILITY.
- EXISTING FACILITIES WITH LARGER FOOTPRINT, THAT REQUIRE ADDITIONAL SETTLEMENT POINTS. (8) POINTS PER FACILITY.
- MULTIPOINT BOREHOLE EXTENSOMETER
- SURFACE SETTLEMENT POINT
- EXISTING OBSERVATION WELL WITH PIEZOMETER
- UTILITY SETTLEMENT POINT

NOTES:

1. STATIONING SHOWN IS FOR I/B TRACK ALIGNMENT.
2. BORE HOLE TO BE DECOMMISSIONED PRIOR TO TUNNEL CONSTRUCTION: BH09–208

ISSUE FOR IDR2

KEY PLAN



DESIGNED	S. FEKETE	2013–08–23 DATE
DRAWN	P. JACOBCHUK	2013–08–23 DATE
CHECKED	S. SWARTZ	2013–08–23 DATE
APPROVED	A. MCGLENN	2013–08–23 DATE

SCALE BAR AS PER 1:1 ANSI D–SIZE SHEET EGL–TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A	2013–04–26	ISSUED FOR IDR	P.J.
B	2013–08–23	ISSUED FOR IDR2	P.J.

PROFESSIONAL SEAL

1800 – 1075 West Georgia Street
Vancouver, B. C.
Canada. V6E 3C9
SNC·LAVALIN Constructors Pacific
JV LOGO
SSJV
DESIGNER
JACOBS ASSOCIATES
Engineers/Consultants
EGRT CONSTRUCTION
BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

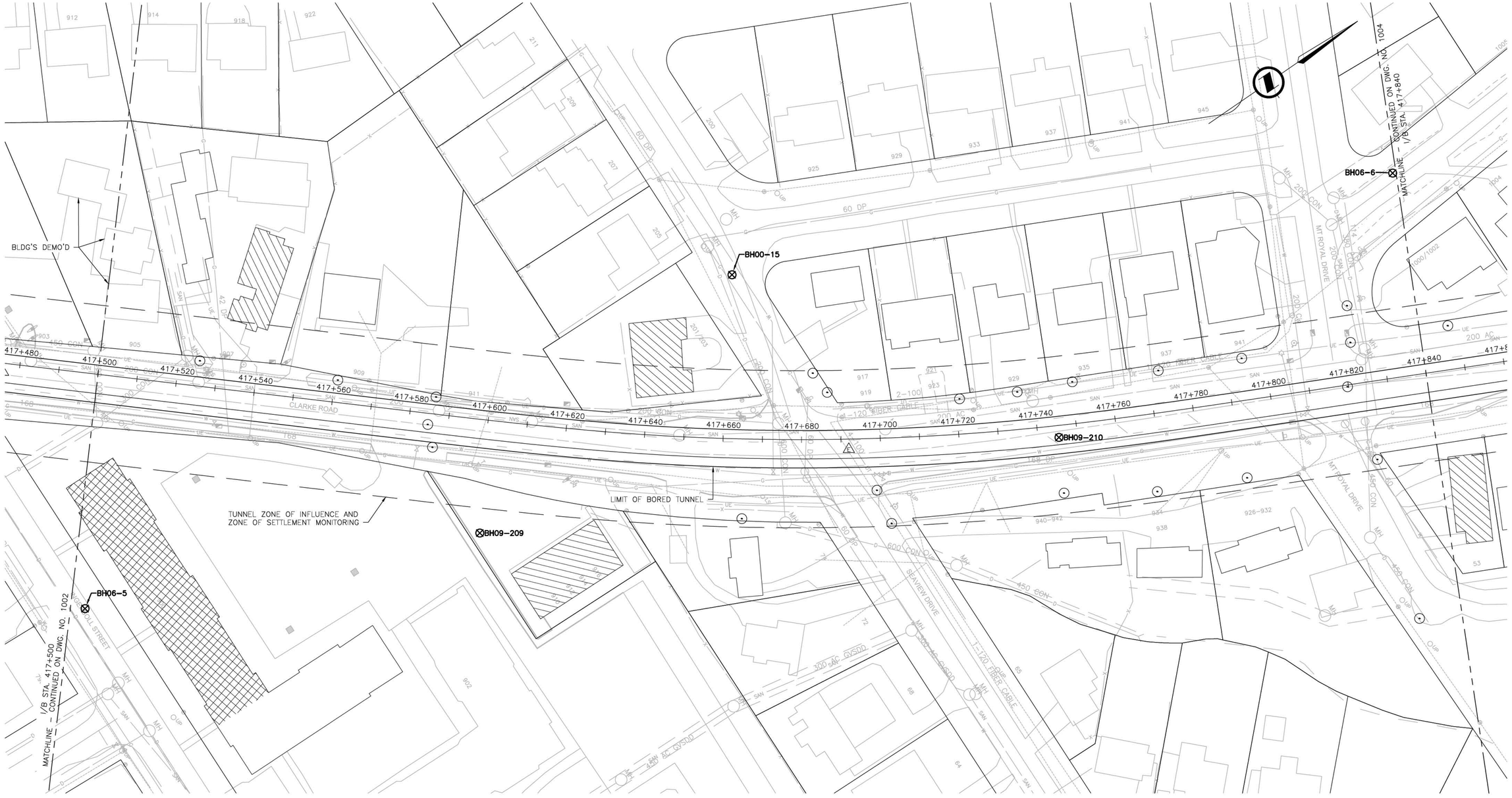
SCALE 1:500
0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT
BORED TUNNEL
GEOTECHNICAL INSTRUMENTATION PLAN
FROM STA 417+160 TO STA 417+500

PROVINCE CONTRACT No. 03902	SUB–CONSULTANT No.
DRAWING No. 511328–12220–S2JA–4GDD–1002	B

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PRIOR TO B

LAYOUT: 1002
PLOT DATE: 2013–10–02 11:46 AM JACOBCHUK, PETER
FILE LOCATION: I:\1459.1 EVERGREEN LINE RAPID TRANSIT PROJECT\CADD\DOCUMENT\CONTRACT DOCS\GEOTECHNICAL INSTRUMENTATION\511328–12220–S2JA–4GDD–1002.DWG



PLAN
SCALE 1:500

LEGEND:

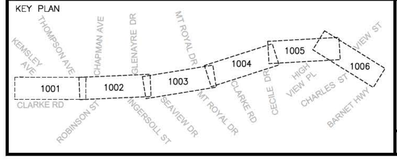
- EXISTING FACILITIES THAT REQUIRE STRUCTURE SETTLEMENT POINTS. (4) POINTS PER FACILITY.
- EXISTING FACILITIES WITH LARGER FOOTPRINT, THAT REQUIRE ADDITIONAL SETTLEMENT POINTS. (8) POINTS PER FACILITY.
- MULTIPOINT BOREHOLE EXTENSOMETER
- SURFACE SETTLEMENT POINT
- EXISTING OBSERVATION WELL WITH PIEZOMETER
- UTILITY SETTLEMENT POINT

NOTES:

1. STATIONING SHOWN IS FOR I/B TRACK ALIGNMENT.
2. BORE HOLES WITH PIEZOMETERS TO BE INCLUDED IN MONITORING PROGRAM: BH09-209
3. BORE HOLES TO BE DECOMMISSIONED PRIOR TO TUNNEL CONSTRUCTION: BH09-210

ISSUE FOR IDR2

KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET EGL-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A	2013-04-26	ISSUED FOR IDR	P.J.
B	2013-08-23	ISSUED FOR IDR2	P.J.

