CONFIDENTIAL

Ottawa Light Rail Transit Project, Confederation Line

Investigation and Root Cause Analysis of June 8, 2016 Sinkhole on Rideau Street

Report Status (Final Draft)
Revision No. 2

McMILLEN JACOBS ASSOCIATES

December 22nd, 2016

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1.0 Background

On the morning of June 8, 2016 a sinkhole developed across the approximately 25-meter width of Rideau Street (i.e., south sidewalk to north sidewalk) from approximately 20 meters east of Colonel By Drive/Sussex Drive and continued eastward over a 20-meter length, as measured at the ground surface. As shown in **Figures 1-1 and 1-2,** the sinkhole was located between 45 Rideau St and 47 -57 Rideau Street on the north side and 10 Rideau Street and 50 Rideau Street (the Rideau Center) on the south side.

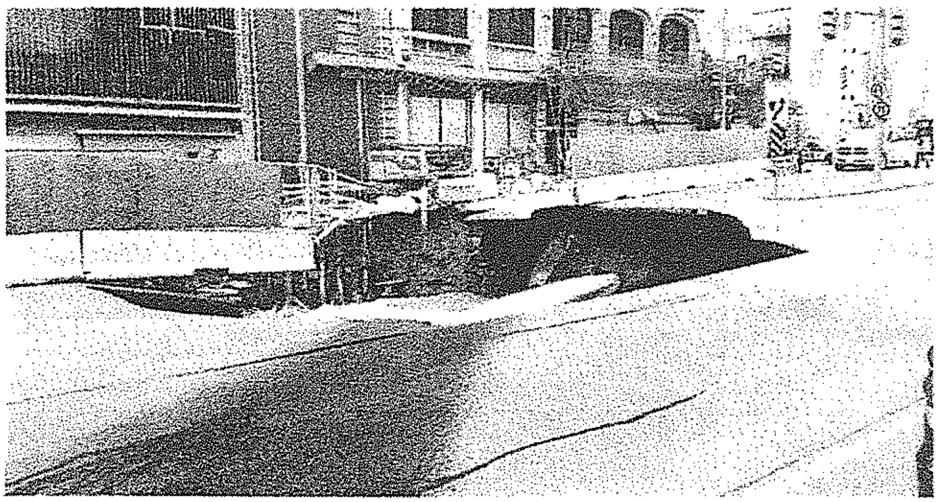

Figure 1-1:Sinkhole on Rideau St. Looking SW at 10 Rideau St.

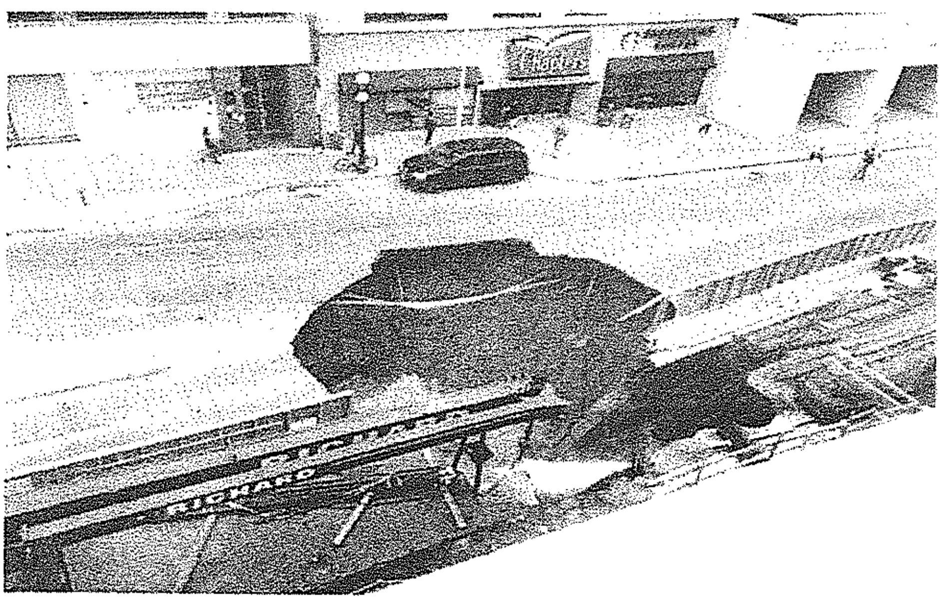

Figure 1-2:Sinkhole on Rideau St. Looking North at 47-57 Rideau St

Figure 1-3 is the plan area of the Rideau Street sinkhole including area streets, buildings, the running tunnel and Rideau Station alignments, watermains, and sinkhole limits

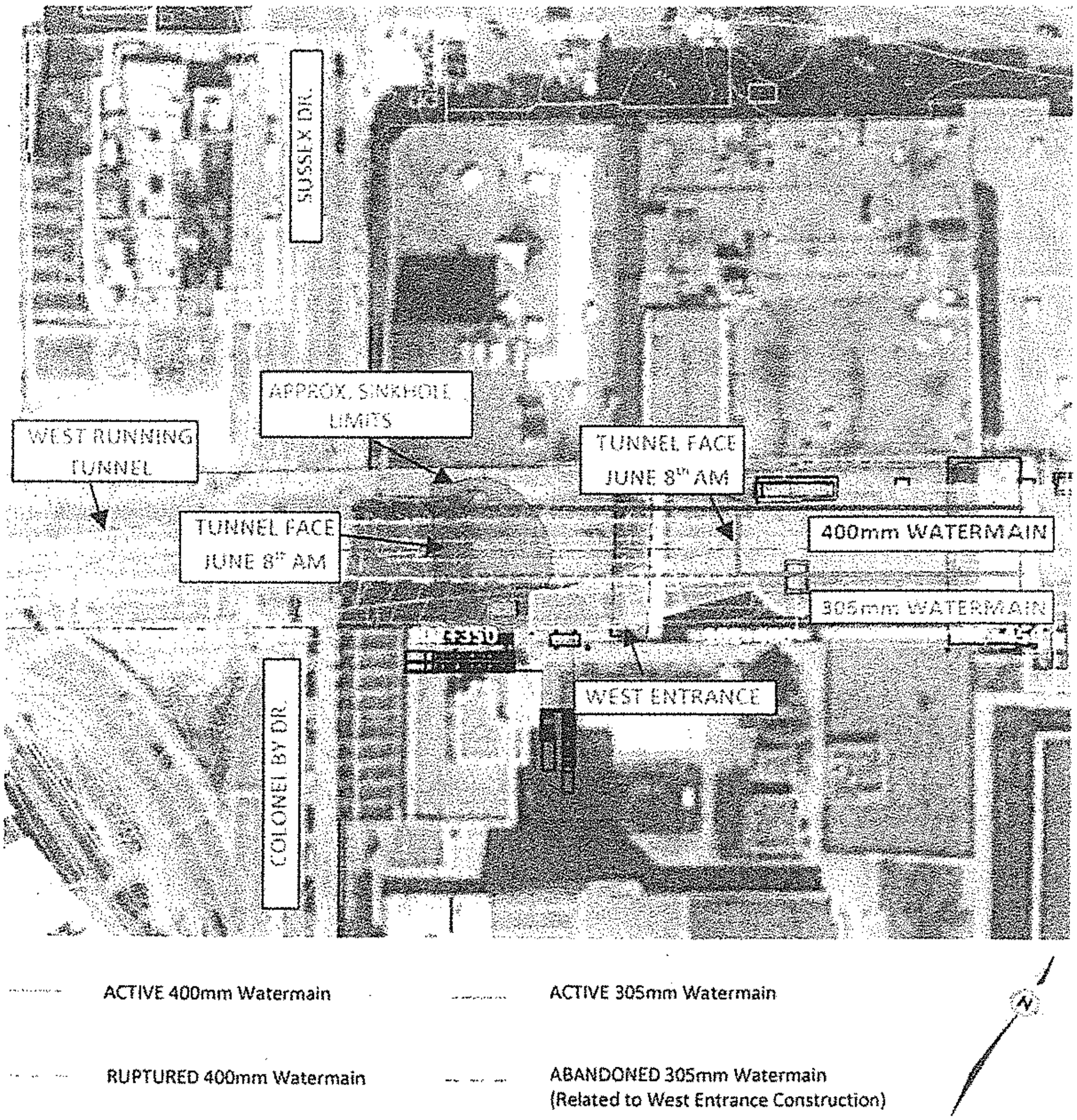

Figure 1-3: Rideau St. Sinkhole Area Plan View

In the area of Rideau Street between Sussex Drive and 150 m to the east, during the weeks leading up to June 8, Ottawa Light Rail Transit Constructors (OLRTC) was proceeding with construction of the Rideau Station West Entrance, advancing the Parliament Station-to-Rideau Station T2 running tunnel (hereinafter referred to as the West Running Tunnel), and initiating the advance of the Rideau Station-Parliament T2 running tunnel from the west end of the Rideau Station cavern (hereinafter referred to as the East Running Tunnel). On June 8 the headings of the West and East Running Tunnels were approximately 50 m apart.

On the morning of June 8, just prior to the sinkhole event, the status of the OLRTC construction in these three work areas was as follows:

- West Entrance: This structure is located on the south side of Rideau Street near Sussex Street and will serve as the pedestrian walkway and escalator down into Rideau Station. On June 8 it consisted of a shored excavation up to approximately 5 to 7 m deep supported by soldier piles (mini-piles), walers, tiebacks, mesh and shotcrete.
- West Running Tunnel: Tunnel advance heading for the Parliament Station-to-Rideau Station from west-to-east under the center of Rideau Street was located at tunnel chainage 102+350 which was about the same location as the west surface manifestation of the sinkhole.
- East Running Tunnel: Tunnel advance heading for the Rideau Station-to-Parliament Station running tunnel from east-to-west under the center of Rideau Street was located at approximate Chainage 102+400, approximately 30 m east of the eastern surface manifestation of the sinkhole.

That morning OLRTC was working at all three of the above locations. Near the west end of the West Entrance excavation prior to development of the sinkhole, the conditions in the area were reportedly dry and stable. However subsequent to formation of the sinkhole, the mini-piles and lagging supporting the excavation in that area collapsed. It is understood that in the early stages of the sinkhole, the work crew had evacuated the area by moving up to surface grade away from the West Entrance area.

It is understood based on review of records provided by OLRTC that at the West Running Tunnel heading significant volumes of soil and water collapsed from the heading face into the tunnel in the 10:15-10:30 AM time frame. Specifically, the following statement regarding observations at the heading was included in the records reviewed: "10:15 am to 10:30 am: Last sump had shown up some soft ground in the middle of the face. Road header stopped and some chunks began falling in. One chunk revealed a stream of high flow muddy water that was now coming in. After about 15 seconds of water inflow without signs of abating, large chunks began falling off the face. All workers and supervisors at the front decided to move back from the face."

At the East Running Tunnel heading, located immediately west of the west end of Rideau Station, but approximately 30 m east of the sinkhole area, reportedly there was no direct impacts due to the sinkhole event.

2.0 Pre-Construction and Post Sinkhole Subsurface Profiles

The section of the tunnel alignment along Rideau Street east of Sussex Drive is underlain by a glacial valley (herein generally referred to as "soft ground" to distinguish it from "bedrock") that is approximately 125 m wide west-to-east (measured at the ground surface) and up to 35 m deep. In general, the valley trends primarily in a north-south direction. **Figures 2-1 and 2-2** illustrate the preliminary design phase (2010-2012) pre-construction geologic profile and the post-sinkhole geologic profile, respectively.

