MEMO

TO: Carlo Steffanutti – Silvercreek Developments Limited

FROM: WSP Canada Inc.

SUBJECT: **Infiltration Study 35-40 Silvercreek Parkway S., Guelph, Ontario**

DATE: **July 5, 2022**

WSP Reference Number: 161-08980-01

1.0 INTRODUCTION

This memorandum summarizes a review of subsurface soil hydraulic conductivities estimated from in-situ infiltration testing and grain size analyses conducted at the property located at 35 & 40 Silvercreek Parkway South, Guelph, Ontario (herein is referred to as "the Site"). The findings of the infiltration testing will be used in the proposed design LID infiltration rates.

A discussion of the observed Site's geological conditions, the analysis and methodology of the hydraulic conductivities estimated from infiltration testing and grain size analyses is provided as a part of this memorandum. It is WSP's understanding that LID infiltration measures (i.e. infiltration trenches and an infiltration basin) are currently being proposed on Site. Infiltration trenches will be located within 'Mixed Use' and 'Apartment' Blocks, and the Infiltration basin will be located within the 'Storm Water Management' Block (reference **Figure 1**), as shown in the (Silvercreek Junction Functional Servicing and Storm Water Management Report prepared by RJ Burnside and Associates Ltd., June 2022). The bottom depth of the proposed LIDs varies with the type of LID and its location on site, with depths ranging from 0.6 m (below existing grade) BEG to 4.0mBEG.

The infiltration testing locations and the ground surface elevations were surveyed by WSP using a Garmin eTrex GPS equipment system. The test pit locations are referenced to by UTM, NAD 83, Zone 17 datum. The ground surface elevations are referenced to geodetic datum. The ground surface elevations are summarized in **Table 4-1** and approximate areas are shown on **Figure 2**.

1.2 ON-SITE SUBSURFACE INVESTIGATIONS

Numerous subsurface investigations have been conducted on the Site since 2000, as summarized in the following **Table 1-2**.

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Table 1-2: Summary of Previous Subsurface Investigations

AUTHOR	DATE	DESCRIPTION OF INVESTIGATION
Geotechnical Investigations		
V.A. Wood Inc.	January, 2005	• Thirty-one (31) boreholes advanced to depths of 4.6 to 9.3mBEG (Elev. 318.9 to 310.3m) across entire Site • Thirteen (13) grain size analyses completed • No monitoring wells installed • Bedrock not encountered
Peto MacCallum Ltd.	March, 2012	• Twenty-two (22) boreholes advanced to depths of 4.8 to 14.2mBEG (Elev. 321.2 to 310.0m) across entire Site • Seven grain size analyses completed • Four monitoring wells installed • Bedrock encountered in four boreholes at elevations between 314.9 to 312.1m
SPL Consultants Ltd	April, 2012	• Five boreholes advanced to depths of 6.2 to 6.7mBEG (Elev. 315.5 to 312.8m) across entire Site • Five monitoring wells installed • Bedrock not encountered • Two rising head tests and two falling head tests completed • Four grain size analyses completed
SPL Consultants Ltd	November, 2012	• Six boreholes and eight infiltration test holes ranging in depth from 2.8 to 11.2mBEG (Elev. 318.7 to 311.5m) • No monitoring wells installed • Bedrock encountered in four boreholes at depths ranging from 2.3 to 10.7mBEG (Elev. 315.6 to 312.0m) • Falling head permeability tests were performed in the eight test holes • Ten grain size analyses completed

AUTHOR	DATE	DESCRIPTION OF INVESTIGATION
SPL Consultants Ltd	August, 2013	• Seven boreholes advanced to depths of 2.1 to 6.5mbg (Elev. 318.2 to 313.0m) across entire Site • No monitoring wells installed • Bedrock not encountered • Forty-one (41) shallow test pits excavated, and samples collected for organic matter content analysis • Thirteen (13) grain size analyses completed
WSP	March, 2018	• Four boreholes advanced to depths of 9.2 to 9.9mBEG (Elev. 312.2 to 310.2m) on the north portion of the Site • Four monitoring wells installed • Bedrock encountered in three boreholes at depths of 9.1 to 9.2 mBEG (Elev. 312.2 to 311.0m) • Two grain size analyses completed
WSP	June, 2019	• Review of background information of available geological and hydrogeological information on the Site • Visual Inspection of the Site and surrounding area to determine topography and drainage • 4 new wells drilled and installed in the NE portion of the site and along Howitt Creek, including nested wells • 3 piezometers installed along Howitt Creek • Update Water Budget incorporating updated site plan • 4 constant head infiltration tests were completed on site, for LID design • 8 test pits were excavated to show shallow subsurface in LID locations
Environmental Investigations		