PROFESSIONAL SEAL

SNC·LAVALIN Constructors Pacific
1800 – 1075 West Georgia Street
Vancouver, B. C.
Canada. V6E 3C9
Certified ISO 9001

JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

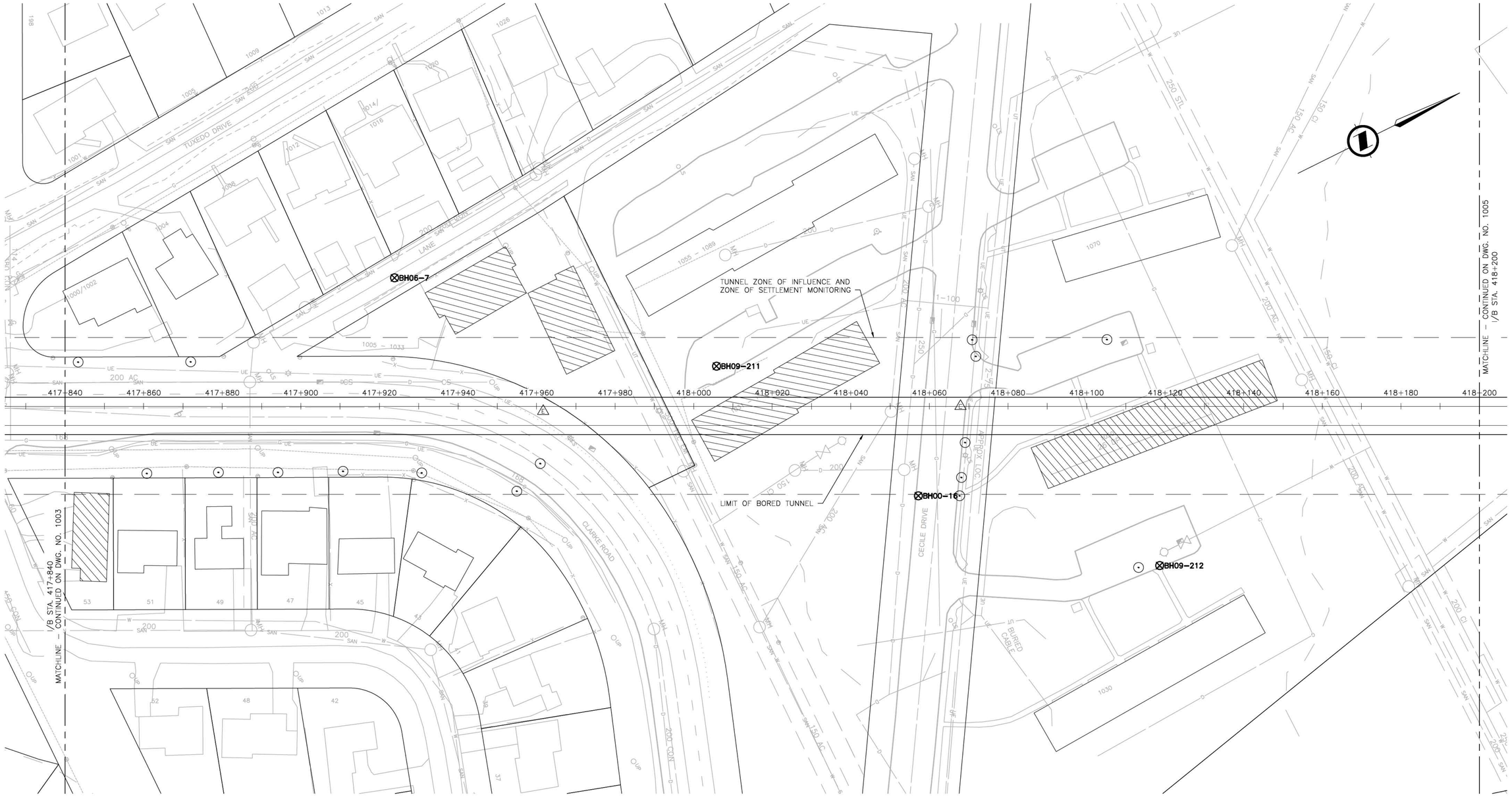
SCALE 1:500
0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT
BORED TUNNEL
GEOTECHNICAL INSTRUMENTATION PLAN
FROM STA 417+500 TO STA 417+840

PROVINCE CONTRACT No. 03902
SUB-CONSULTANT No.
DRAWING No. 511328-12220-S2JA-4GDD-1003 B

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PRIOR TO B
TRA-2015-00011
Page 90

LAYOUT: 1003
PLOT DATE: 2013-10-02 11:47 AM JACOBCHUK, PETER
FILE LOCATION: I:\449.1 EVERGREEN LINE RAPID TRANSIT PROJECT\CADD\DOCUMENT\CONTRACT DOCS\GEOTECHNICAL INSTRUMENTATION\511328-12220-S2JA-4GDD-1003.DWG



LEGEND:

- EXISTING FACILITIES THAT REQUIRE STRUCTURE SETTLEMENT POINTS. (4) POINTS PER FACILITY.
- EXISTING FACILITIES WITH LARGER FOOTPRINT, THAT REQUIRE ADDITIONAL SETTLEMENT POINTS. (8) POINTS PER FACILITY.
- MULTIPOINT BOREHOLE EXTENSOMETER
- SURFACE SETTLEMENT POINT
- EXISTING OBSERVATION WELL WITH PIEZOMETER
- UTILITY SETTLEMENT POINT

PLAN

SCALE 1:500

NOTES:

1. STATIONING SHOWN IS FOR I/B TRACK ALIGNMENT.
2. BORE HOLES WITH PIEZOMETERS TO BE INCLUDED IN MONITORING PROGRAM: BH09-211, BH00-16

ISSUE FOR IDR2

LAYOUT: 1004
PLOT DATE: 2013-10-02 11:49 AM JACOBCHUK, PETER
FILE LOCATION: K:\4459.1 EVERGREEN LINE RAPID TRANSIT PROJECT\CADD\DOCUMENT\CONTRACT DOCS\GEOTECHNICAL INSTRUMENTATION\511328-12220-S2JA-4GDD-1004.DWG

KEY PLAN

DESIGNED	S. FEKETE 2013-08-23 DATE
DRAWN	P. JACOBCHUK 2013-08-23 DATE
CHECKED	S. SWARTZ 2013-08-23 DATE
APPROVED	A. MCGLENN 2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET
EGL-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A	2013-04-26	ISSUED FOR IDR	P.J.
B	2013-08-23	ISSUED FOR IDR2	P.J.

