APPENDIX E – GEOTECHNICAL ASSESSMENT REPORT

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

EGLINTON CROSSTOWN LIGHT RAIL TRANSIT (ECLRT) GEOTECHNICAL INVESTIGATION

TORONTO, ONTARIO

IBI Group

PROJECT: TRANETOB01242AA

Final Report March 3 2010

Coffey Geotechnics Inc.
20 Meteor Drive Etobicoke Ontario M9W 1A4 Canada
T (+1) (416) 213 1255 F (+1) (416) 213 1260 coffey.com

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

March 03, 2010

IBI Group
30 International Boulevard
Toronto, Ontario
M9W 4P3

Attention: Mr Fouad Mustafa, P.Eng.

Dear Sir,

RE: Geotechnical Assessment for Eglinton Crosstown LRT

Please find attached the geotechnical assessment report for the proposed Eglinton Crosstown LRT.

If you have any comments or enquiries please contact the undersigned.

For and on behalf of Coffey Geotechnics Inc.

Zuhtu Ozden, P.Eng.
Senior Principal

Coffey Geotechnics Inc.
20 Meteor Drive Etobicoke Ontario M9W 1A4 Canada
T (+1) (416) 213 1255 F (+1) (416) 213 1260 coffey.com

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PRELIMINARY GEOTECHNICAL ASSESSMENT

EGLINTON CROSSTOWN LIGHT RAIL TRANSIT

1 INTRODUCTION

Coffey Geotechnics Inc. (Coffey) was retained by Transit City Group (TCG) on behalf of the Toronto Transit Commission (TTC) to contribute to the Eglinton Crosstown LRT (ECLRT) project.

This report presents preliminary geotechnical information on the subsurface conditions along the proposed alignment of ECLRT. Comments on geotechnical aspects of design and construction are also provided.

This report has drawn upon borehole information collected from various sources, including previous geotechnical investigations conducted on behalf of City of Toronto and TTC.

2 DESCRIPTION OF PROJECT

The Eglinton Crosstown LRT is approximately 33 km in length from Kennedy Station in the east to the Lester B. Pearson International Airport in the west. The LRT will operate at the surface in the centre of Eglinton Avenue from Commerce Boulevard to Black Creek Drive in the west and from Brentcliffe Road to Kennedy Road in the east. However, between Black Creek Drive and Brenticliffe Road, the width of Eglinton Avenue is too narrow to accommodate two lanes of traffic in each direction and the LRT; therefore, the LRT will operate underground in this section, constructed predominantly within the Eglinton Avenue right of way.

The LRT will provide connection with the Spadina Subway, the Yonge Subway, the Danforth Subway, Scarborough RT, and the proposed Jane LRT, Don Mills LRT and the Scarborough/Malvern LRT lines.

Figure 1 shows the proposed ECLRT routes in relation to the current and the proposed subway and LRT lines. Interfaces will be established beneath the existing stations at Eglinton West (Allen Road) and Eglinton (Yonge Street). New underground stations are to be constructed at:

- Keele Street
- Caledonia Road
- Dufferin Street
- Oakwood Avenue
- Allen Road
- Bathurst Street
- Chaplin Crescent
- Avenue Road
- Yonge Street
- Mount Pleasant
- Bayview Avenue
- Laird Drive