AUTHOR	DATE	DESCRIPTION OF INVESTIGATION
Golder Associates Ltd.	July, 2004a	• Thirty-six (36) test pits excavated to depths of 1.8 to 4.5mBEG across entire Site • Twelve (12) boreholes to depths of 2.1 to 8.6mBGE • Seven monitoring wells installed • Two grain size analyses completed
Golder Associates Ltd.	July, 2004b	• Seven boreholes advanced to depths of 4.6 to 11.3mBEG (Elev. 317.19 to 313.8m) on south portion of the Site • Seven monitoring wells installed

2.0 APPROACH

The infiltration testing program included the following tasks completed by WSP staff:

1. Selected locations of proposed infiltration testing in coordination with the Client's Stormwater Engineer Consultant, R.J. Burnside & Associates Limited (R.J. Burnside).
2. Ground truthing the proposed test locations in the field. Eight (8) locations were proposed in the Site, as shown in **Figure 2**.
3. Completed public locates to confirm absence of buried utilities at test locations, through Ontario One Call.
4. Coordinated with a private locator to provide clearance of underground utilities at the proposed test locations.
5. The testing locations (8) were opened using an excavator (Kieswetter Excavating Inc.) to a depth 0.2m above the testing depth and hand augured for an additional 0.2 m. At all locations two (2) in-situ tests were completed at Target (T) depth, and two (2) in-situ tests were completed at deeper (D) depth. Testing depths ranged from 0.6m to 4.6m below ground surface (mbgs). Testing locations were restored to original conditions after the tests were performed.
6. Collected representative soil samples from each test pit at the LID target depth and submitted selected soil samples for grain size distribution analysis, including hydrometer.
7. Conducted an infiltration test at each testing depth using a Guelph Permeameter to measure the rate at which water infiltrates into the soil. The Guelph Permeameter instrument was rented from Hoskin Scientific. This instrument was used to estimate field-saturated hydraulic conductivity from observed infiltration rates. A hydraulic conductivity equation using the rate of change in Static Water Level (SWL) was used to estimate the percolation rate or infiltration rate for the soils tested.

8 Prepared a technical memorandum to document the methods, test locations, test observations, calculated test values and the range of infiltration rates.

3.0 FIELD WORK

The testing locations and depths were discussed and confirmed with R.J. Burnside from May 6, 2022, with one (1) in-situ test planned per proposed infiltration trench (6), and two (2) in-situ tests planned at the proposed infiltration basin (1). Two (2) in-situ tests were completed at the bottom of the proposed LID Target depth (expressed as T) and two (2) in-situ tests were completed at deeper (expressed as D) depth. The test depths are summarized in **Table 1**.

The field work for the in-situ infiltration testing at the Site was carried by WSP between June 14 and 20, 2022. The infiltration testing was carried out by WSP field technicians and a Heavy Equipment Operator from Kieswetter was made available to WSP to excavate the eight (8) test pits INF22-1 T/D, INF22-2 T/D, INF22-3 T/D, INF22-4 T/D, INF22-5 T/D, INF22-6, INF22-7 T/D, and INF22-8 T/D at locations illustrated on **Figure 2.** During testing, records were maintained of the soil profile observed and the depth to water (if observed). The test pits were back-filled and restored by Kieswetter to the original conditions after the infiltration tests.

At location INF22-4, Fill Sandy Silt was encountered from ground surface to 0.45mbgs until a layer of cement was encountered and the excavator was unable to penetrate this layer. This location was backfilled, and INF22-4A was chosen as an alternative. The soils at INF22-4A, we encountered topsoil to 0.2, and then encountered another cement layer with a thickness of 0.1m, from 0.3mbgs to 1.74mbgs a medium sand, with some fine and coarse sand was encountered.

4.0 OBSERVED CONDITIONS

4.1 SOIL CONDITIONS

In total, 9 test pit locations were opened by excavator based on the proposed LID depths. Based on the soil conditions observed during the test pit program, all test pits were found to encounter native soils. At location INF22-4, Fill Sandy Silt was encountered from ground surface to 0.45mbgs until a layer of cement was encountered and the excavator was unable to penetrate this layer. This location was backfilled, and INF22-4A was chosen as an alternative. The following summary of the data is intended to provide a description of the general characteristics of these deposits based off findings from all test pits opened in this study. Descriptions of soil conditions observed at each test pit location are provided in the Guelph Permeameter Field Data Sheets, provided as **Appendix A**.