Figure 2-1, which is based on test borings taken during the preliminary engineering phase of the project and included in the Project Agreement indicates that the geologic profile along the tunnel alignment consisted of approximately 3 m of fill underlain by limited depths of clay which were, in turn, underlain by 25-30 m of variable consistency glacial till soils. The boring logs shown in **Figure 2-1** indicate that approximately 75% of the soils across the valley were expected to consist of silty sand, sand and sand/gravel with the remaining 25% to be mainly silt along with small amounts of near surface fill and clay. Several of the borings had approximately 20 m depths of silty sand.

However, the borings nearer the west and east limits of the valley had 15-20 m depths of less silty sand and greater depths of sand and gravel.

The post-sinkhole test borings and Cone Penetrometer Tests (CPT), confirmed the generally more granular nature of the subsurface materials near the tunnel horizon at the west limits of the glacial valley.

The groundwater levels in this section of Rideau Street at the time of the 2010-2012 preliminary engineering phase studies were approximately 4 m to 6 m below surface grade. This groundwater level corresponds to a hydrostatic head of approximately 15m above the West Running Tunnel crown level.

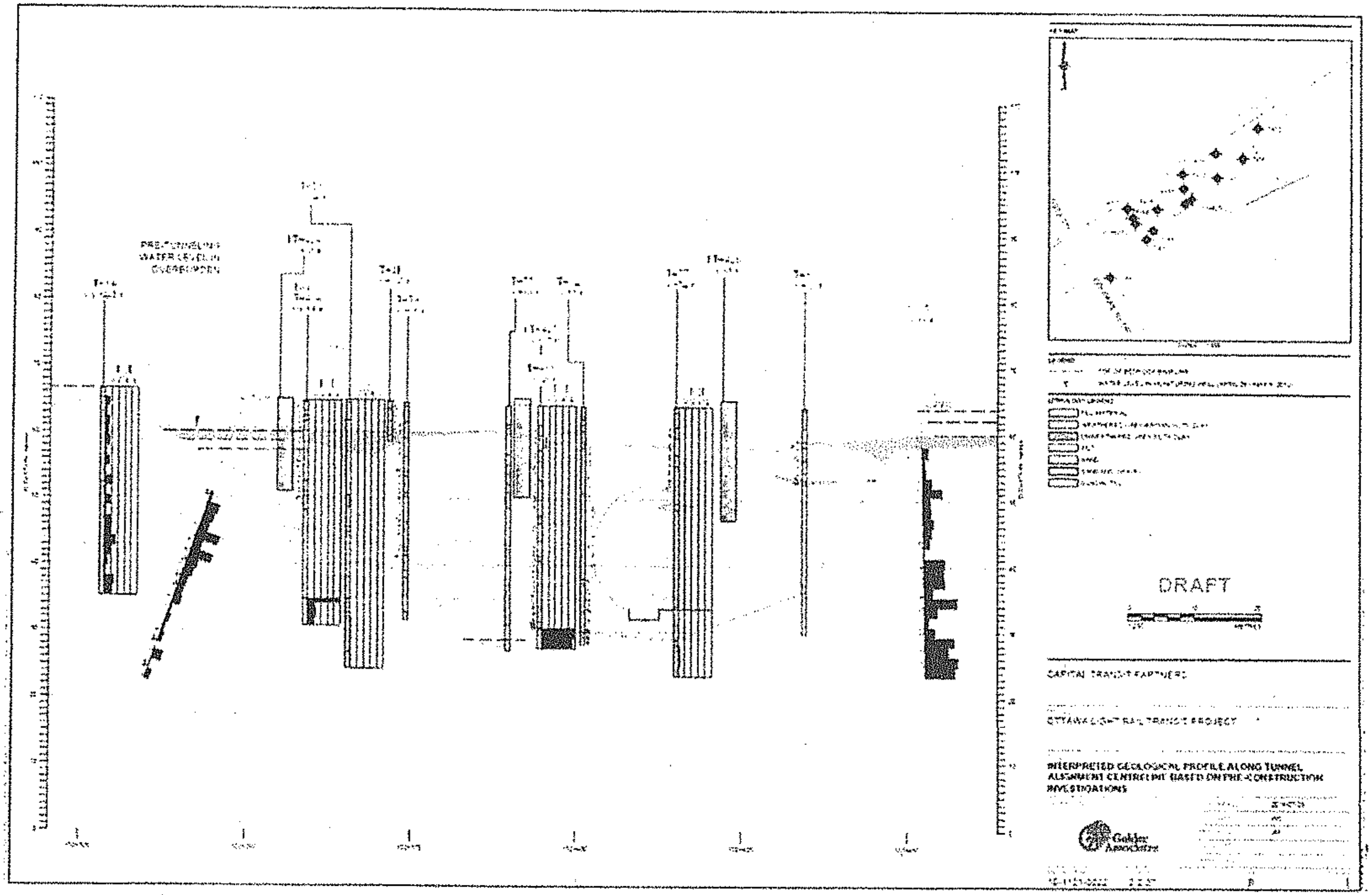

Figure 2-1: Subsurface Geologic Profile (Pre-Construction)

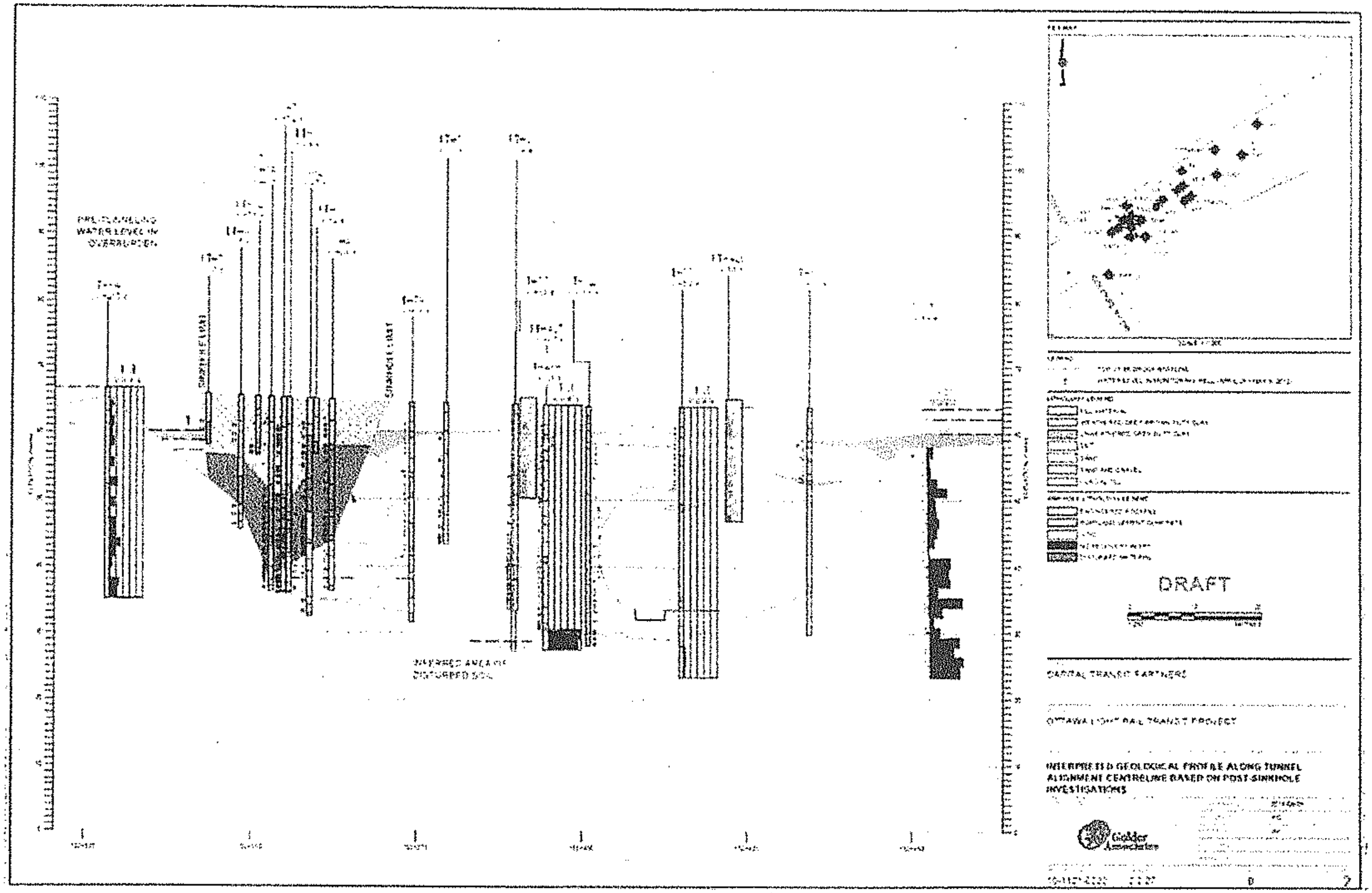

Figure 2-2: Subsurface Geologic Profile (Post-Sinkhole)

3.0 Buried Utilities

The buried utilities in the sinkhole area, typically at a depth of 2-3 m below the ground surface, consisted of a combination of several active pipes and conduits in addition to a number of abandoned in-place utilities. The active utilities, all of which were either destroyed or suffered some degree of damage due to the sinkhole, included:

- Two City of Ottawa water mains (305 mm diameter ductile iron pipe (DIP)/PVC and 400 mm diameter PVC pipe) (Refer to Figure 1-3)
- One City of Ottawa lateral water main with a flexible expansion coupling connection at 41 Rideau Street,
- One City of Ottawa 600/750 mm diameter concrete storm sewer,
- One City of Ottawa 375 mm diameter concrete sanitary sewer,
- One Enbridge 100 mm diameter polyethylene gas line,
- One Hydro Ottawa concrete-encased electrical duct bank,
- One Bell concrete-encased communications cable duct bank.

Based on the evidence available, the utilities abandoned prior to initiation of the OLRTC project work are believed to have been of no consequence to the sinkhole event.

4.0 Rideau Area OLRTC Activities and Timeline

Along Rideau Street the glacial valley is located approximately between Sussex Drive to the west and the East Pedestrian Bridge to the east, a distance of approximately 125 m. Near-surface and subsurface activities associated with the OLRTC tunnel project activities in this glacial valley began in April 2015 and continued at various depths and locations with increasing frequency up to the time of the June 8, 2016 sinkhole event. The tunnel construction work itself was performed primarily by OLTRC or its sub-contractors. In addition, OLTRC had engaged a consulting firm specializing in managing tunnels advanced and supported utilizing the Sequential Excavation Method (SEM) tunneling approach being employed by OLRTC. This firm, Dr. Sauer & Partners (DSP), monitored and advised OLRTC with respect to the tunnel excavation advance and designed the temporary support requirements for the entire tunnel alignment (i.e., both the bedrock and soft ground segments).

4.1 Rideau Station West Entrance

The Rideau Station West Entrance is a structure up to 15 m wide (north-to-south) x 35 m length (west-to-east) located on the south side of Rideau Street near Colonel By Drive. The West Entrance includes a lower level escalator entrance at the east end that will descend on an incline into the west end of Rideau Station.

4.1.1 Caisson Installation and Watermain Pipe Leak

(Refer to **Attachment 1** for more details addressing the subjects discussed in this sub-section)

The initial subsurface construction work performed by OLRTC for the Rideau Station West Entrance included the installation of thirteen 1-m diameter caissons drilled between September and December 2015 from surface grade down into bedrock. These foundation support units were installed to serve as future support for the West Entrance super-structure. On November 7, 2015 one of the large diameter caissons was being drilled using a mobile crane and a rotary drill rig from 13 m to 36 m below grade at a distance of 9 m from what was on November 13, 2015 determined to be a leak in the 305 mm DIP watermain located on the south side of Rideau Street. (Note this caisson was the closest to the location of the November 13 watermain leak).