PROFESSIONAL SEAL

1800 - 1075 West Georgia Street
Vancouver, B. C.
Canada. V6E 3C9

SNC·LAVALIN Constructors Pacific

Certified ISO 9001

JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500

0 25

SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

BORED TUNNEL

GEOTECHNICAL INSTRUMENTATION PLAN

FROM STA 417+840 TO STA 418+200

PROVINCE CONTRACT No. 03902	SUB-CONSULTANT No.
DRAWING No. 511328-12220-S2JA-4GDD-1004	B

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PRECEDING IT

PLAN
SCALE 1:500

LEGEND:

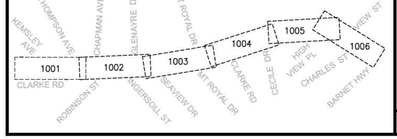
- EXISTING FACILITIES THAT REQUIRE STRUCTURE SETTLEMENT POINTS. (4) POINTS PER FACILITY.
- EXISTING FACILITIES WITH LARGER FOOTPRINT, THAT REQUIRE ADDITIONAL SETTLEMENT POINTS. (8) POINTS PER FACILITY.
- MULTIPOINT BOREHOLE EXTENSOMETER
- SURFACE SETTLEMENT POINT
- EXISTING OBSERVATION WELL WITH PIEZOMETER
- (U) UTILITY SETTLEMENT POINT

NOTES:

1. STATIONING SHOWN IS FOR I/B TRACK ALIGNMENT.
2. BORE HOLES WITH PIEZOMETERS TO BE INCLUDED IN MONITORING PROGRAM: BH09–215, BH09–214
3. BORE HOLES TO BE DECOMMISSIONED PRIOR TO TUNNEL CONSTRUCTION: BH09–213.

ISSUE FOR IDR2

KEY PLAN



DESIGNED	S. FEKETE	2013–08–23 DATE
DRAWN	P. JACOBCHUK	2013–08–23 DATE
CHECKED	S. SWARTZ	2013–08–23 DATE
APPROVED	A. MCGLENN	2013–08–23 DATE

SCALE BAR AS PER 1:1 ANSI D–SIZE SHEET EGL–TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A	2013–04–26	ISSUED FOR IDR	P.J.
B	2013–08–23	ISSUED FOR IDR2	P.J.

PROFESSIONAL SEAL

SNC·LAVALIN Constructors Pacific
1800 – 1075 West Georgia Street
Vancouver, B. C.
Canada. V6E 3C9
Certified ISO 9001

JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500
0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT
BORED TUNNEL
GEOTECHNICAL INSTRUMENTATION PLAN
FROM STA 418+200 TO STA 418+540

PROVINCE CONTRACT No. 03902
SUB–CONSULTANT No.
DRAWING No. 511328–12220–S2JA–4GDD–1005 B

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTER SMALLER THAN B

TRA-2015-00011
Page 92

LAYOUT: 1005
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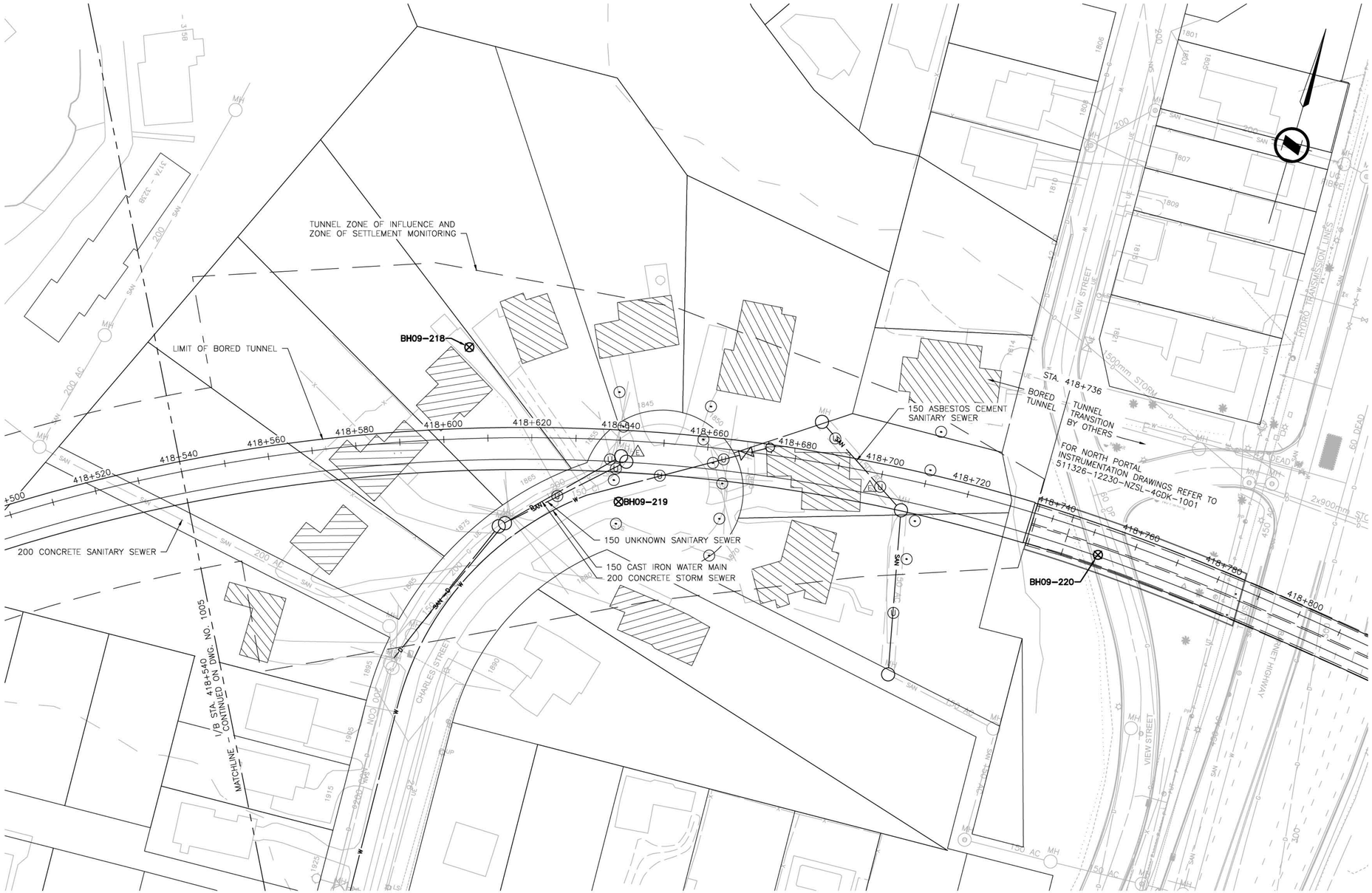