TOPSOIL

A layer of topsoil, up to 100-200 mm in thickness, was observed at the ground surface across the Site. The topsoil is generally dark brown in colour containing an appreciable number of roots and humus.

SILT, SAND, AND SAND & GRAVEL

Cohesionless deposits of sandy silt, silty sand, gravelly silty sand, and silty sand and gravel are predominant throughout the Site and encountered in all test pits. Cobble/boulder sizes were observed throughout the granular deposits.

4.2 SUMMARY OF GROUNDWATER CONDITIONS

Evidence of groundwater seepage was observed in test pit INF22-1 T/D, on June 16, 2022 at an approximate depth of 3.9mbgs. The depth of water was observed to rise to approximately 0.1m from the bottom of the excavation. At all other test pit locations evidence groundwater seepage was not observed. Further details on test pits and groundwater seepage can be found in **Table 4.1**.

Table 4.1 Summary of Test Pits and Groundwater Seepage

TEST PIT NO.	GROUND ELEV (MASL)	TEST PIT DEPTH		GROUNDWATER SEEPAGE		NOTES
		Depth (m)	Elev. (masl)	Depth (m)	Amount	
INF22-1	317	3.9	313.1	0.1	Seeping	Groundwater pooling at surface during infiltration testing duration, caving at 3.6 m
INF22-2	318	4.45	313.55	Dry	Dry	Open and dry
INF22-3	317	4.6	312.4	Dry	Dry	Open and dry
INF 22-4	317	0.45	316.55	Dry	Dry	Concrete slab in bottom of test pit, unable to excavate further
INF22-4A	315	1.74	313.26	Dry	Dry	Sandy Silt fill, Open and dry
INF22-5	320	1.7	318.3	Dry	Dry	Open and dry
INF22-6	315	1.6	313.4	Dry	Dry	Open and dry
INF22-7	319	2.7	316.3	Dry	Dry	Open and dry
INF22-8	319	2.7	316.3	Dry	Dry	Open and dry

5.0 HYDRAULIC CONDUCTIVITY ESTIMATES

5.1 INFILTRATION TEST RESULTS

The infiltration tests were conducted using the Guelph Permeameter to determine saturated (wetted) hydraulic conductivity within the unsaturated zone. The tests were conducted by introducing a constant head of water in the borehole and maintaining the head of water using the combined reservoir method. The change in water levels within the reservoir were measured at consistent time intervals. Saturated (wetted) hydraulic conductivity was calculated based on the field measurements of the reservoir level, using the method provided by Soil Moisture Ltd. (2012). Calculations reflect the one-head method. A total of thirty (30) in-situ tests were completed at eight (8) locations, where testing occurred at target depth of the LID and at deep depth ranging 0.5m to 1m below target depth. Testing locations were provided by R.J. Burnside from the Functional Servicing and Storm Water Management Report (June 2022) based on locations and depths of on-site LIDs. based on locations and depths of on-site LIDs.

The test was initially performed by applying a constant head of water of 0.10 m (10 cm) and recording the change in the Guelph Permeameter reservoir water level over time. Depending on the rate of change observed during the first three minutes of testing, the constant head set within the Guelph Permeameter reservoir was adjusted to allow for appropriate measurements of the water level (i.e. increase or decrease in the constant head of water being applied).

At the testing locations INF22-7D and INF22-8D the in-situ tests were completed by initially applying a constant head of water of 0.10 m. Due to the slow rate of water level change in the reservoir, the constant head of water was changed to 0.2 m.

Due to a rapid change in water level in the reservoir the initial constant head pressure of 0.1m was changed to 0.05m at the following testing locations: INF22-4T, INF22-4D, INF22-5T, INF22-5D and INF22-6D.

Testing at INF22-1T (target) was proposed to be at a depth of 3.95 mbgs, and INF22-1D was proposed to be at a depth of 4.5 mBEG or 4.95 mBEG. Testing was raised to 2.9mbgs for target in-situ testing, and to 3.7 mBEG for deep in-situ testing, due to observed groundwater seepage in the test pit at an approximate depth of 3.9 mBEG. The deep locations for INF22-2d and INF22-3d were only able to reach depths of 0.55 to 0.6m below the target depth, due to reaching maximum extent of the excavators, and slope stability of the test pit.