On November 12, 2015 a fire hydrant within the planned West Entrance excavation area was relocated from within the west end of the area to a point 8 m west so as to be just outside the west end of the Rideau Station West Entrance excavation limits. Subsequently, the hydrant was connected to the 305 mm watermain at a point west of the segment of that pipe that had been cut, capped and abandoned in order to construct the West Entrance facility. Available field records do not indicate any subsequent issues involving what was determined at the time to be the successful relocation of the hydrant.

Mid-morning of November 13, 2015 the caisson drilling sub-contractor reportedly noticed water coming to the surface of the pavement in the general area just north of the proposed West Entrance. The City of Ottawa was notified and it was determined that the source of the water was likely a leaking/broken watermain. As confirmation, once the ductile iron pipe (DIP) 305mm watermain in that area was de-pressurized the surface leakage stopped. By late afternoon of the same day the watermain repair had been completed by cutting and capping the 305mm DIP east of the leak location and the watermain some distance west of the cap plug was abandoned in anticipation of the upcoming excavation work to be associated with the West Entrance construction.

In July 2015 OLRTC had contracted with a water leak detection company, Echologics, to install an acoustic-based leak detection system in the 305mm and the 400mm pressurized watermains along Rideau Street between Nicholas Street and Sussex Drive. However, on November 13 when the leak was visually observed on Rideau Street, there had been no forewarning of the leak by the acoustic leak detection system. Subsequently, it was indicated by Echologics that a signal had been noted by the system on a daily basis since November 9 (a period of 4 days). Unfortunately, the signal had been of an unexpected frequency so it had gone unreported to OLRTC by Echologics.

Subsequent to the leak detection and repair, it was noted that an OLRTC piezometer located on Rideau Street approximately 70 m east of the leak had experienced a rise in groundwater level of 2 m during the same November 9 to November 13 time frame as the unexpected frequency Echologics signal. Furthermore, after the leak repair of November 13 the groundwater level at that piezometer returned to its pre-November 9 level. As indicated in Attachment 1, the leak detection system data and the piezometer reading led OLRTC to conclude that the leak observed on November 13 had been on-going since November 9.

On November 13 OLRTC commissioned a local professional engineering firm, Paterson Group, to evaluate the soils surrounding the excavated leak area to determine the potential of a void extending beyond the immediate area of the leak repair that could potentially result in future deformation or collapse in the Rideau Street area. The Paterson Group was also asked at that time by OLRTC to offer an opinion on the probability that the surface loadings associated with the caisson drill and/or crane rigs could have caused additional stress in the watermain resulting in the leakage incident. The Paterson Group report concluded that there was no likelihood of future deformation or soil collapse in the area beyond that exposed for the repair work and that the caisson drill and crane vehicular traffic loadings did not result in over-stressing the 305 mm DIP. However, the Paterson Group report did not provide an indication of the cause of the watermain leak.

4.1.2 Re-Routing and Abandonment of 305mm Watermain

(Refer to **Attachment 1** for more details addressing the subjects discussed in this sub-section)

Figure 4 is an excerpt from a drawing prepared by Robinson Consultants showing modifications to the 305 mm watermain in November 2015. These modifications include relocation of a fire hydrant at the west end of the Rideau Station West Entrance excavation, repair of a watermain break and construction of a cross-connection between the 305 mm watermain and the 400 mm watermain on the north side of Rideau Street to allow the portion of the 305 mm watermain within the Rideau Station West Entrance to be abandoned.

In addition to the modifications shown on Figure 4-1, it is understood that in early December 2015 OLRTC construction equipment struck the hydrant and caused it to leak and repairs were completed shortly thereafter. It is further understood that design and excavation and backfilling work required for the watermain modifications and repairs was the responsibility of OLRTC and that the work on the watermain itself required for the modifications and repairs was the responsibility of City staff.

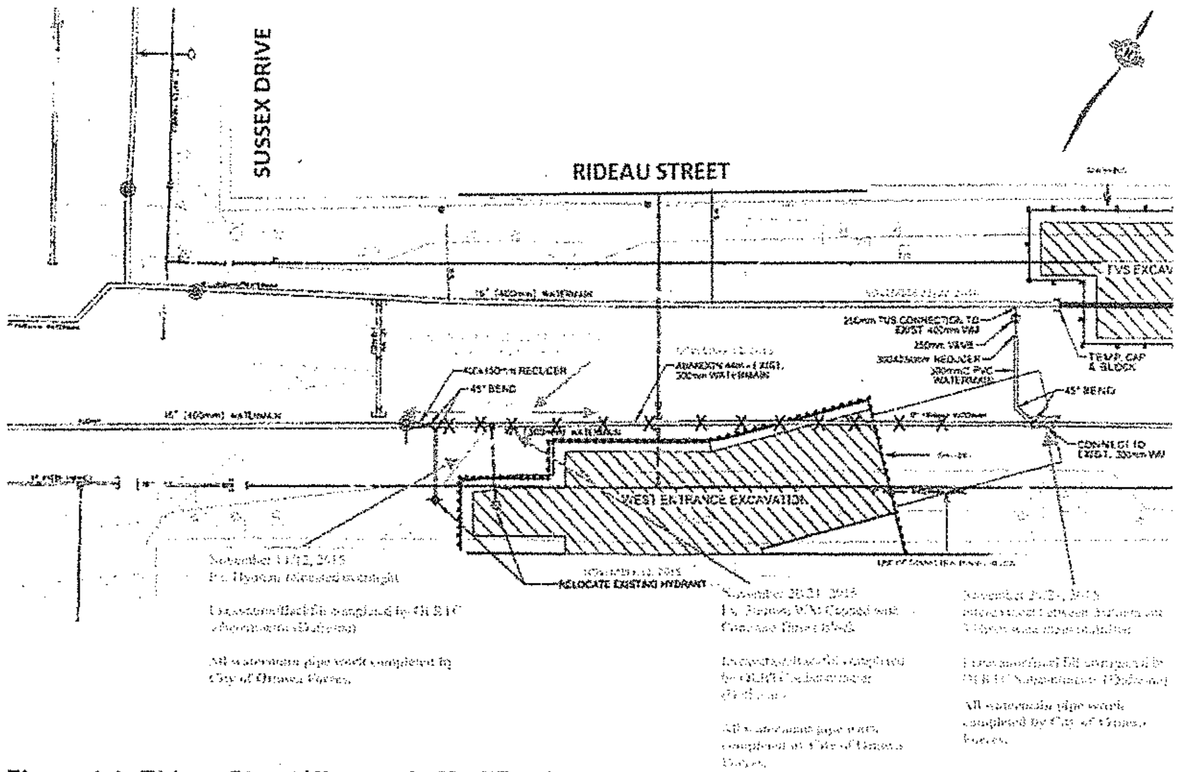

Figure 4-1: Rideau Street Watermain Modifications

4.1.3 Support of Excavation and Escalator Pipe Umbrella Installation

The support of excavation (SOE) for the Rideau Station West Entrance soils consisted of soldier piles (mini-piles), walers, tiebacks and mesh-reinforced shotcrete. The mini-pile drilling/installation started in mid-December 2015 and completed in late January 2016. Excavation of the West Entrance footprint itself began in early February 2016 and continued until late May 2016 when installation of the 3rd level of tiebacks associated with the 3rd level of walers was completed. According to a June 3, 2016 Certificate of Conformance issued by A. Borregales Rivera, P. Eng., the SOE had been installed in accordance with drawings prepared for OLRTC by the firm Site Canada in September 2015.

Also, starting in early April work associated with installation of the first escalator pipe umbrella support at the east end of the West Entrance was initiated and continued intermittently through May.

4.2 West Running Tunnel

The excavation for this portion of the West Running Tunnel was initiated at the east end of Parliament Station in mid-December 2015 in the vicinity of Chainage 101+740, approximately 600 m west of the heading on June 8, 2016. Along this 600 m length of tunnel all of the excavation had been in bedrock until the western limit of the soil-filled glacial valley was encountered on June 8, 2016 at the tunnel face in the vicinity of Chainage at 102+349.5/102+350. Reportedly up to near Chainage 102+350, the subsurface conditions along the running tunnel had been favorable to excavation.

In the 2-week time frame leading up to June 8, the tunnel heading support and advance activities had included reaching Chainage 102+336 on May 24 and advancing to 102+348 by May 27. There were no comments in the Required Excavation and Support (RES) Meeting Minutes regarding any stability or unusually high groundwater inflows along this 12 m section of tunnel advanced in rock between Chainage 102+336 and 102+348. RES meetings are meetings held between OLRTc and DSP staff at the beginning of each day to discuss required excavation support for the current work day.

4.3 Rideau Station Cavern

Rideau Station, located between Nicholas Street and Sussex Drive, originates at its east end near Nicholas Street and terminates to the west approximately 70 m east of Sussex Drive. Excavation of the Rideau Station cavern in glacial soils began in April 2015 near Chainage 102+450 and proceeded to the west under Rideau Street. (Note that the overall Rideau Station cavern excavation had begun in November 2014 near Chainage 102+600. However, the 150 m length between Chainage 102+600 and 102+450 was in bedrock, not soft ground). By late May 2016 the Rideau Station cavern excavation had been advanced to its west end through glacial valley soils up to approximately Chainage 102+403.

4.4 East Running Tunnel

In early May 2016 OLRTC installed a few 18 m length pipe umbrella segments over the south side of the East Running Tunnel top heading looking westward toward Parliament Station. With interruptions over the ensuing weeks, that East Running Tunnel umbrella was completed on June 6. This milestone was followed by initiating the advance of one drift of the East running Tunnel excavation westward at Chainage 102+403 early on June 7. Over the course of that day and the following night it was noted by OLTRC/DSP that the advance was slowed by groundwater inflows, ground instability and the need to shotcrete in order to attempt to reduce the groundwater inflows and stabilize the heading. This effort continued up to approximately 10:30 AM on June 8 at which time the heading was evacuated due to news of the sinkhole development in the vicinity of Chainage 102+350 to 102+370 (i.e., 30-50 m west of the East Running Tunnel face location).

5.0 OLRTC Construction Methods

As stated above, to the west and east of the Rideau Street glacial valley soft ground subsurface conditions, the running tunnels and stations had been primarily excavated in limestone bedrock using the Sequential Excavation Method (SEM) with three road headers. The SEM running tunnels were single horseshoe-shaped tunnels approximately 10 m wide. Two of the three stations are located beneath Queen Street and are about 175 m in length with spans of 18 m and heights of 14 m. Rideau Station, located below Rideau Street, is approximately 160 m long with a span of about 21 m and height of 16 m which is partially constructed in glacial till soils.

For a 50 m length the west portion of the Rideau Station envelope and a 60 m section of the West Running Tunnel (i.e. Parliament to Rideau Station running tunnel) span a buried glacial valley which is overlain by relatively thin deposits of clay and fill. The length of the entire soft ground section at tunnel level was estimated at 110 m and the soft ground extended to a maximum of approximately 35 m below the surface grade.

OLRTC had developed and employed several construction approaches originally established for the sections of the tunnel advanced primarily through bedrock from the West Portal and East Portal. Then, related to having to manage greater settlements and other risks in the portion of the tunnel alignment through the soil-filled glacial valley additional measures were initiated. These included modifications to excavation support requirements related to the SEM tunnel advance in soil as shown in **Figure 5-1.** OLRTC's original plans for mining the SEM section of running tunnel included advancing the tunnel from east to west. At some point in time it was decided to also advance the running tunnel from west to east which means advancing the tunnel from bedrock into soil.