PLAN
SCALE 1:500

LEGEND:

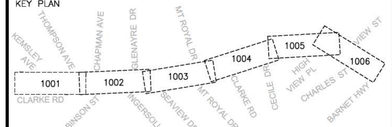
- EXISTING FACILITIES THAT REQUIRE STRUCTURE SETTLEMENT POINTS. (4) POINTS PER FACILITY.
- EXISTING FACILITIES WITH LARGER FOOTPRINT, THAT REQUIRE ADDITIONAL SETTLEMENT POINTS. (8) POINTS PER FACILITY.
- MULTIPOINT BOREHOLE EXTENSOMETER
- SURFACE SETTLEMENT POINT
- EXISTING OBSERVATION WELL WITH PIEZOMETER
- UTILITY SETTLEMENT POINT

NOTES:

1. STATIONING SHOWN IS FOR I/B TRACK ALIGNMENT.
2. BORE HOLES WITH PIEZOMETERS TO BE INCLUDED IN MONITORING PROGRAM: BH09-18, BH09-219

ISSUE FOR IDR2

KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET
EGL-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A	2013-04-26	ISSUED FOR IDR	P.J.
B	2013-08-23	ISSUED FOR IDR2	P.J.
B	2013-10-04	REVISED PER COMMENTS	P.J.

PROFESSIONAL SEAL

1800 - 1075 West Georgia Street
Vancouver, B. C.
Canada. V6E 3C9

SNC·LAVALIN Constructors Pacific

JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

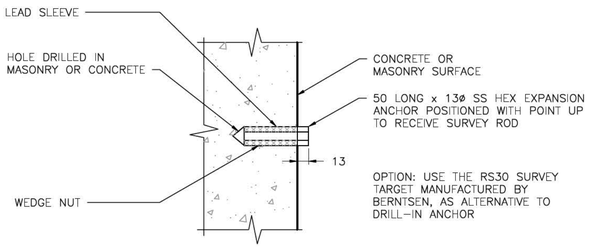
SCALE 1:500
0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT
BORED TUNNEL
GEOTECHNICAL INSTRUMENTATION PLAN
FROM STA 418+540 TO STA 418+736

PROVINCE CONTRACT No. 03902	SUB-CONSULTANT No.
DRAWING No. 511328-12220-S2JA-4GDD-1006	C

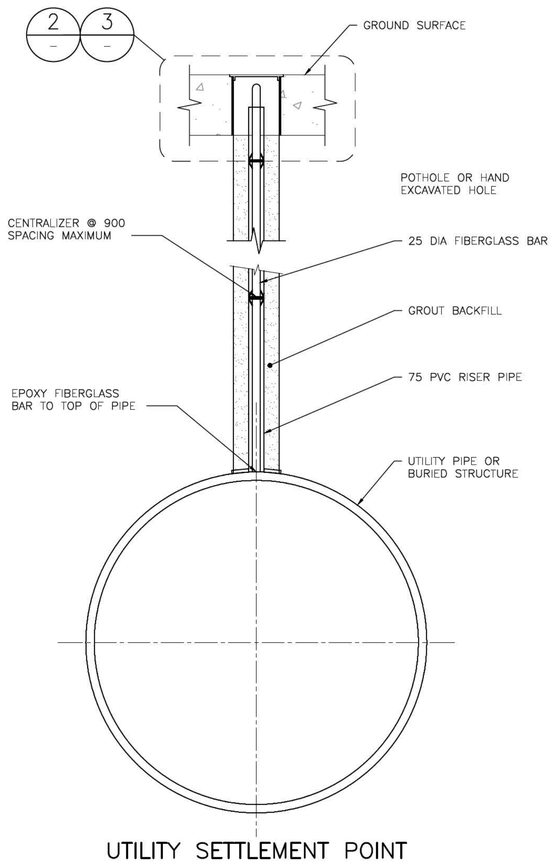
SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS BEFORE IT
TRR-2015-00011

LAYOUT: 1006
PLOT DATE: 2013-10-02 11:52 AM JACOBCHUK, PETER
FILE LOCATION: I:\4459.1 EVERGREEN LINE RAPID TRANSIT PROJECT\CADD\DOCUMENT\CONTRACT DOCS\GEOTECHNICAL INSTRUMENTATION\511328-12220-S2JA-4GDD-1006.DWG



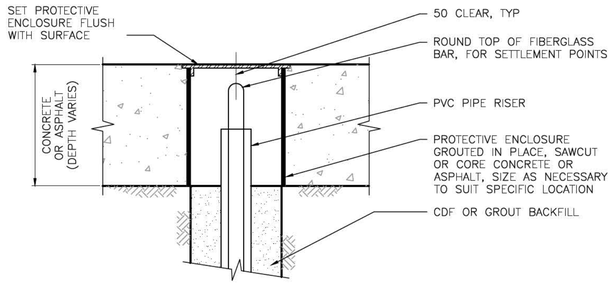
STRUCTURE SETTLEMENT POINT IN MASONRY OR CONCRETE WALL

1 / – DETAIL
SCALE NTS



UTILITY SETTLEMENT POINT

4 / – DETAIL
SCALE NTS

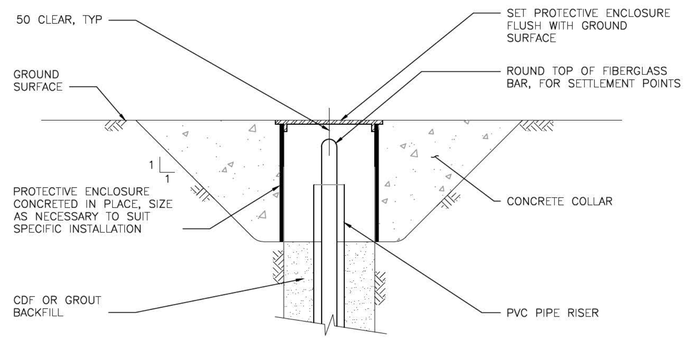


PROTECTIVE ENCLOSURE IMPROVED AREAS

2 / – DETAIL
SCALE NTS

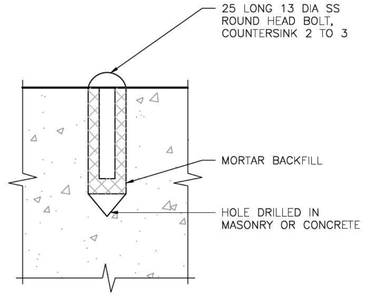
NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS NOTED OTHERWISE.