Figure 1 - Eglinton Crosstown LRT Route

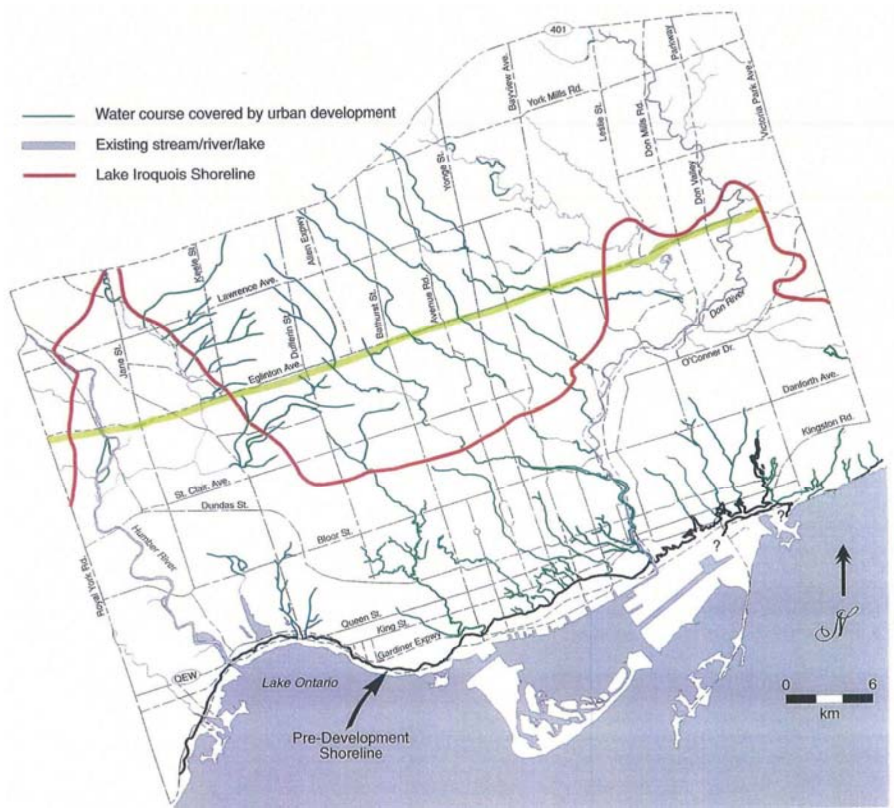

Figure 2 – Streams and Rivers in Central Metro Toronto Area (Report, "Eglinton Crosstown LRT – Single vs. Twin Tunnelling – A Study", Transit City Group, 2009)

3 PHYSIOGRAPHY AND DRAINAGE

On a regional scale, the topography slopes gently southward towards Lake Ontario, which is approximately 7km south of the project site. However, the local terrain generally varies from east to west where hilltops, formed during various glacier and interstadial activities, have been eroded by streams draining southward into Lake Ontario as shown in Figure 2. The river erosion of the till deposits has developed into valleys that are relatively steep sided. It is of interest to note that the bedrock contours suggest that present river system formed along pre-glacial streams, which eroded deep into the soft shale.

The deposits in the Toronto area were formed by successive continental glaciation and contain unsorted tills that are relatively impervious as well as stratified to sorted materials that have wide ranges in their permeability. Due to the various glaciations which advanced and retreated, there are successions of till sheets separated by various meltwater and interstadial deposits. The buried shoreline of ancient Lake

Iroquois, depicted in Figure 2, is composed of beach cobble, sand and gravel and may be subject to artesian pressures where it crosses the alignment. As such, the hydrologic conditions at the site are rather complex since the low permeability glacial tills tend to impede groundwater flow; whereas, the interstadial deposits of silt and sand serve as local shallow aquifers. The groundwater seepage below the weathered surface of the bedrock is generally quite small.

The alignment of the ECLRT crosses the following rivers and streams sorted from west to east: Mimico Creek, Humber River, Black Creek, Don River West, Don River East, Wilson Brook, and Massey Creek. Alluvial deposits are possible in these areas and possibly some soft ground.

The topography along the tunnel section of the alignment slopes downhill in the vicinity of the intersection of Old Forest Hill Road and Eglinton Avenue where a hillcrest is located around El. 185 m. At the base of this hill, West Don River forms a valley to the east where the terrain is about El. 105 m; and Black Creek forms a valley to the west where the terrain is about El. 110m. The groundwater at the project site drains west to Black Creek, east to West Don River, and south into Lake Ontario. The piezometric water levels at the site range from several meters head of artesian pressure along the western hill slope to levels that are a few meters below the tunnel invert near the hilltop and along the eastern hillside.

4 GEOLOGICAL SETTING

The general geology of Toronto region consists of various Quaternary deposits overlying shale bedrock.

The Quaternary overburden typically consists of recent alluvial deposits; glacial tills; glaciolacustrine sand, silt, and clay deposits; granular beach deposits; and, glaciofluvial silt and sand deposited during and after the various advances and retreats of the glacial ice.

The recent natural alluvial deposits are found within the flood plains of existing rivers and streams, such as the Humber River, Black Creek, and Don River. Generally these sediments vary from bouldery gravels in stream beds to organic-rich sands and silts along the flood plains. In addition to naturally formed deposits, emplaced fills can be found in the area.