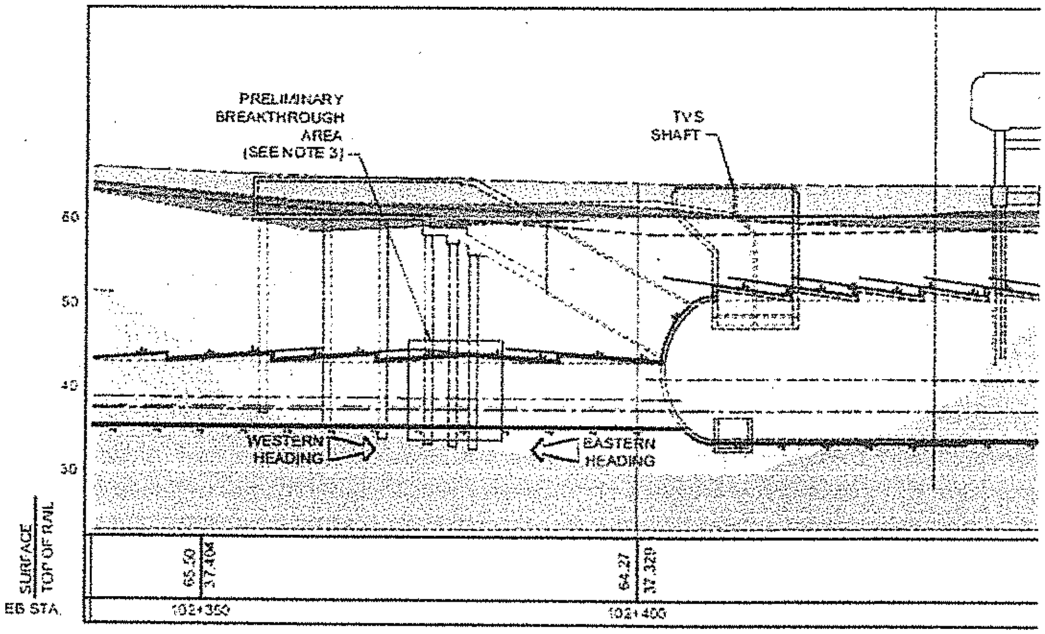

Figure 5-1: Temporary Support Profile for Glacial Valley Soft Ground Conditions

5.1 Sequential Excavation Method (SEM)

The running tunnels and caverns were constructed using principles of SEM, which allows for adjusting the construction sequence designated for each advance length, timing of support installation, and type of support allowed for tunneling through rock, soft ground, and a variety of variable ground conditions. Excavation and support criteria were designated in the OLRTC/DSP design drawings and were modified in the field, as necessary, based on the observed rock mass or soil properties. Overall, there were several classes of support in rock and more robust support in soft ground.

5.2 Management and Field Personnel

In conjunction with the Segment Manager, the SEM Engineer's role is to ensure that the RES process was followed and no excavation or support work was allowed to proceed without a daily RES Minutes of Meeting documenting required excavation support. The participants in the RES process included personnel from both OLRTC and DSP. During SEM excavation, the SEM Engineer supervised the tunnel work and reportedly had the authority to direct and stop the work. Additionally, the SEM Engineer assured design compliance, approved suggested/required field changes and verified the overall quality of the work. For this project, ground support class changes were authorized under a Required Excavation and Support Sheet (RESS). As previously indicated, a daily RES meeting was held with the SEM Engineer and the Segment Manager and a RES Minutes of Meeting was issued daily. OLRTC/DSP daily RES and RESS (issued as needed) were typically forwarded to the City within 24 hours of the RES meeting. As examples, the documents received included:

- RES Meeting No.768, RES Meeting No.769, and RES Meeting No.770 (inadvertently dated June 8 should have been dated June 9). (See **Attachment 2**)
- RESS 95 SC Soft Ground from Chainage 102+348.5 (West) and 102+403.0 (East) (See **Attachment 2**)

For executing the excavation and ground support activities, OLRTC employed a SEM Tunnel Supervisor, tunnel superintendent, foreman and a crew of workers. The work oversight and compliance was the responsibility of the SEM Engineer, SEM Inspector, and the Chief Geotechnical Engineer. Overseeing the work and confirming compliance was the field engineer, an SEM Inspector, and the Chief Geotechnical Engineer. Generally, tunneling works continued 24 hours/day and were reportedly overseen the entire time by the SEM Inspector with spot checks performed by the SEM Engineer and/or the Chief Geotechnical Engineer. Additional tasks such as face mapping, probe hole logging, and groundwater inflow assessments were also performed by the Chief Geotechnical Engineer.

5.3 Running Tunnel – Excavation and Support

5.3.1 Excavation

The T2 running tunnel consists of horseshoe-shaped sections, with dimension of the full envelope ranging from approximately 6-7 m height (depending on the ground support class) by approximately 9.5 m wide. Top heading excavation precedes bench removal with the top heading heights averaging 5.5 m. Within the soft ground section, the tunnel advance sequence typically consisted of excavating at least three pockets in the top heading while maintaining a support core.

Tunneling operations were performed using the following equipment:

- Excavation:
  - Soft ground: Terex TE210
  - Rock: Sandvik MT720 road header(s)
- Shotcreting: Normet Spraymec, Transmixer
- Mucking: CAT Scoop Tram
- Grouting: ChemGrout Equipment
- Drilling: RoboDrill

5.3.2 Support

In bedrock, the length of an advance round of tunnel was 1-3 m with the ground support typically consisting of pattern rock bolts, and depending on the class of bedrock; spiles, lattice girders, fiber reinforced shotcrete, wire mesh and face bolts.

For soft ground conditions, the maximum allowable round advance length was 1.5 m. T2 running tunnel ground support and additional support which included 18 m long pipe umbrella roofs (with 6m overlap) and lattice girders at 1.5 m spacing. **Table 5-1** provides pipe umbrella installation details for the West and East Running Tunnel headings in-place at Chainage 102+348.5 and 102+403, respectively, at the time of the June 8 sinkhole event. Refer to **Attachment 3** for OLRTC tabulation of grout and water inflow quantities.

Table 5-1: Pipe Umbrella Summary

Date	Pipe Umbrella Station	Inflow (l/m)	Grout Take (l)	Notes
May 27-June 6,2016	102+348.5 (West Running Tunnel)	276	17,297	1. During installation, encountered soft ground close to the face for almost every pipe 2. Design volume 10,200 liters
June 2-June 6, 2016	102+403 (East Running Tunnel)	242	6,623	1. During installation, encountered soft ground for the entire length of every pipe 2. Design volume 2,094 liters

Typically, a temporary shotcrete invert was constructed 2-3 rounds behind the top heading and a support core was maintained. In addition to a flashcrete layer, a fiber reinforced shotcrete layer was applied to both the face and invert. Required face support measures had included fiber reinforced shotcrete layers, self-drilling anchors (SDA) with load distribution beams and wire mesh layers, as needed.

Additional support measures, based on in-situ observations that were implemented under the direction of the SEM Engineer, included:

- Probing and dewatering (e.g., perforated or solid drain pipes),
- Rebar or grouted pipe spiles,
- Pocket excavations,
- Face bolts and spot bolts

5.3.3 Observational Probe Holes

To determine the exact location of contacts between different geologic units and observe and measure groundwater inflows, probe holes were drilled into the tunnel face. These probe holes were typically located close to the tunnel crown but sometimes at other locations in the heading face. Probe holes overlapped but their frequency and location was determined by the ground support class type. **Table 5-2** shows the probe holes performed in the West Running Tunnel during the weeks preceding June 8 when soft ground was encountered in the tunnel face. Refer to **Attachment 4** for **Table 5-2** details.

Table 5-2: Probe Hole Summary – West Running Tunnel

Date	Probe Hole No.	Chainage	Length (m) (Interpreted termination station)	Notes
May 18, 2016	RT-PH-05	102+324.0 Crown (North)	18.8 (102+342.8)	No soft ground contact, minor water inflow from approx. 10 m depth
May 24, 2016	RT-PH-06	102+336.0 Crown (North)	13.8 (102+349.8)	Soft ground contact was at 13.0 m +/-, (i.e. chainage 102+349+/- high amount of water inflow from the soft ground; 26 l/m
May 24, 2016	RT-PH-07	102+336.0 Center (North)	14.5 (102+350.5)	Soft ground contact was at 13.5 m,+/- (i.e. Chainage 102+349.5+/-) high amount of water inflow from the soft ground; 38 l/m

5.4 Rideau Station Cavern, T2 Running Tunnel and West Entrance Settlement Data Collection

5.4.1 Surface Settlement Points

OLRTC Drawing OLR-80-2-0000-DRD-0023, include in **Attachment 5**, shows the Surface Settlement Points (SSPs) along Rideau Street. The purpose of the SSPs is to monitor surface settlement in response to construction activity. A total of 20 SSPs were installed and monitored along Rideau Street on a frequent basis from early 2016 until June 8. The SSPs consist of 2 m long steel rods embedded in the ground and were located in groupings of three in a north-south direction with a point on the north, middle and south side of Rideau Street, respectively. From this arrangement of SSPs a total of six north-south cross-sections are represented between Chainage 102+350 and 102+435 with the east-west interval between cross-sections varying from 5 m to 35 m. The maximum separation distance of 35 m was between SSP sections located at Chainage 102+350 and 102+385. The sinkhole, as manifested along the Rideau Street surface, extended between approximately Chainage 102+350 and 102+370.In a similar manner and using the same SSPs locations, three west-to-east cross-sections were considered along the north, middle and south sides of Rideau Street.

In 2014, trigger levels for these SSPs, were originally set at 10 mm for an amber alert level (i.e., intermediate level) and 25 mm for a red alert level (highest level). Then in April 2016 those alert levels were revised upward for many of the SSPs in the Rideau Station soil-filled valley area (approximately Chainage 102+330 to 102+450). **Figure 5-2** shows an example of the original and revised alert level settlement limits along with measured settlements that typically increased as a result of OLRTC excavation and ground support activities in the Rideau Station Cavern. Refer to **Attachment** 6, DSP-86-2-RISU-MEM-0006-Rev 1 for an explanation of trigger level revisions in Rideau Station.