The results of the infiltration testing are summarized in **Table 1** and presented graphically on **Figure 3**. **Figure 3** shows the observed field saturated hydraulic conductivity estimates and uses relationships published by the “Ministry of Municipal Affairs and Housing – Building Development Branch” to relate the test values to “infiltration rate” (in mm/hour) or “percolation time” (in mins/cm). As can be seen on **Figure 3**, these concepts are inversely related (a low value in one is high for the other).

The results are also presented in **Appendix A**. **Appendix A** shows the rate of infiltration recorded in the field as well as other field observations along with components of the equation used to calculate the saturated hydraulic conductivity (Ksat). The field saturated hydraulic conductivity was calculated at each testing level, corresponding to the approximate depth of the proposed LID bottoms and at additional testing depths below the proposed LID bottom, at depths of 1.6-4.45 mBEG.

Per testing location and depth, two tests were proposed to get a geometric mean of hydraulic conductivity (K_{sat}) and a geometric mean of infiltration rates. When two tests were calculated the geometric mean varied one order of magnitude for K-values, which could be caused by compaction influence from the excavator bucket at each location and the potential presence of lenses of course or finer materials. The geometric mean was calculated using the estimated infiltration rates to allow for an improved representation of the soil horizon at the LID subsurface target depth.

The field saturated hydraulic conductivity was calculated to vary from 3.2 x 10^{-8} m/sec to 2.8 x 10^{-4} m/sec within the approximate bottom level of the proposed LIDs. This range of field saturated hydraulic conductivity is consistent with the expected range for the soils encountered at the Site (see attached **Table 1**).

Collectively, the rate of infiltration measured using the Guelph Permeameter methodology is representative of the discrete location of the testing and may not reflect variability of soil conditions within the full footprint of the proposed LID infiltration system.

5.2 GRAIN SIZE ANALYSIS

WSP collected eight (8) soil samples during the test pit activities, from depths ranging between 0.7 and 4.6-mbgs and submitted the soil samples for grain size analysis (including hydrometer). The soil samples were collected from the target testing depth of the proposed LIDs. Based on the results of the hydrometer analysis, hydraulic conductivities were estimated using Hazen Formula Method (for coarse textured native soils) and Puckett et al Method (for fine grained native soils) . Grain size analysis was conducted for comparison with the hydraulic conductivity results estimated from in-situ GP testing. Grain size analysis can be found in **Table 2.**

5.2.1 HAZEN FORMULA METHOD

The Hazen formula method is suitable for estimating hydraulic conductivities of sands where the effective grain size is between 0.1 and 3.0 mm (Fetter, 2001). Hazen formula method applies an empirical relationship to estimate a hydraulic conductivity, K, m/sec, which is as follows:

$$K = 0.01 * C * (d_{10})^2$$

Where:

K = bulk hydraulic conductivity (m/sec);

d10 = grain size at which point 10% of the soil passes the sieve (mm); and,

C = a constant generally set at 1 for these units.

A summary of the hydraulic conductivity estimates from grain size distribution curves are provided in **Table 2**. Grain size distribution curves are provided in **Appendix B**.

Hazen formula method was used at testing location INF22-5 due coarser materials being collected at this location. Using the Hazen formula method, the hydraulic conductivity estimated at the proposed LID target depth at INF22-5 was 1.45 x 10^{-4}m/sec, compared to the in-situ geometric mean hydraulic conductivity value of 3.4x10^{-6} m/sec. .

Collectively, the rate of infiltration estimated using the Hazen is representative of the discrete location and scale of the soil samples and is reasonably consistent; however, may not reflect the potential variability of soil conditions within the full footprint of the proposed LID infiltration system.

5.2.2 PUCKETT ET AL METHOD ANALYSIS

The Puckett et. Al. Method (Bradbury and Muldoon, 1990) was used to estimate the hydraulic conductivities for the fine-grained soils, which is as follows:

$$K = (4.36 \; x \; 10^{-5}) \; x \; e^{-0.1975 \; x \; \%Clay}$$

Where:

K = hydraulic conductivity (m/s); and

% Clay = percent of the total sample finer than 0.002 millimeters by weight.

A summary of the hydraulic conductivity estimates from grain size distribution curves are provided in **Table 2**. Grain size distribution curves are provided in **Appendix B**.