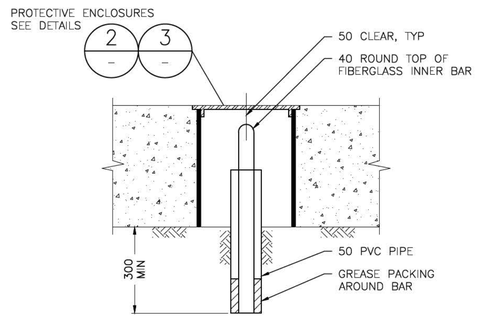
PROTECTIVE ENCLOSURE UNIMPROVED AREAS

3 / – DETAIL
SCALE NTS



SURFACE SETTLEMENT POINT IN HORIZONTAL SURFACE

5 / – DETAIL
SCALE NTS



NEAR SURFACE SETTLEMENT POINT

6 / – DETAIL
SCALE NTS

ISSUE FOR IDR2

LAYOUT: 4001
PLOT DATE: 2013-10-02 11:52 AM JACOBCHUK, PETER
FILE LOCATION: I:\V4459.1 EVERGREEN LINE RAPID TRANSIT PROJECT\CADD\DOCUMENT\CONTRACT DOCS\GEOTECHNICAL INSTRUMENTATION\511328-12220-S2JA-4GDD-4001.DWG

KEY PLAN

DESIGNED	S. SWARTZ	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	A. MCGLENN	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET EGL-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A	2013-04-26	ISSUED FOR IDR	P.J.
B	2013-08-23	ISSUED FOR IDR2	P.J.

PROFESSIONAL SEAL

SNC·LAVALIN Constructors Pacific
1800 – 1075 West Georgia Street
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Canada. V6E 3C9
Certified ISO 9001

JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500
0 25
SCALE BAR

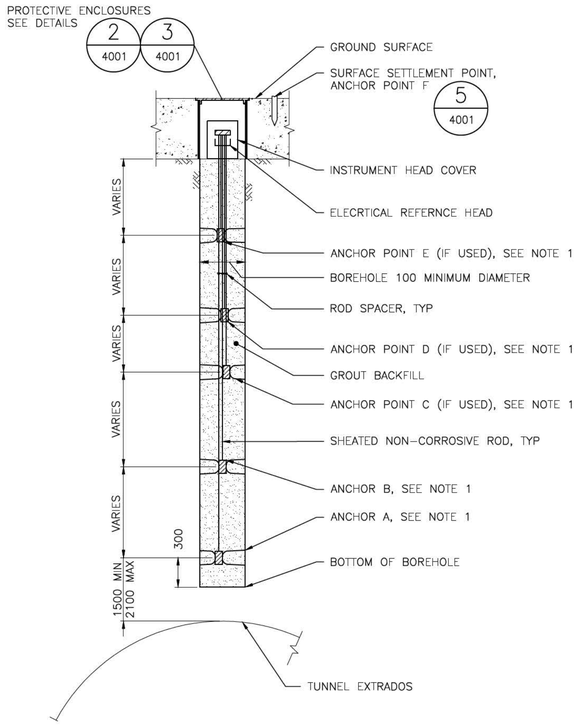
EVERGREEN LINE RAPID TRANSIT PROJECT
BORED TUNNEL
DETAILS
FROM 1 OF 2

PROVINCE CONTRACT No. 03902
SUB-CONSULTANT No.
DRAWING No. 511328-12220-S2JA-4GDD-4001 B

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTER SERIES 'A'

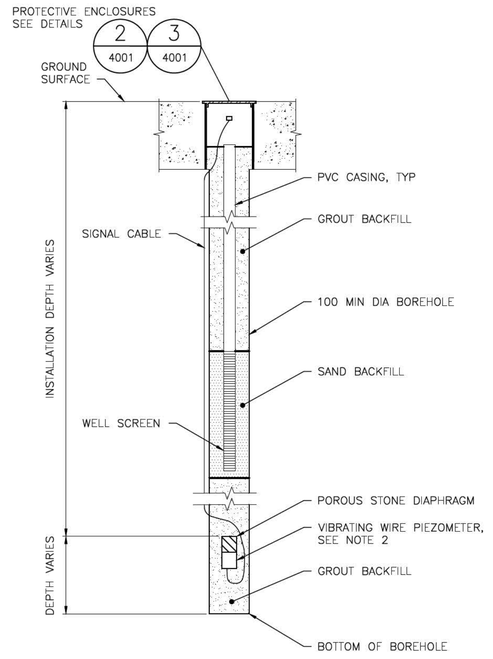
NOTES:

1. FOR DEPTHS OF ANCHORS, SPACE ANCHORS APPROXIMATELY EVENLY BETWEEN ANCHOR A AND THE GROUND SURFACE. DO NOT EXCEED 10m SPACING BETWEEN ANCHORS.
2. PIEZOMETERS HAVE BEEN INSTALLED DURING PREVIOUS WORK. NO NEW INSTALLATIONS ARE REQUIRED.
3. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS NOTED OTHERWISE.



TYPICAL MULTIPOINT BOREHOLE EXTENSOMETER

2 DETAIL – SCALE NTS



TYPICAL OBSERVATION WELL AND VIBRATING WIRE PIEZOMETER INSTALLATION

3 DETAIL – SCALE NTS

ISSUE FOR IDR2

LAYOUT: 4002
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FILE LOCATION: I:\4459.1 EVERGREEN LINE RAPID TRANSIT PROJECT\CADD\DOCUMENT\CONTRACT DOCS\GEOTECHNICAL INSTRUMENTATION\511328-12220-S2JA-4GDD-4002.DWG

KEY PLAN

DESIGNED	S. SWARTZ	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	A. MCGLENN	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

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EGL-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A	2013-04-26	ISSUED FOR IDR	P.J.
B	2013-08-23	ISSUED FOR IDR2	P.J.