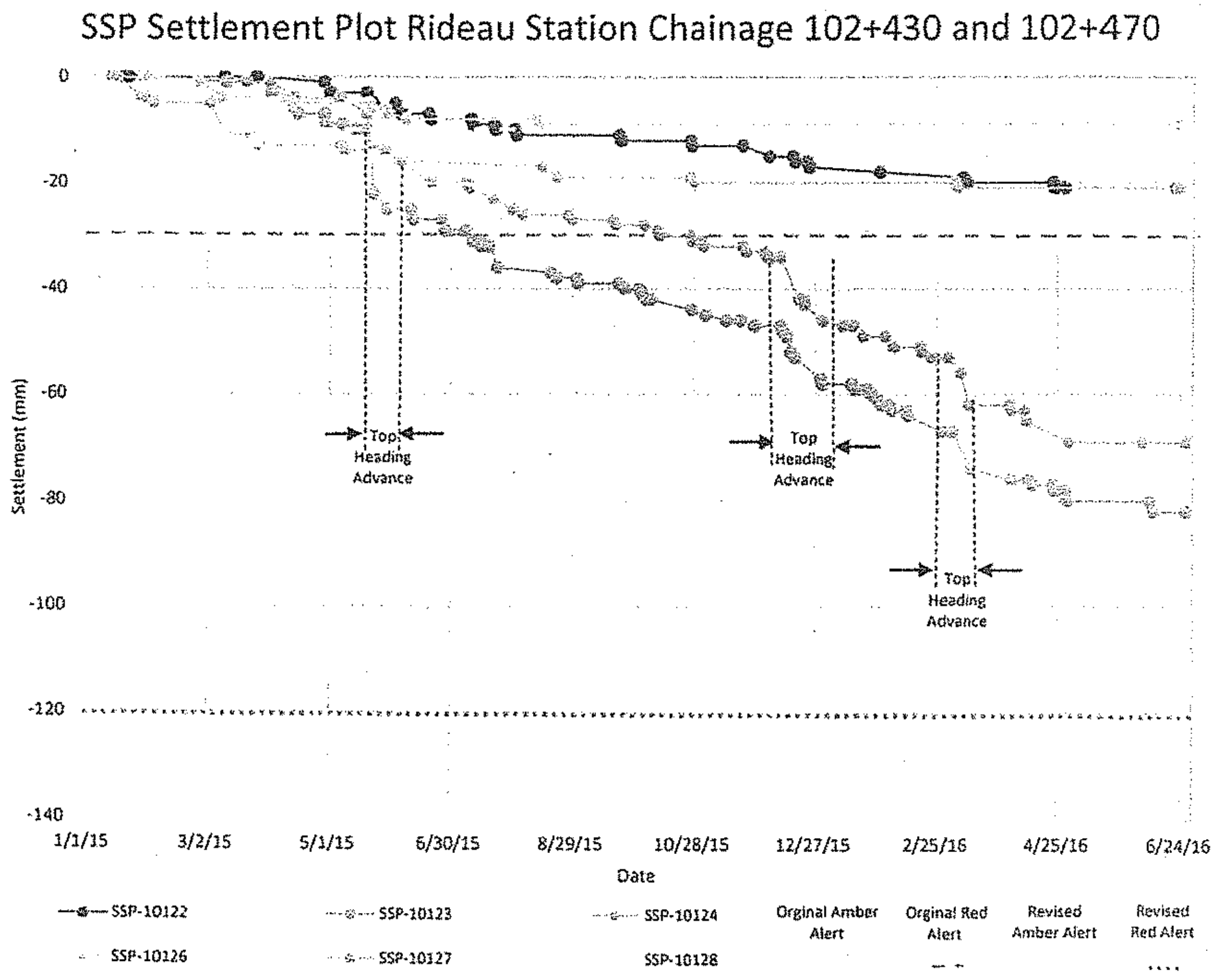

Figure 5-2: SSP Settlements – Rideau Station SSP Settlements and Alert Levels

5.4.2 Structural Monitoring Points

The trigger levels for Structural Monitoring Points (SMPs) mounted on structures adjacent to the tunnel alignment, have always had amber alert levels of 10 mm and a red alert levels of 25 mm since the start of tunnel construction in 2014. During the March, 2016 - June 8, 2016-time frame, approximately 20 SMPs were regularly being monitored at several Rideau Street buildings between Chainage 102+330 and 102+450. In particular, these devices were located on the 45 Rideau St, 47-57 Rideau St, 73 Rideau St and 50 Rideau St (Rideau Center) structures. As such, the only structure in the general area of the June 8 sinkhole that did not have SMPs being monitored was 10 Rideau St. (Reportedly, this was because of the large extent of re-modeling/re-construction on-going with that structure).

5.4.3 Extensometers

Multi-level extensometers were also installed and monitored by OLRTC/DSP in the soil-filled glacial valley. The amber and red alert levels for these instruments are 15 mm and 30 mm, respectively. There were two of these monitoring instruments being read regularly between March 2016 and June 8. Both were located near the middle of Rideau Street at Chainage 102+340 and 102+380.

5.4.4 In-Tunnel Monitoring

Within the Rideau Station Cavern and running tunnel excavations, there were various deformation and convergence monitoring devices each with designated alert levels. Within the Rideau Station Cavern, the vertical and transverse deflection points were installed every 5 m from Chainage 102+460 to 102+404. In the West Running Tunnel advancing from west-to-east these type of deflection points was located every 15 m and the closest to the tunnel heading at Chainage 102+348.5 on June 8 was at Chainage 102+335. All of the installed Rideau Station Cavern and running tunnel deflection points were being monitored on a regular basis throughout the several weeks prior to June 8.

5.4.5 Inclinometer

One inclinometer, located adjacent to the west end of the Rideau Station West Entrance excavation, was installed in January 2016 and was being monitored regularly from April 2016 up to June 4, 2016.

5.4.6 Piezometers

Piezometers and monitoring wells located within 200 m of the June 8 sinkhole form the basis for assessing groundwater levels that were impacted by events prior to and during the sinkhole event. There were a total of 13 piezometer/monitoring wells, seven of them with single level sensors and six with 2 - 3 sensor levels. All 13 locations are shown on the **Attachment 7**, OLRT Drawing OLR-12-3-0000-DRK-0021.

Nine of these devices (51044-51052) had been initially installed at the time of the preliminary engineering phase test boring investigation activities completed in 2012. Six of these piezometers were along Rideau Street between Chainage 102+360 and 102+480 while the other three were south or north of Rideau Street on Colonel Bye Drive or Sussex Drive. The remaining four devices (52006, 52007, 52026 and 52029), all located south of Rideau Street on Colonel By Drive, were more recently installed by OLRTC.

All 13 locations were being monitored on a regular basis prior to June 8 and all had been read in the June 4-7-time frame. However, it was noted that several of the readings at some of the locations were beyond the vibrating wire piezometer sensor range noted on each respective plot which resulted in some question as to the validity of those readings.

5.4.7 Rideau Station West Entrance Support of Excavation Monitoring

In March 2016 approximately 25 monitoring points were installed on all sides of the Rideau Station West Entrance Support of Excavation (SOE) system. Up to approximately May 27th 2016 the majority of these points were read on a routine basis and no unusual deflections appear to have been reported. After May 27th, 2016 only 5 to 8 of the monitoring points at the east end of the excavation were read on a routine basis. It is not clear why the reading frequency was reduced.

6.0 Watermain Risk Mitigation

In early 2015 OLRTC issued reports addressing the mitigation of potential damage to structures, roadways and utilities along the tunnel alignment within the Rideau Street soil-filled glacial valley between approximate Chainages 102+300 to 102+450. The reports included a document titled "Rideau Street Utilities Mitigation", dated May 10, 2015. This report is included herein as **Attachment 8** and it includes a report by Robinson Consultants titled "Rideau Street Watermain Settlement Mitigation Report".

In these reports, it is noted that the tunneling activities could result in up to an expected 150mm of settlement. The area of maximum settlement was expected to be along a 15m wide x 60m length along Rideau Street from near the west end of the West Entrance (near the West Pedestrian Bridge) to 60m east of the west end of the West Entrance (near the East Pedestrian Bridge) (i.e., between Chainage 102+360 and 102+420). In particular, the active utilities buried 2-3 m below Rideau Street were of most concern.

These included two watermains, a sanitary sewer, a storm sewer, a gas line, an electric cable enclosure box and a communications cable box. In terms of potential adverse impact to the roadway, adjacent structures and tunnel construction; the focus was on any failure of the watermains. Therefore, the Robinson report focused on assessing mitigation options primarily for the watermains (and to a lesser degree to the storm and sanitary sewers).

Two overall mitigation approaches were addressed. One involved replacement of the two watermains, the 305 mm DIP along the south side of Rideau Street and the 400mm PVC pipe along the north side of Rideau Street, with a new and more settlement resistant line such as a HDPE pipe. The other approach involved increased settlement monitoring, less extensive modifications to the watermain systems, intervention in case settlement increases occurred rapidly or excessively, including specific mitigation plans addressing the watermains, sewer lines, gas line and electrical/communications cable duct banks. These mitigation plans were also addressed in **Attachment 8**. During this same time frame, OLRTC elected to follow the settlement monitoring-based approach as opposed to the approach involving complete replacement of the two watermains.

OLRTC reported to the City of Ottawa that the modifications to the existing watermains would include the installation of flexible joint couplings at five water service connections for building locations along Rideau Street where differential settlement between a building and the adjacent sidewalk/street might occur. In addition, an acoustic system to detect leaks along pressurized buried piping with flowing water was to be installed. Construction records from OLRTC and the City of Ottawa confirm that the five flexible joint couplings were successfully installed by OLRTC in the September to October 2015 time frame. Likewise, the acoustic leak detection system was installed and monitoring initiated by EchoLogics in August 2015 along the two watermains.

The manufacturers of the DIP and PVC pipe that were installed in 1982 and 1993, respectively, provided allowable angular distortion/deflection limits. These limits were reported by OLRT as 510 mm for a 5.5 m length of 300mm DIP offset between joints and 160mm offset between joints for a 6m length of 400 mm PVC pipe (see **Attachment 8**).

7.0 Measured Settlements

As reported above, in the glacial valley area OLTRC/DSP regularly monitored, on variable schedules, the various categories of geotechnical instrumentation in the weeks leading up to June 8th.

7.1 Surface Settlement Points (SSPs) and Extensometers

Of the 20 SSPs and two Extensometers monitored between Chainage 102+300 and 102+450, SSPs 10109-10112 were located near Chainage 102+350 and were destroyed as a result of the sinkhole. The two Extensometers survived the sinkhole event but were both removed by June 14 as a result of the repair and re-construction activities along Rideau Street. **Figures 7-1 and 7-2** illustrate the measured settlements and the time rate of settlement increases typically associated with specific, or on-going, OLRTC activities within, or adjacent to, this portion of the running tunnel in the vicinity of the sinkhole.

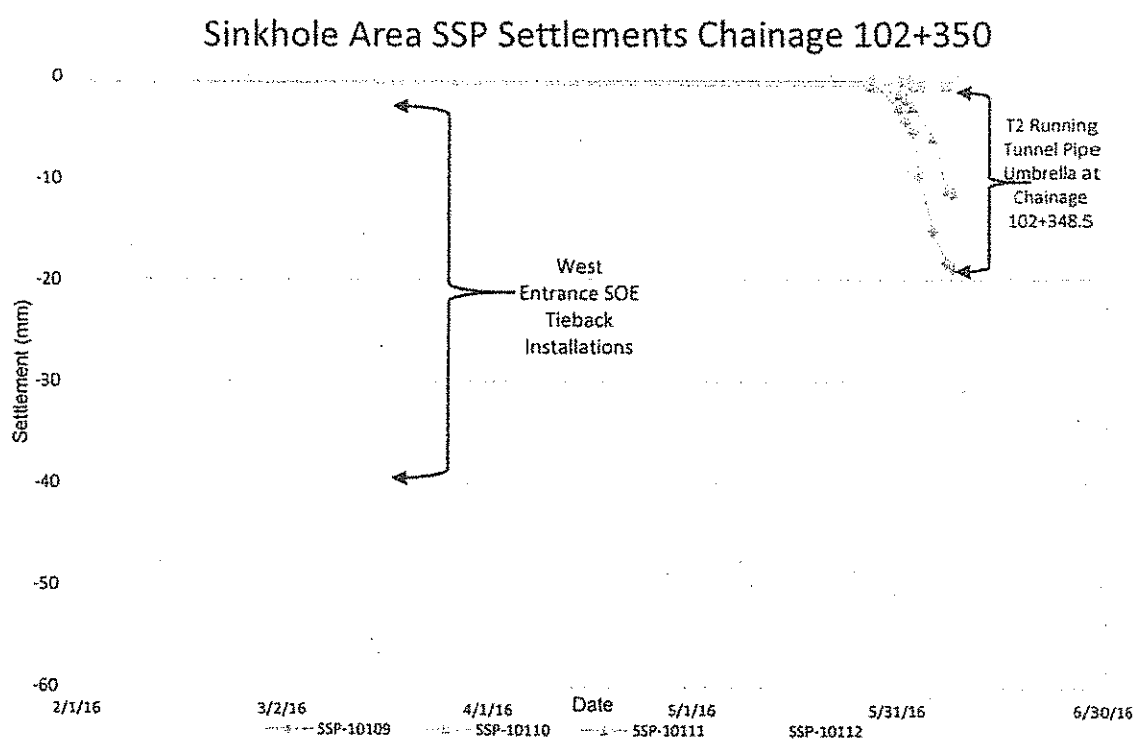

Figure 7-1: Sinkhole Area SSP Settlements Chainage 102+350

Points 10109-10111 were initially installed and monitored since August 2015 while point 10112 was installed and monitored since February 2016. Point 10112 located close to the west end of the Rideau Station West Entrance excavation underwent approximately 40 mm settlement in the March 2016 time frame and then an additional 8 mm settlement by April 21. Between April 21 and June 8, SSP 10112 did not undergo any additional settlement. The nearly 50 mm settlement of SSP 10112 between mid-March and mid-April correlates with the time frame for the excavation and tieback installations for the West Entrance SOE.