From the published geological data, the Toronto area experienced at least three glacial and two interglacial periods, during which time a sequence of glacial and interglacial deposition took place. Towards the end of the last ice age, when Wisconsinan glacier withdrew from the Lake Ontario basin to the north and to the east, Lake Iroquois, the forerunner of the present Lake Ontario, was established. The entire sequence of these glacial, interglacial and lacustrine deposits is, however, seldom found intact and usually one or more of these units are absent at any one location.

Figure 3 presents a plan showing the interpreted surface geology in the vicinity of the Eglinton Crosstown LRT (Geological Survey P2204).

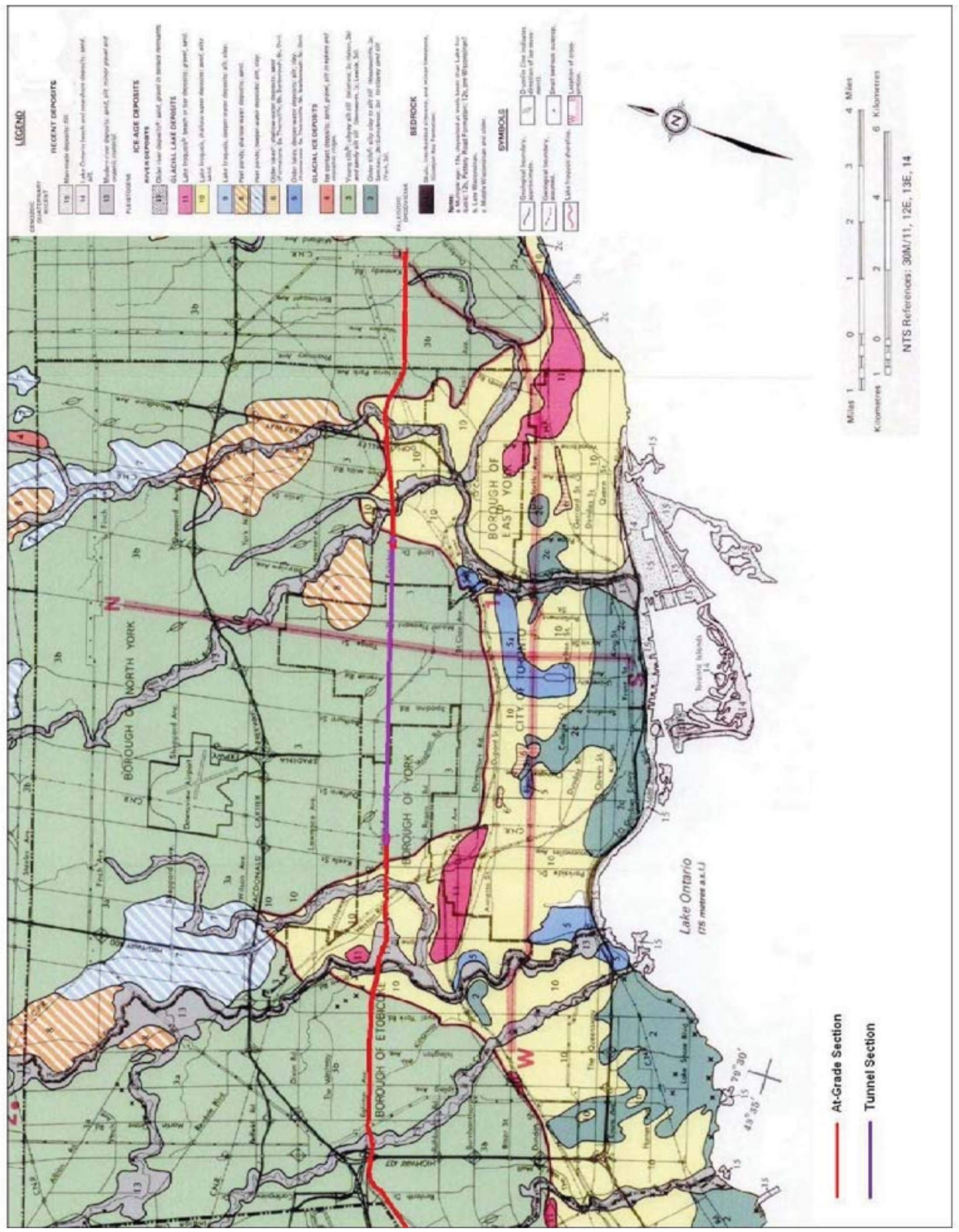

Figure 3 - Surface Geology of Toronto (Geological Survey P2204)