PROFESSIONAL SEAL

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SNC·LAVALIN Constructors Pacific
Certified ISO 9001
JV LOGO SSJV
DESIGNER JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION
BRITISH COLUMBIA Ministry of Transportation and Infrastructure
SCALE 1:500
0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT
BORED TUNNEL
DETAILS
FROM 2 OF 2

PROVINCE CONTRACT No. 03902
SUB-CONSULTANT No.
DRAWING No. 511328-12220-S2JA-4GDD-4002 B

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PRIOR TO "B"

SSJV

EVERGREEN LINE RAPID TRANSIT PROJECT

AMENDMENT TO COMBINED CRIAR/IMP/I&M SUBMISSION

Prepared by:	Samuel Swartz, P.E. (WA, CA)	
Reviewed by:	Andrew McGlenn, P.Eng., S.E.	
Reviewed by:		
Approved by:	Andrew McGlenn, P.Eng., S.E.	
	Name, Title	Signature

Document No.	**511328-12220-S2JA-4GCR-0002**	Rev: 01
SLCW-SELI, Joint Venture		2014/06/24

E:\Evergreen Design\Settlement and Instrumentation\Doc1.docx

JACOBS ASSOCIATES
Engineers/Consultants

PROJECT MEMORANDUM

To:	Marco Moccichino
cc:	Ardalan Hamidi
From:	Samuel Swartz, Andrew McGlenn, P.Eng.
Job No.:	4459.2
Date:	June 23, 2014
Subject:	Amendment to Combined CRIAR/IMP/I&M Submission

1 Introduction

The SELI - SNC-Lavalin Joint Venture (SSJV) has requested that Jacobs Associates revise the current Combined CRIAR / IMP / I&M to adjust the frequency of geotechnical instrumentation monitoring, and to revise the locations of geotechnical instrumentation along the project alignment. The following is a general overview of changes in this amendment:

- Section 8.8.2: Revise monitoring frequencies for Schedules A and B.
- Figure 8: Revise Drawings 511318-12220-S2JA-4GDD-1001, 1002 and 1004 for extensometer locations.

This technical memorandum summarizes these revisions and provides justification for the changes.

2 Revisions to Monitoring Frequencies

The following revisions are made to portions of Section 8.8.2 of the Combined CRIAR/IMP/I&M, focusing on changes to Schedules A and B. Changes are made based upon RFV – Instrumentation & Monitoring Plan, Ref. 511325-00000-SWSL-30CC-0266, which provided clarification on monitoring requirements for Existing Conditions above the tunnel.

Schedule A – For settlement points within 50m of portals

Steps 1 to 4: No changes.

5. For TBM launch (North Portal instruments):
    a. Read instrument daily for 3 days prior to TBM launch.
    b. Continue with daily readings until TBM is greater than 50m beyond the instrument.
    c. Obtain weekly readings until TBM is greater than 200m beyond the instrument.

1166 Alberni Street, Suite 1408, Vancouver, BC V6E 3Z3, Canada Phone: (604) 336-8630 Fax: (604) 336-8631

d. Obtain one monthly reading after weekly readings, and compare readings. If readings are within +/- 2mm, readings can be discontinued; otherwise continue monthly readings until successive readings are within +/- 2mm.
e. Reading frequency shall be increased if excessive settlement are recorded before, during, or after TBM passage per SSJV's discretion.

6. For TBM retrieval (South Portal instruments):
   a. Obtain weekly readings when the TBM is within 200m from instrument.
   b. Obtain daily readings after TBM passes and until TBM is greater than 50m beyond the instrument.
   c. Obtain weekly readings until TBM is greater than 200m beyond the instrument.
   d. Obtain one monthly reading after weekly readings, and compare readings. If readings are within +/- 2mm, readings can be discontinued; otherwise continue monthly readings until successive readings are within +/- 2mm.
   e. Reading frequency shall be increased if excessive settlement are recorded before, during, or after TBM passage per SSJV's discretion.

Schedule B – For settlement points above tunnel

1. Obtain baseline readings as described in Section 8.8.1
2. Obtain weekly readings when the TBM is within 200m from instrument.
3. Obtain daily readings after TBM passes and until TBM is greater than 50m beyond the instrument.
4. Obtain weekly readings until TBM is greater than 200m beyond the instrument.
5. Obtain one monthly reading after weekly readings, and compare readings. If readings are within +/- 2mm, readings can be discontinued; otherwise continue monthly readings until successive readings are within +/- 2mm.
6. Reading frequency shall be increased if excessive settlements are recorded before, during, or after TBM passage per SSJV's discretion.

3 Revisions to Extensometer Locations

SSJV has adjusted the locations of extensometers to optimize locations. This optimization results in a reduction of the total number of extensometers from 12 to 9 along the alignment. Extensometers in proximity to the portals in lowest cover areas are maintained. Three extensometers in the deeper portions of the alignment and in locations presenting challenges for installation were eliminated, but remaining extensometer locations were adjusted to provide regular intervals on extensometers. Changes to the extensometer locations are presented in Appendix A, with changes specifically made to Figure 8, Drawings 511328-12220-S2JA-4GDD-1001, 1002 and 1004. All other extensometers and geotechnical instrumentation remain unchanged.

4 References

SSJV/Jacobs Associates. October 2013. Combined CRIAR/IMP/I&M Submission, Bored Tunnel Segment, Section 220, Document 511328-12220-S2JA-4GCR-0001, Rev. B. Evergreen Line Rapid Transit (ELRT) Project, Greater Vancouver, BC.

Province of British Columbia. May 2014. RFV – Instrumentation and Monitoring Plan, Ref. 511325-00000-SWSL-30CC-0266. Evergreen Line Rapid Transit (ELRT) Project, Greater Vancouver, BC.

Appendix A Revised Drawings for Figure 8

LEGEND:

- EXISTING FACILITIES THAT REQUIRE STRUCTURE SETTLEMENT POINTS. (4) POINTS PER FACILITY.
- EXISTING FACILITIES WITH LARGER FOOTPRINT, THAT REQUIRE ADDITIONAL SETTLEMENT POINTS. (8) POINTS PER FACILITY.
- (E) MULTIPOINT BOREHOLE EXTENSOMETER
- SURFACE SETTLEMENT POINT
- EXISTING OBSERVATION WELL WITH PIEZOMETER
- (U) UTILITY SETTLEMENT POINT

PLAN

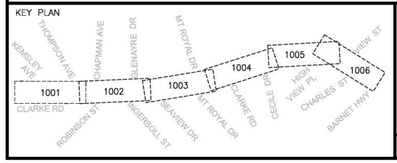
SCALE 1:500

NOTES:

1. STATIONING SHOWN IS FOR I/B TRACK ALIGNMENT.
2. BORE HOLES WITH PIEZOMETERS TO BE INCLUDED IN MONITORING PROGRAM: BH09-207, BH06-3, BH00-13
3. BORE HOLES TO BE DECOMMISSIONED PRIOR TO TUNNEL WITHIN 100m: BH00-13.