Points 10109 and 10111 located over the West Running Tunnel near the western limit of the sinkhole did not deflect during the March to late May 2016 time frame. However, between May 27 and June 8 these two SSPs deflected up to an additional 19 mm as shown in **Figure 7-1**. This latter two-week time frame correlates with the West Running Tunnel support activities after the top heading reached Chainage 102+348 and the pipe umbrella installation eastward of the heading was underway. The OLRTC field reports from the first week of June refer to drilling, grouting and water inflow issues associated with the installation of that pipe umbrella.

It is noted that SSP 10110, located along the south side of Rideau Street, did not undergo any deformation over the 10-month period during which it was regularly monitored. This was a unique situation for any of the 20 SSPs monitored along the soil-filled valley section of the tunnel.

Further to the east, in the area of Chainage 102+370 to 102+375 (i.e. in proximity to the East Runnel Tunnel face, Chainage 102+403), there were two geotechnical instrumentation devices - SSP 10113 and Extensometer 40015. **Figure 7-2** illustrates that SSP 10113 showed a settlement increase of 10 mm in mid-March plus an additional 30 mm between May 31 and June 8. These settlements related to East Running Tunnel pipe umbrella installation and tunnel face advance activities. These increased settlements are demonstrative of the instability and erodibility of the saturated sandy glacial soils under a hydrostatic head when subjected to drilling and excavation activities related to pipe umbrella installation and tunnel advance.

The near surface anchor of Extensometer 40015 deflected 15 mm between March 15 and March 20 but no additional settlement was recorded between the end of May and June 8.

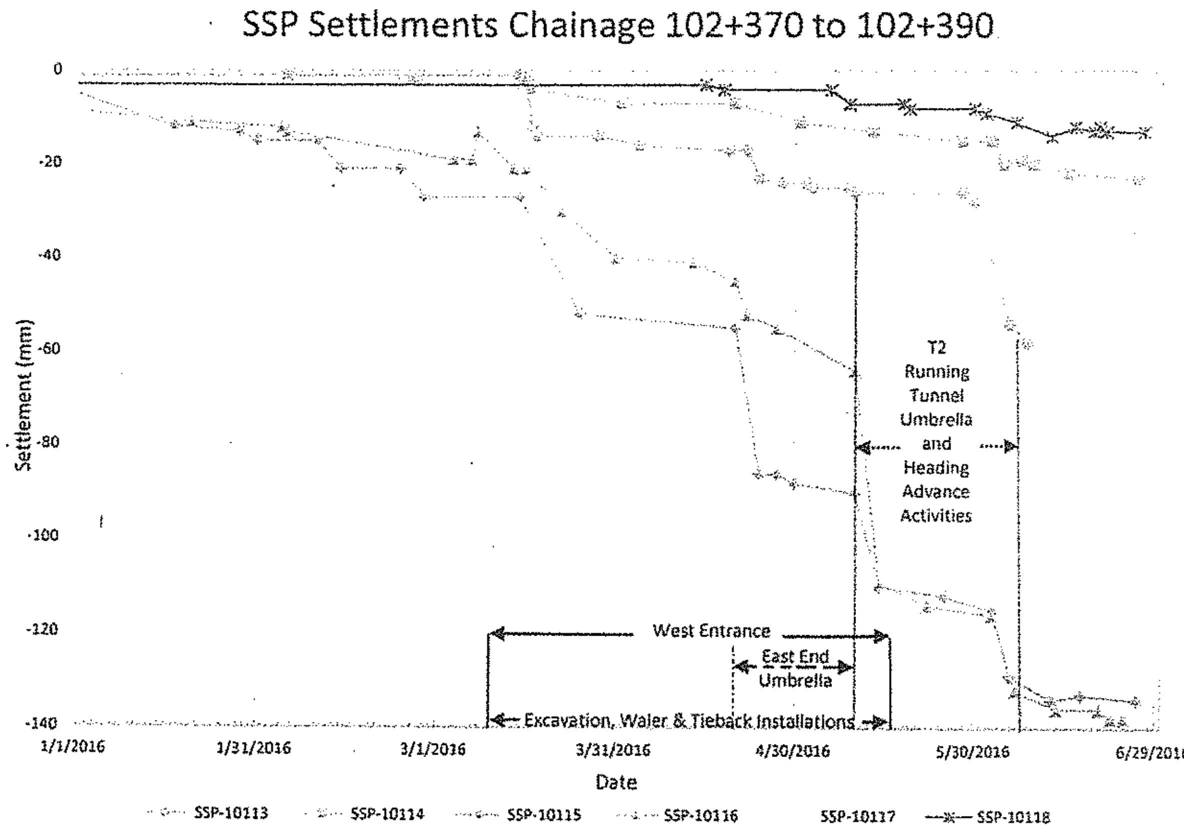

Figure 7-2: SSP Settlements Chainage 102+370 to 102+390

Continuing eastward beyond the east end of the sinkhole area, there were four more north-to-south cross sections evaluated for increases in settlements across Rideau Street. At each of these cross-sections, nearby OLRTC activity time frames were overlain with the settlement history time frame. Although the ground surface settlements noted at these locations do not seem to have been a direct factor in the June 8 sinkhole development, it is of interest to observe that there was correlation when settlements increased notably with tunnel-related activities occurring within the same time frame. As shown in **Figures 7-1 and 7-2**, the cross-section closest to the West Entrance exhibited settlement increases that related primarily to work associated with installation of the SOE (e.g., excavating, waler, tieback and pipe umbrella installations).

Proceeding eastward, the remaining cross-sections evaluated for settlement increases were in the Rideau Station cavern between Chainage 102+405 and 102+420. At all locations, SSP settlement increases were associated with the respective time frames during which OLRTC was either installing pipe umbrellas or advancing the tunnel excavation. As an example, **Figure 7-3** illustrates the settlements recorded at SSPs 10199-10201 and 10220-10222 from the first part of April 2016 to the beginning of May 2016. As shown, these settlement increases are associated with pipe umbrella installations and Rideau Station top heading excavation advances from Chainage 102+423 to 102+403.

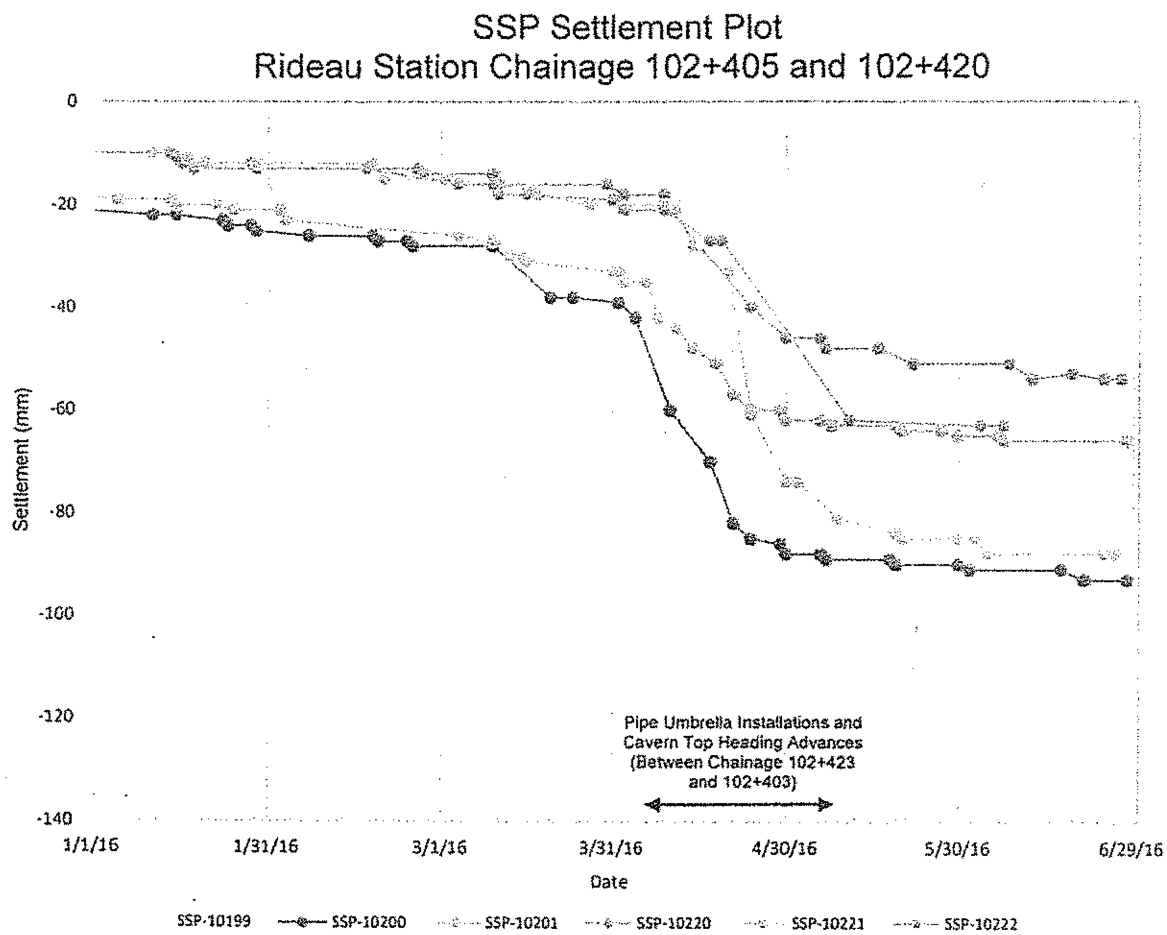

Figure 7-3: SSP Settlement - Rideau Station Chainage 102+405 to 102+420

Extensometer 40014 (located at Chainage 102+340) readings had been monitored since early 2015. Over the 1½ years there had been occasional single readings showing upward settlements of 5-10 mm and then an immediate return to stable readings over extensive time frames. Because the short-term upward settlement movements were noted periodically over the life of this instrument and because they were upward movements versus the expected downward settlements, it is difficult to relate these readings to nearby construction activities of any nature.

7.2 Structural Monitoring Points (SMPs)

Seven structures in the general area of the sinkhole were monitored for settlement between April and June 8, 2016 at a total of approximately 65 SMP locations. These included the four buildings on the north side of Rideau St (45 Rideau St, 47-57 Rideau St, 73 Rideau St (Hudson Bay Company Connection) and Freiman Building), plus two buildings on the south side of Rideau St (Metropolitan Building and 50 Rideau Center) and the East Pedestrian Bridge (extending across Rideau St with foundation supports on both side of the street and shoring supports on the south side). The only building in this immediate area not being monitored leading up to June 8th was at 10 Rideau St (at the corner of Rideau St and Colonel By Drive) which was undergoing renovations.