The oldest Quaternary deposits are the Illinoian age represented by the York Till which is overlain by Sangamonian-aged interglacial deposits (sands, silts, and clays) of the Don Formation. The Wisconsinan age is represented by deposits formed during several glacier advances and retreats. These deposits are represented by the Scarborough, Pottery Road, and Thorncliffe Formations set down during glacial retreats, and the Sunnybrook Till from the Early Wisconsinan time and Leaside Till (Newmarket Till and Halton Till) from the Late Wisconsinan period. These tills were deposited during periods of ice advances into the Ontario basin. Typically, the tills consist of a heterogeneous mixture of gravel, sand, silt and clay size particles in varying proportions. Cobbles and boulders are not uncommon.

The soils below the upper till are generally heavily pre-consolidated, primarily due to the height of ice which covered most of the area. As such they provide good foundation materials and can stand above water table at relatively steep side slopes in temporary excavations. These are however exceptions to this where the tills have been reworked due to water action at the frontal lobe locations or other natural phenomena, such as ice inclusion when first transported and subsequent melting which caused weak zones in the till. These weaker tills are locally referred to as ‘ablasion tills’. The last major glacial event during late Wisconsinan age was the occupation of the current Lake Ontario basin by former glacial Lake Iroquois. This resulted in the deposition of glaciolacustrine sediments mostly silts, sands and gravels along its shoreline and gradually finer-grained sands, silts and clays further off-shore in deeper water. Table 1 presents the sequence of soil deposition discussed above.

Table 1 - Geological Formations and Events in Toronto Area (After Karrow, 1967)

Stage	Formation or Event (formal names of formations are in italics)		Lithology
Recent		Lake Ontario Beaches	Beach sand, gravel
		Alluvium	Clay, silt, sand, gravel
		Swamp and bog deposits	Marl, muck, peat
		Streams and terrace deposits	Clay, sand, gravel
Wisconsin	Late	Lake Iroquois	Clay, sand, gravel
		Early peripheral lakes	Clay, sand
		Leaside Till	Silty sand till
		Lake and stream deposits	Varved clay, sand
		Meadowcliffe Till	Silty clay till
		Lake and stream deposits	Varved clay, sand
		Seminary Till	Clayey sand till
	Middle	Thorncliffe Formation	Varved clay, sand
	Early	Sunnybrook Till	Silty clay till
		Scarborough Till	Clay, silt, sand, wood
Sangamonian		Don Formation	Clay, sand, wood
Illinoian		York Till	Clayey sand till

The Quaternary deposits overlay bedrock of the Middle Ordovician age Georgian Bay Formation which is a bluish and grey shale with interbeds of sandstone, siltstone, limestone and dolostone. The bedrock surface gently slopes to the southeast at a rate of about 5 m/km. The upper portion of the bedrock is commonly weathered for a depth of 0.6 to 1.0 m and even within this weathered zone hard sandstone and even harder limestone layers are not uncommon. In some areas, especially in the western half of Toronto, a till-shale layer may be found immediately above the bedrock. Figure 4 presents a north-south geological section along Yonge Street crossing the proposed ECLRT route.