The hydraulic conductivities estimated using the grain size distribution plots and the Puckett et al method ranges from 4.1×10^{-6} m/sec to 1.3×10^{-5} m/sec, representative of soil samples collected at the target testing depth of each proposed LID. The estimated hydraulic conductivity values are within the expected range of soil textures observed at the target testing depth during the shallow hand auguring. The values calculated using the Puckett et. al. method were noted to be within one order of magnitude when compared to the in-situ testing K_{Sat} values.

Collectively, the rate of infiltration estimated using the Puckett et. al. method is representative of the discrete location and scale of the soil samples and is reasonably consistent; however, may not reflect the potential variability of soil conditions within the full footprint of the proposed LID infiltration system.

5.3 DISCUSSION ON INFILTRATION TESTING

A safety correction factor is typically incorporated into the LID design to ensure that there is sufficient conservatism is considered to account for the variability in field conditions, potential reductions in soil permeability due to compaction or smearing during construction and gradual accumulation of fine sediments over the lifespan of the LID infiltration system. Table C3 in the Stormwater Management Criteria (TRCA, 2012) provides a range of safety factors that are to be applied to the measured infiltration rate of the proposed bottom elevation of the LID infiltration system.

To determine the appropriate safety factor that should be applied to the estimated infiltration rate at each proposed LID, the ratio of the mean (geometric) measured infiltration rate at the proposed bottom depth of the LID to the mean (geometric) measured infiltration rate below the bottom depth of the LID were calculated at each location. Using the recommendation safety factors provided in Table C3 (TRCA, 2012) and the calculated ratio at each location, an applicable safety factor was selected for each proposed LID location. A summary of the calculated ratios are shown and the selected safety factors are presented in **Table 1**.

In consideration of the available information from both in-situ and grain size analysis testing methods, WSP recommends using the geometric mean of the estimated infiltration rates at the approximate bottom depth of the proposed infiltration trenches and infiltration basin, based on the in-situ infiltration testing. The associated in-situ infiltration testing completed within each infiltration feature and the calculated geometric means at each proposed LID at target depth are summarized in **Table 1**.

The recommended infiltration rate for design purposes that consider the safety factor are as follows:

-the infiltration basin in Block 25 had a rate of 19 mm/hr with a safety factor of 3.5;

-the infiltration trench in Block 2 had a rate of 20 mm/hr with a safety factor of 3.5;

-the infiltration trench in Block 3 had a rate of 204 mm/hr with a safety factor of 2.5;

-the infiltration trench in Block 20 had a rate of 43 mm/hr with a safety factor of 2.5;

-the infiltration trench in Block 19 had a rate of 26 mm/hr with a safety factor of 2.5;

-the infiltration trench in Block 18 had a rate of 15 mm/hr with a safety factor of 3.5; and,

-the infiltration trench in Block 1 had a rate of 10 mm/hr with a safety factor of 2.5.

6 CONCLUSIONS

A. Based on the results of the in-situ infiltration testing carried out using the Guelph Permeameter, the recommended infiltration rates for design purposes, per LID, that consider the safety factor are as follows:

- the infiltration basin in Block 25 had a rate of 19 mm/hr with a safety factor of 3.5;
- the infiltration trench in Block 2 had a rate of 20 mm/hr with a safety factor of 3.5;
- the infiltration trench in Block 3 had a rate of 204 mm/hr with a safety factor of 2.5;
- the infiltration trench in Block 20 had a rate of 43 mm/hr with a safety factor of 2.5;
- the infiltration trench in Block 19 had a rate of 26 mm/hr with a safety factor of 2.5;
- the infiltration trench in Block 18 had a rate of 15 mm/hr with a safety factor of 3.5; and,
- the infiltration trench in Block 1 had a rate of 10 mm/hr with a safety factor of 2.5.

7 REFERENCES

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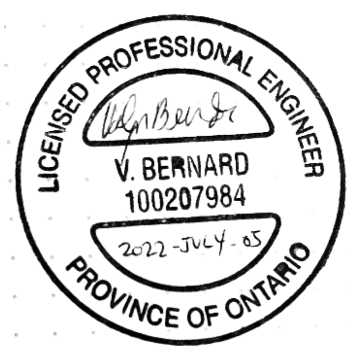

Attachments:
Figure 1: Site Plan
Figure 2: Infiltration Testing Locations
Figure 3: Infiltration Test Results – 35–45 Silvercreek Parkway, Guelph, ON
Table 1: Summary of In-Situ Infiltration Testing Results
Table 2: Summary of Estimated Hydraulic Conductivity Results
Appendix A: Guelph Permeameter Field Data and Calculation Sheet
Appendix B: Particle Distribution Reports