All four of the SMPs at 45 Rideau St and 47-57 Rideau St indicated 2 – 6 mm of additional settlement in the June 8 to June 11-time frame. Prior to June 8 and subsequent to June 11 all of the four SMP settlements were stable. As shown in **Figure 7-4**, there was no significant settlement effect on the SMPs at 73 Rideau Street (SMPs 21141 and 21241) prior to, during or after June 8.

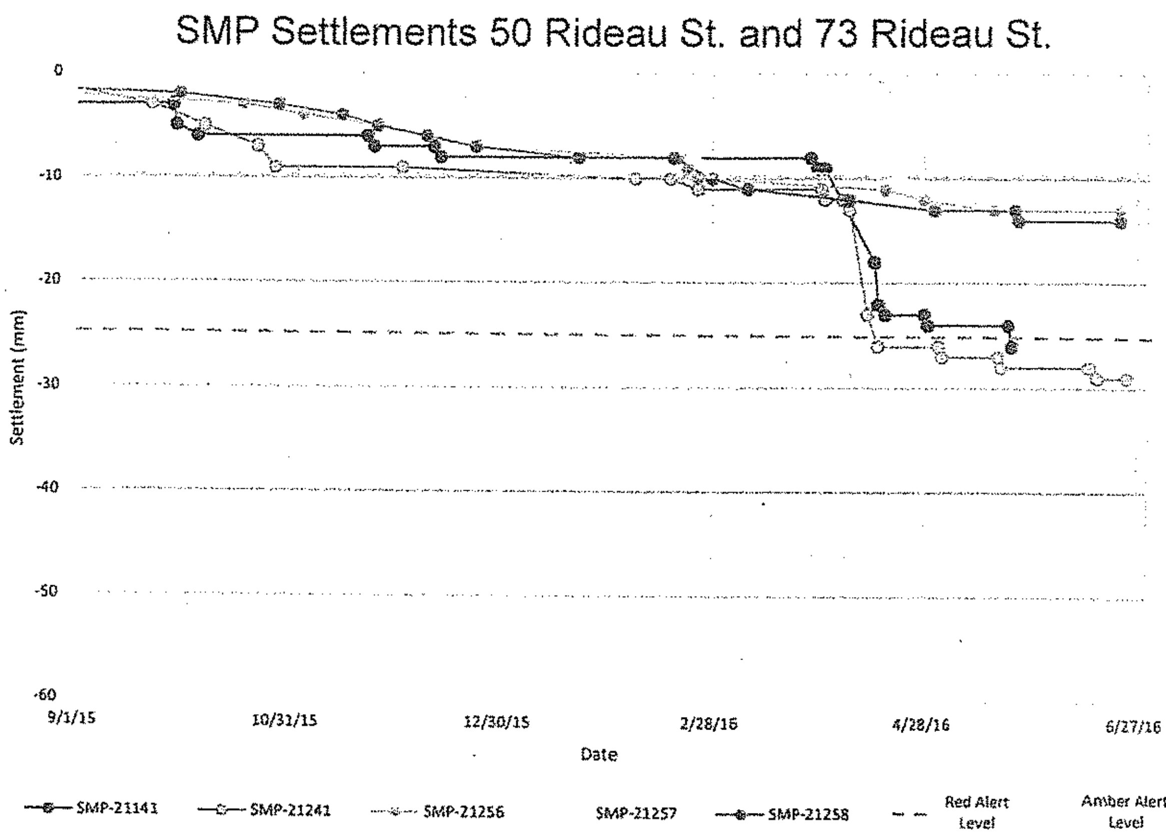

Figure 7-4: SMP Settlements – 50 Rideau St. and 73 Rideau St.

There were a total of 28 SMPs/SSPs monitored for the Freiman Building of which there had been two red alert levels and one amber alert level exceedances for at least one month prior to June 8. On June 8 and the subsequent time frame, all three of these SMPs remained stable and only one of the remaining 25 SMPs incurred a 3 mm settlement increase. At the Metropolitan Building, 15 of the 18 monitored SMPs/SSPs were stable at least one month prior to, during and subsequent to June 8, as were three amber alert level locations. **Figure 7-4** illustrates that there were three SMPs being monitored at 50 Rideau Street (Rideau Center) (SMPs 21256-21258). All three were stable at least one month prior to, during and subsequent to June 8. Finally, on the East Pedestrian Bridge two of the SMPs had alert level exceedances (one amber and one red) many months prior to June 8 while the remaining six locations were not in alert level. But all of the eight locations were stable prior to, during and subsequent to June 8.

7.3 Inclinometer

Inclinometer 30012 was located within 2 m of the west end of the West Entrance. Lateral displacements measured at this instrument were not indicative of any increased movement in the days leading up to the June 8 sinkhole event.

7.4 Piezometers

Twelve of the 13 piezometers located within 200m of the sinkhole had readings that indicated some change in groundwater levels around the time of the June 8 sinkhole event. The 13th instrument's sensor (#51049) was beyond the sensor range for readings.

Seven of the piezometers, with a total of 12 sensor levels, were located quite close to the sinkhole area along Rideau Street, including one of them (51046) that was destroyed by the sinkhole. The remaining six devices were located further to the north, south or east (well beyond the sinkhole). The three piezometers closest to the sinkhole, including 51046 as shown in **Figure 7-5**, experienced primarily steady or dropping groundwater levels in the days leading up to June 8. For example, piezometer 51046, located about 10 m to the east of the West Running Tunnel face on the day of the sinkhole exhibited an approximately 6 m drop in groundwater level during West Running Tunnel pipe umbrella installation. It should also be noted that water levels dropped in this piezometer during installation of a pipe arch umbrella for the Rideau Station cavern in early to mid-May 2016 and that water levels recovered somewhat after completion of that pipe umbrella.

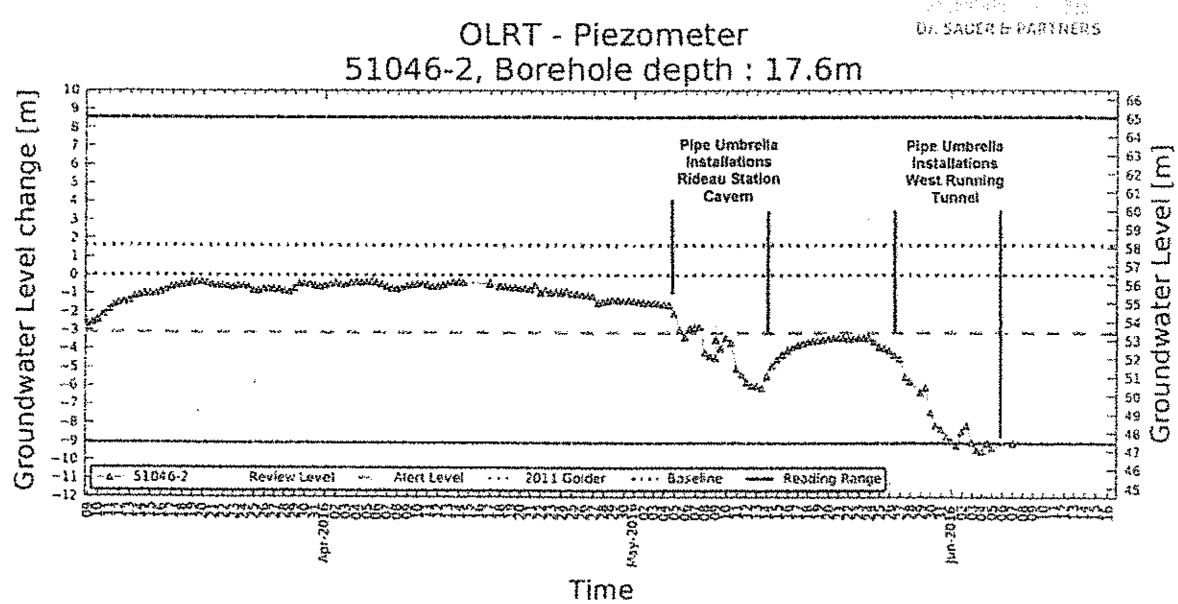

Figure 7-5: Piezometer 51046 Groundwater Level Readings- Chainage 102+360

8.0 Examination of 300 mm Watermain Sample

On June 23, 2016, 15 days after the sinkhole occurred and just prior to completion of backfilling of the sinkhole, a sample of the top of the 305 mm watermain that included a fracture surface was cut-out of the watermain exposed on the west side of the sinkhole. The specific location where the sample was obtained is shown in **Attachment 9**. This sample was visually examined and micro-examined by Integrity Testing Laboratory, Inc. (ITL) on September 16th and again on October 18th 2016. The results of ITLs examination are presented in a letter report dated November 9th 2016, which is included in **Attachment 10**. The conclusions reached by ITL based on their examination are summarized in the following excerpt from their report:

> "...based on the presented limited evidence, the failure of the pipe can be described as due to an external force applied to the top portion of the pipe. This force initiated a crack at the upper surface and bended the pipe that in turn caused the fracture to change direction and propagate as observed, in two directions along the circumference of the pipe. The defect found in the wall of the pipe did not contribute to the initiation of the fracture. The observed mode of failure also eliminates the over pressurization of the pipe as the cause for the failure."

The firm Simpson Gumpertz & Hager, Inc. (SGH) were engaged to review and comment on ITLs report. To provide context for their review, SGH were provided photographs of the sinkhole from its early stages of development to the time that the sample from the top of the 305 mm watermain was obtained. SGHs comments on the ITL report are included in their letter dated 22nd November 2016 (**Attachment 11**). SGH indicated that it is difficult to make definitive judgements about the fracture characteristics without first-hand examination of the sample. However, they did provide relevant comments based on the information available to them. Key elements of SGHs conclusions are provided in the following excerpts from their letter:

> "The fracture characteristics cannot be definitively linked to an external force that was acting over time. Instead field photos indicate multiple potential sources for external damage to the pipe after initiation of the sinkhole..."

> "Fracture morphology is mostly ductile like tearing, indicative of overstess, such as by bending due to loss of pipe support from ground settlement."

> "The ITL images show no evidence of a pre-existing leak or a pre-existing crack or defect that propagated into the final rupture."

9.0 Summary, Conclusions and Limitations

This section presents a summary of information and observations that are judged to be pertinent to the assessment of the root cause of the sinkhole that developed on Rideau Street on the morning of June 8th 2016, our conclusions as to the likely sinkhole root cause scenario, a discussion of possible alternative root cause scenarios and finally, limitations of this report.

9.1 Pertinent Information and Observations

Information and observations available to McMillen Jacobs Associates as of November 1st, 2016 that are judged to be pertinent to the assessment of the root cause of the sinkhole that developed on Rideau Street on the morning of June 8th 2016 can be summarized as follows:

- The sinkhole was associated with the collapse of the face of the west running tunnel. It is significant to note that **Figure 9-1** taken at approximately 8 AM on June 8, illustrates what appears to still be a full face of bedrock in the West Running Tunnel face in vicinity of Chainage 102+349.5. As shown in **Figure 9-2**, at the time of the collapse the west running tunnel face was at approximately Chainage 102+ 350 in so-called mixed-face conditions, meaning that there was both soil (soft ground) and bedrock present in the face, with the soil present on the south side of the face. The collapse appears to have started in the 10:15 – 10:30 AM time frame, when it became apparent to the personnel at the tunnel face that a combination of high water flows and ground instability at the tunnel face was serious enough to mandate their quick evacuation of the heading.