ISSUE FOR IDR2

KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET
EGL-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A	2013-04-26	ISSUED FOR IDR	P.J.
B	2013-08-23	ISSUED FOR IDR2	P.J.
C	2013-10-04	REVISED PER COMMENTS	P.J.
D	2014-01-21	REVISED EXTENSOMETER LOCATIONS	P.J.

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JV LOGO
SSJV
DESIGNER
JACOBS ASSOCIATES
Engineers/Consultants
EGRT CONSTRUCTION
BRITISH COLUMBIA
Ministry of Transportation and Infrastructure

SCALE 1:500
0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

BORED TUNNEL
GEOTECHNICAL INSTRUMENTATION PLAN
FROM STA 416+790 TO STA 417+160

PROVINCE CONTRACT No. 03902
SUB-CONSULTANT No.
DRAWING No. 511328-12220-S2JA-4GDD-1001 D

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PREVIOUS TO TRA-2015-00011

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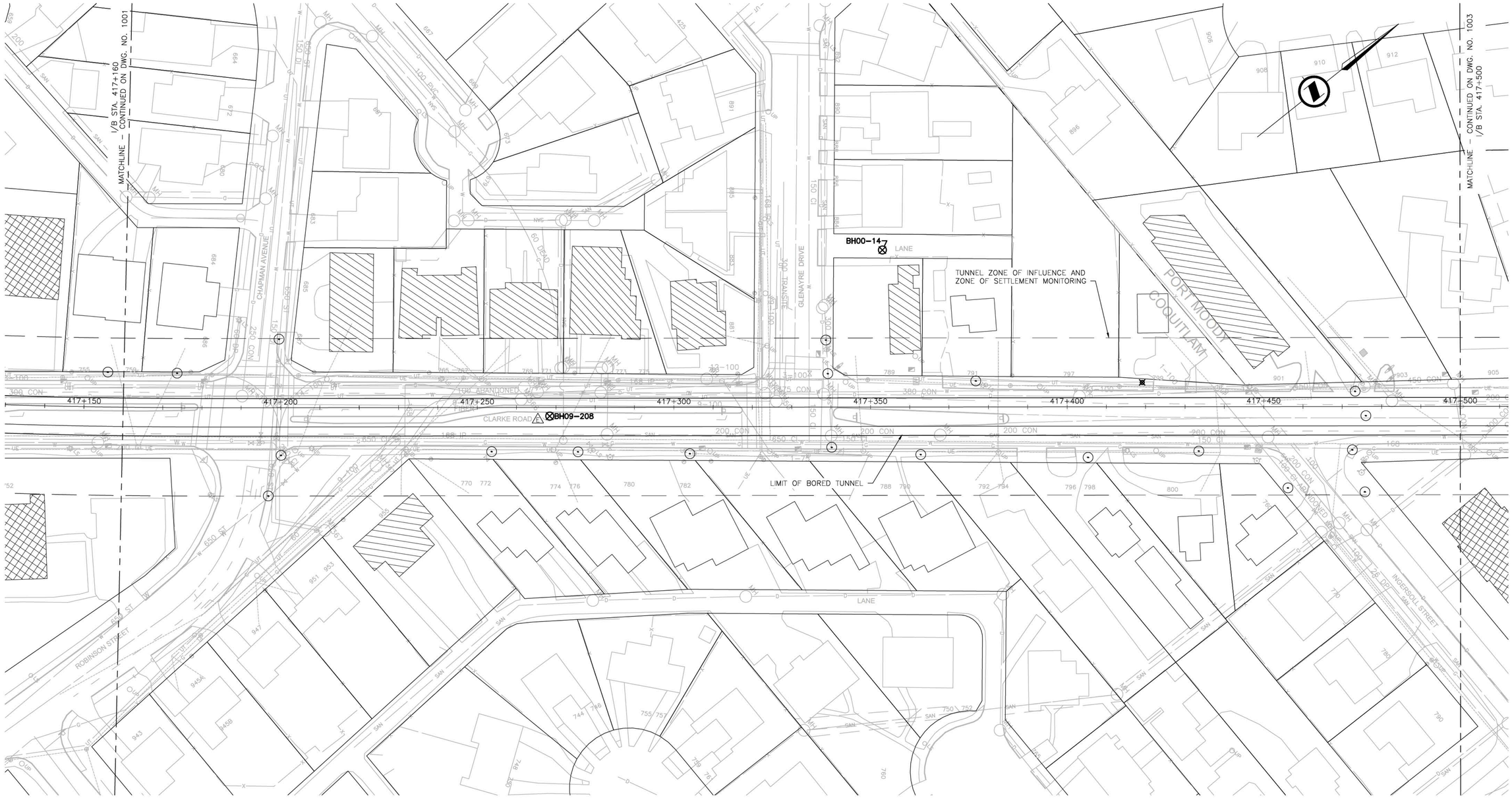


PLAN
SCALE 1:500

LEGEND:

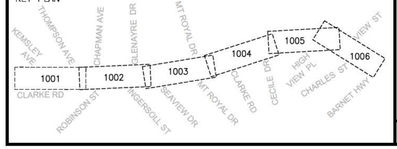
- EXISTING FACILITIES THAT REQUIRE STRUCTURE SETTLEMENT POINTS. (4) POINTS PER FACILITY.
- EXISTING FACILITIES WITH LARGER FOOTPRINT, THAT REQUIRE ADDITIONAL SETTLEMENT POINTS. (8) POINTS PER FACILITY.
- MULTIPOINT BOREHOLE EXTENSOMETER
- SURFACE SETTLEMENT POINT
- EXISTING OBSERVATION WELL WITH PIEZOMETER
- UTILITY SETTLEMENT POINT

NOTES:

1. STATIONING SHOWN IS FOR I/B TRACK ALIGNMENT.
2. BORE HOLE TO BE DECOMMISSIONED PRIOR TO TUNNEL CONSTRUCTION: BH09-208

ISSUE FOR IDR2

KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET EGL-TITLEBLOCK.dwg

REVISIONS

REV	DATE	DESCRIPTION	BY
A	2013-04-26	ISSUED FOR IDR	P.J.
B	2013-08-23	ISSUED FOR IDR2	P.J.
C	2014-01-21	REVISED EXTENSOMETER LOCATIONS	P.J.

PROFESSIONAL SEAL

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SNC·LAVALIN Constructors Pacific
Certified ISO 9001
JV LOGO SSJV
DESIGNER JACOBS ASSOCIATES Engineers/Consultants
EGRT CONSTRUCTION
BRITISH COLUMBIA Ministry of Transportation and Infrastructure
SCALE 1:500
0 25
SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT
BORED TUNNEL
GEOTECHNICAL INSTRUMENTATION PLAN
FROM STA 417+160 TO STA 417+500

PROVINCE CONTRACT No. 03902
SUB-CONSULTANT No.
DRAWING No. 511328-12220-S2JA-4GDD-1002 C

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PRIOR TO
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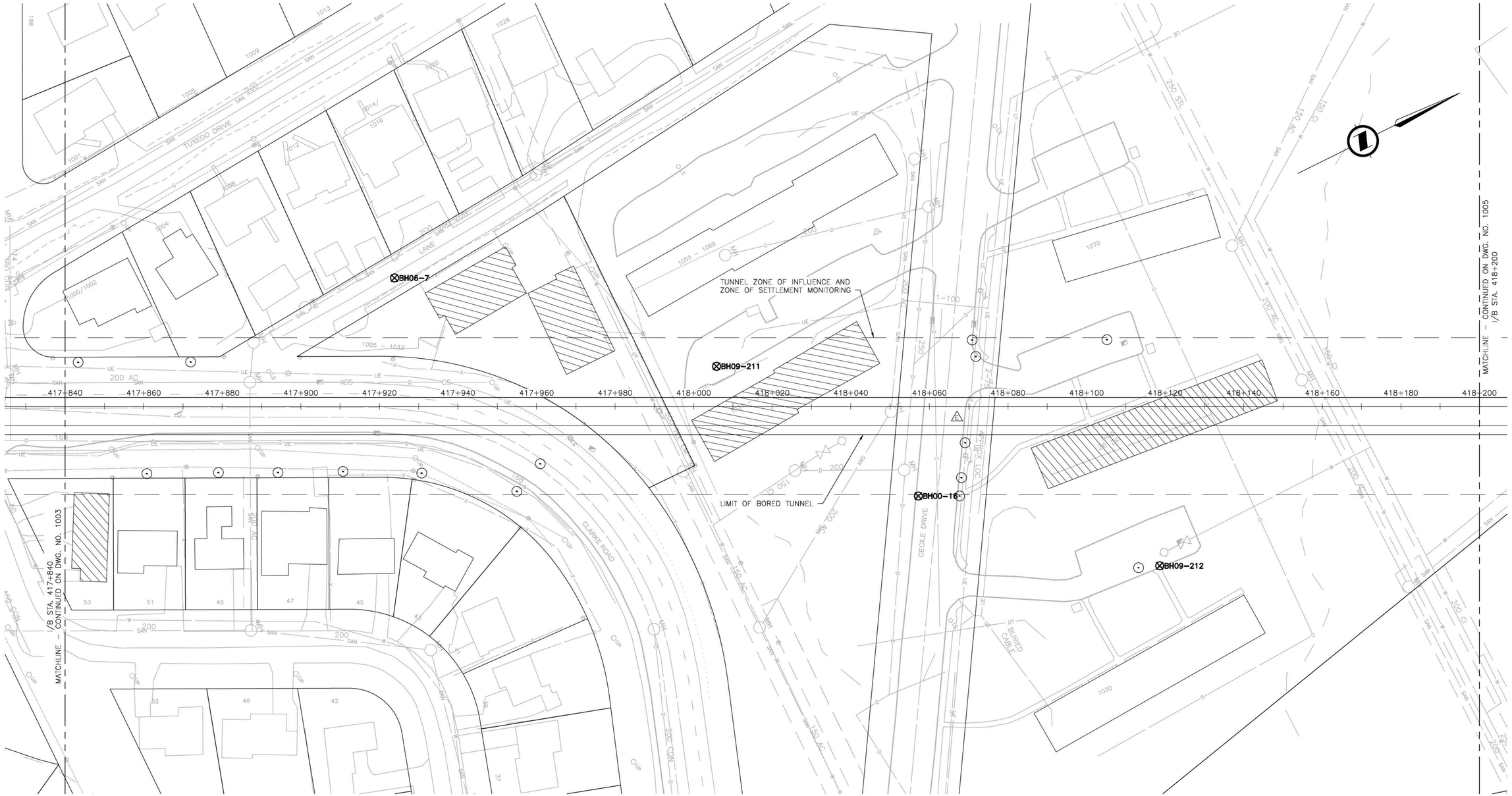

LEGEND:

- EXISTING FACILITIES THAT REQUIRE STRUCTURE SETTLEMENT POINTS. (4) POINTS PER FACILITY.
- EXISTING FACILITIES WITH LARGER FOOTPRINT, THAT REQUIRE ADDITIONAL SETTLEMENT POINTS. (8) POINTS PER FACILITY.
- MULTIPOINT BOREHOLE EXTENSOMETER
- SURFACE SETTLEMENT POINT
- EXISTING OBSERVATION WELL WITH PIEZOMETER
- UTILITY SETTLEMENT POINT

PLAN

SCALE 1:500

NOTES:

1. STATIONING SHOWN IS FOR I/B TRACK ALIGNMENT.
2. BORE HOLES WITH PIEZOMETERS TO BE INCLUDED IN MONITORING PROGRAM: BH09-211, BH00-16

ISSUE FOR IDR2

LAYOUT: 1004
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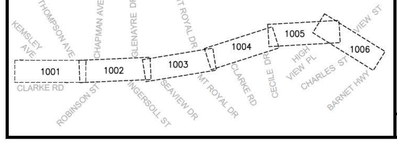
KEY PLAN



DESIGNED	S. FEKETE	2013-08-23 DATE
DRAWN	P. JACOBCHUK	2013-08-23 DATE
CHECKED	S. SWARTZ	2013-08-23 DATE
APPROVED	A. MCGLENN	2013-08-23 DATE

SCALE BAR AS PER 1:1 ANSI D-SIZE SHEET
EGL-TITLEBLOCK.dwg

REVISIONS

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A	2013-04-26	ISSUED FOR IDR	P.J.
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C	2014-01-21	REVISED EXTENSOMETER LOCATIONS	P.J.

PROFESSIONAL SEAL

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Canada. V6E 3C9

SNC·LAVALIN Constructors Pacific

Certified ISO 9001

JV LOGO: SSJV

DESIGNER: JACOBS ASSOCIATES Engineers/Consultants

EGRT CONSTRUCTION

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

SCALE 1:500

0 25

SCALE BAR

EVERGREEN LINE RAPID TRANSIT PROJECT

BORED TUNNEL
GEOTECHNICAL INSTRUMENTATION PLAN
FROM STA 417+840 TO STA 418+200

PROVINCE CONTRACT No.	SUB-CONSULTANT No.
03902	

DRAWING No. 511328-12220-S2JA-4GDD-1004 C

SUPERCEDES PRINTS OF THIS NUMBER WITH LETTERS PRECEDING IT