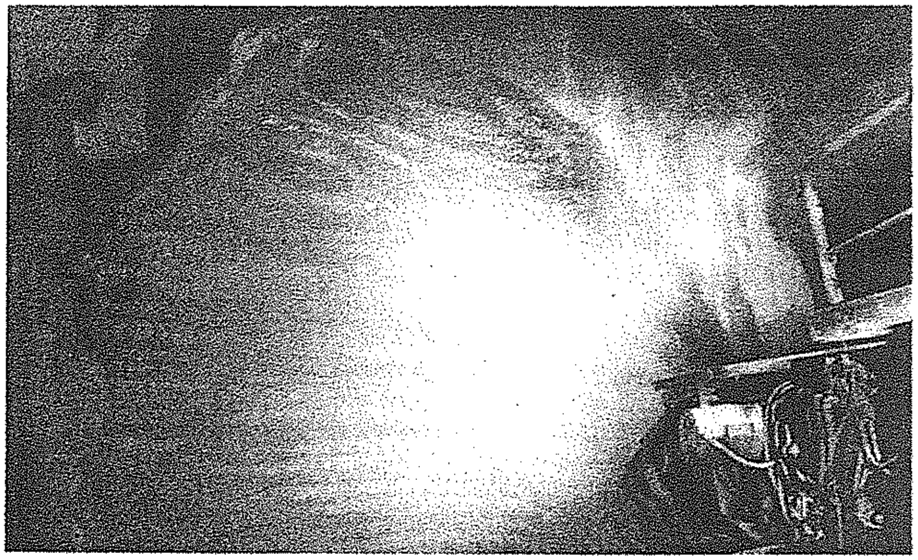

Figure 9-1:Chainage 102+349.5 Bedrock Heading Photo (June 8th 2016 at 8AM)

Figure 9-2: Chainage 102+350 Bedrock and Soft Ground Heading Photo (June 8, 2016 at approximately 10:20 AM, prior to time of complete face collapse)

- The surface manifestation of the sinkhole initiated on the south side of Rideau Street approximately 2 to 4 meters east of the west running tunnel face, and progressed to the north side of Rideau Street. The exact time of the initial surface manifestations of the sinkhole is uncertain based on available information, however by 10:30 to 10:35 AM the sinkhole had expanded across the southern half of Rideau Street. Refer to **Figure 1-1** and **Figure 1-2.**

- Failures of a 305 mm watermain located on the south side of Rideau Street and a 400 mm watermain located on the north side of Rideau Street occurred in connection with the sinkhole. The 305 mm watermain on the south side of the street failed prior to the 400 mm watermain which failed as a result of the sinkhole expanding to the north across Rideau Street

- Test borings taken during the preliminary engineering phase of the project and included in the Project Agreement indicated that saturated sandy soils below groundwater level could be anticipated at the location of the west running tunnel face at approximately Chainage 102+350. In a fully saturated condition (i.e. below the groundwater level), these soils would be anticipated to become highly unstable and behave in a flowing manner when exposed during the excavation process. Refer to **Figure 2-1**.

- Probe holes drilled sub-horizontally from the west running tunnel face in late May 2016 when it was at approximately Chainage 102 + 336 (i.e. 14 meters west of its position on June 8th) indicated soft ground was to be expected at approximate Chainage 102+350, consistent with information from preliminary engineering phase test borings included in the Project Agreement. These probe holes yielded relatively high rates of groundwater inflow (i.e., 26 to 38 liters/minute per probe hole), consistent with the anticipated saturated sandy soils below the groundwater level. Refer to **Table 5-2** and **Attachment 4.**

- During the period from May 26th to June 7th 2016, when the west running tunnel face was in bedrock at approximately Chainage 102+348.5 the installation of the planned pipe umbrella took place. Installation of the pipe umbrella was reported to be time consuming and difficult and there were repeated references to water inflows (reported total inflow of 276 l/min), grout wash-outs and high grout take quantities (reported 17,297 l total quantity grout injected). These conditions were similar to the previous probe hole observations. Refer to **Table 5-1** and **Attachment 3**.

- The groundwater level in the vicinity of the west running tunnel prior to starting of the pipe umbrella installation was approximately 10 m above the tunnel crown. Once drilling for this pipe umbrella was initiated the groundwater level began to drop. By the time the pipe umbrella installation was completed, the groundwater level, as reflected in Piezometer 51046, located approximately 10 meters east of the west running tunnel face, had stabilized at a level approximately 4 m above the tunnel crown. The lowering of the groundwater level as measured in the piezometer is indicative of inflow into the tunnel heading in connection with the pipe umbrella installation process. Refer to **Figure 7-5.**

- Settlement of the ground surface above the West Running Tunnel pipe umbrella at Chainage 102+348.5 occurred during pipe umbrella installation (i.e. during the period from May 26th to June 7th 2016). Where it was measured at settlement monitoring points located directly above the tunnel face, the magnitude of ground surface settlement ranged up to approximately 20 mm. There were no settlement monitoring points within 25 m east of the tunnel face, however ground surface settlement would be anticipated to be greater than 20 mm east of the tunnel face in the zone of pipe umbrella installation. This conclusion is supported by the observation that ground surface settlement was observed to manifest itself in opening of joints and pre-existing cracks in the sidewalk on the north side of Rideau Street adjacent to the zone of pipe umbrella installation, as seen in **Figure 9-3.** There were no such observations on the south side of Rideau Street because the sidewalks there had been displaced by the excavation for the West Rideau Station entrance. This ground surface settlement is likely related to loss of ground during installation of the pipe umbrella. A similar relationship between pipe umbrella installation and surface settlement was observed in connection with pipe umbrella installation for the Rideau Station located to the east of the sinkhole.

Figure 9-3:47-57 Rideau Street Sidewalk/Curb Separation Photo (June 6, 2016)

- Excavation for the West Rideau Station Entrance, the western end of which was adjacent to the sinkhole, was completed in mid-May 2016. The portion of this excavation adjacent to the sinkhole was approximately 5.5 meters deep and was supported with soldier piles and shotcrete lagging and tiebacks which extended under Rideau Street. In addition, 1-meter diameter drilled shaft foundations had been installed within the footprint of the West Rideau Station Entrance prior to beginning excavation. There were settlement monitoring points adjacent to the eastern end of the excavation and ground surface settlement associated with drilled shaft installation, tieback installation and excavation was observed adjacent to the excavation. Similar ground surface settlements were documented via an SSP on the west side of the excavation.

- It is understood that the original plans for mining the section of running tunnel with mixed face conditions (i.e. both soil and bedrock at the tunnel face) near chainage 102+350 was to advance the tunnel from east to west which would mean advancing the tunnel from soil into bedrock. At some point in time it was decided to also advance the running tunnel from west to east which resulted in advancing the tunnel from bedrock into soil. For the SEM tunneling method, it is generally considered less risky to advance a tunnel from soil into bedrock.

9.2 Likely Sinkhole Root Cause Scenario

The available information and observations indicate that it is highly likely that the root cause of the sinkhole was instability of the saturated sandy soil under approximately 4 meters of groundwater pressure on the south side of the west running tunnel face near Chainage 102+350 which in turn lead to loss of ground up through the soil profile. This loss of ground likely occurred very rapidly because the ground had previously been disturbed and loosened in response to pipe umbrella installation and the West Rideau Station Entrance excavation. This loss of ground then likely resulted in loss of support for the 305 mm watermain on the south side of Rideau Street and its subsequent catastrophic rupture. Water flowing from this rupture then caused erosion of the loosened, sandy soils below the watermain and the flow of a vast amount of soil into the west running tunnel, thereby creating the large sinkhole.

9.3 Alternative Sinkhole Root Cause Scenarios

9.3.1 Pre-Existing Watermain Leaks

The available information and observations suggest that leakage to the extent of being the root cause of the sinkhole was not occurring from either the 305 mm water main on the south side of Rideau Street or the 400 mm watermain on the north side of Rideau Street prior to June 8th. The information and observations that support this conclusion include:

- There was no observed increase in groundwater levels prior to June 8th, 2016 as would be expected if significant leakage from either watermain was occurring. Such an increase in groundwater levels was observed in connection with a leak that occurred in the 305 mm watermain in mid- November 2015. In fact, groundwater levels in the vicinity of the sinkhole dropped on the order of 6 meters in response to west running tunnel construction activity in the days leading up to the sinkhole.

- As shown in **Figure 9-4**, there was no observed significant leakage of water into the Rideau Station West Entrance as would be expected if the adjacent 305 mm watermain on the south side of Rideau Street had significant leakage.

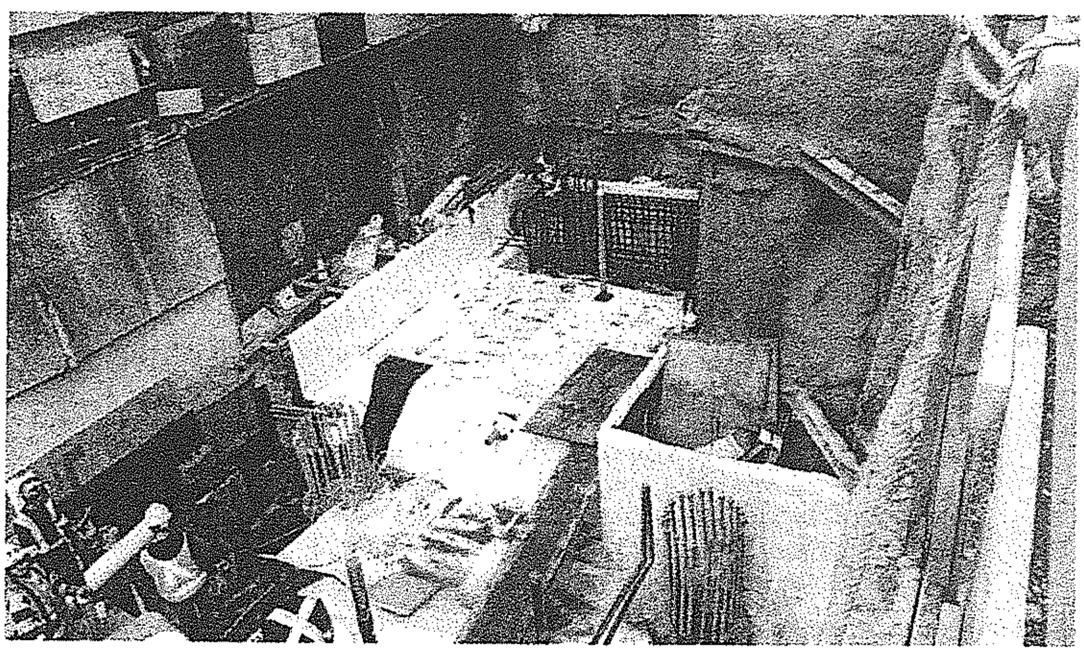

Figure 9-4: West Entrance (West End) Conditions on June 8,2016 at 8AM (prior to sinkhole)

9.3.2 Watermain Rupture Independent of OLRT Construction Activities

While it is possible that a rupture of the 305 mm watermain on the south side of Rideau Street due to some mechanism unrelated to OLRTC construction activity at about the same time as unstable mixed face conditions were encountered in the west running tunnel face, this scenario is considered highly unlikely based on available information. SGH noted in their letter dated November 22nd, 2016 that "ITL's forensic examination provides no evidence that the 300 mm PVC watermain is linked to the root cause of the sinkhole."

9.4 Limitations

This report was prepared based on information and observations included in the "Rideau Street Shared Data" folder on the OLRT e-builder web site as of November 30th 2016. It is understood that additional data may become available in the future. McMillen Jacobs Associates reserves the right to revise the conclusions presented in this report as appropriate based on review of any additional information that becomes available.