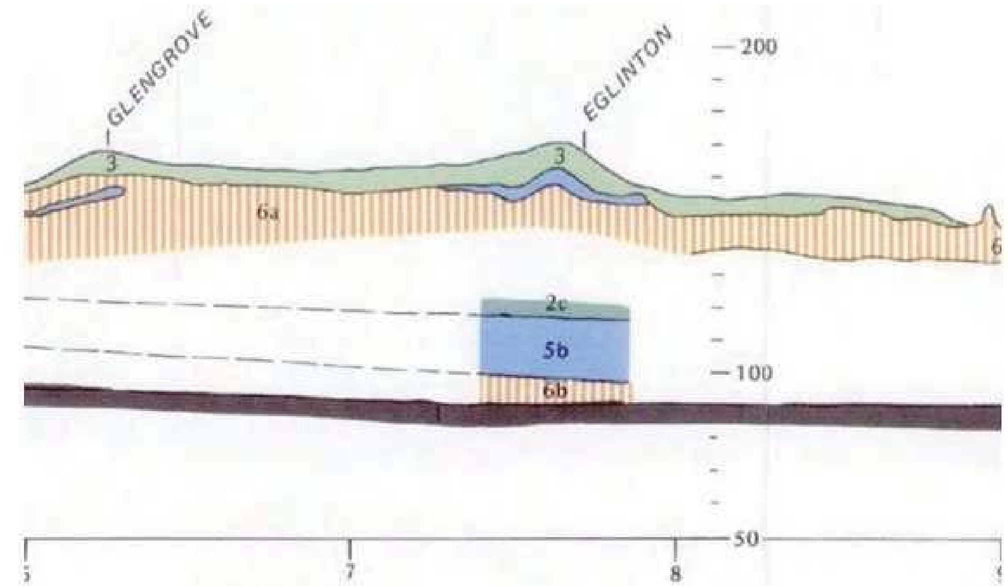

Figure 4 – North-South Geological Section along Yonge Street (horizontal scale in kilometres)

(see Figure 3 for definition of geological units)

Stress relief features such as folds and faults are common in the bedrock. In these features, the rock is heavily fractured and sheared, and contains layers of shale rubble and clay. Weathering is much deeper than the surrounding rock in these features and often there is a lateral migration of stress relief features, resulting in sound unweathered bedrock overlying fractured and weathered bedrock. The stress relief features are usually in the order of 4 to 6 m wide, but the depth can vary from 4 to 5 m to in excess of 10 m. These features occur randomly.

The bedrock contains significant locked in horizontal stresses. The stresses can impose significant loads on tunnel or excavation walls in a time-dependent manner (i.e. time allows a horizontal deformation along with a corresponding decrease in locked-in horizontal stresses).

Methane gas exists at some locations in the bedrock, normally below the top 1.0 m and more concentrated with depth. Appropriate care and monitoring is essential in all confined bedrock excavations, particularly caissons and tunnels. While some methane gas leak may occur to the overburden soils, especially in the more pervious (i.e. sandy and gravelly soils), from the bedrock, problems associated with this occurrence are uncommon. The presence of methane gas is possible and occurs sporadically based on local experience. However, the exact locations of the occurrences will need to be further investigated by drilling additional boreholes.

Bedding joints in the bedrock are very close-to-close, smooth planar in the shale and rough planar in the limestone. Significant vertical jointing is common. Occasional clay seams are also found in the bedrock (up to 75 mm thick), primarily in the horizontal direction.

4.1 Hydrogeology

Groundwater seepage below the top 1 m is generally small, however, at several locations large quantities have been encountered, especially close to a large source of water, due to the movement of water through the fractures within the rock.

The groundwater at the site along the underground tunnel section drains flowing west to Black Creek, east to West Don River, and south to Lake Ontario. Water levels ranges\ from several meters of artesian pressure along the west hill slope to a few meters below the tunnel invert near the hilltop and along the east hillside.

Existing piezometric levels in the tunnel horizon are expected to range from approximately 110 m at the western end of the tunnelled portion near Black Creek Drive rising to approximately 158 m between Dufferin Street and Bathurst Street and falling to approximately 140 m at Bayview Avenue. Groundwater flow occurs towards Lake Ontario to the south and laterally toward lower lying areas in the Humber River Valley and the Don River Valley. Perched groundwater can be expected to occur within shallow layers of sandy native soils and within fills.

Downward hydraulic gradients are apparent in piezometric records in the higher ground between Dufferin and Bathurst Streets indicating a zone of recharge to the groundwater system while upward gradients and slightly artesian conditions are noted in lower lying areas near Black Creek indicating groundwater discharge.

Borehole records show that significant thicknesses of sand are present within interpreted interglacial deposits present between Glenhaven Street and Hoyle Avenue. These deposits will have the capacity to allow groundwater flow into excavations and the tunnel face.

4.2 Bedrock Levels

The presence of shale bedrock is recorded at elevations ranging from 99 m to 105 m between Yarrow Road and Richardson Avenue near the western limit of the proposed area to be constructed in tunnel. Elsewhere boreholes did not reach bedrock.

An interpretation of bedrock contours in Metropolitan Toronto prepared by the Ontario Department of Mines (Preliminary Map 102) shows bedrock elevations in the range 60 m to 90 m between Yarrow Road and Richardson Avenue. The Department of Mines interpretation is that bedrock levels are falling steeply to the west into the Humber River palaeovalley at this location and minor realignment of the interpreted contours would bring them into consistency with the borehole records. The interpreted bedrock contours rise to approximately elevation 110 m beneath Dufferin Street and gradually fall to elevation 60 m near Brentcliffe Road at the eastern limit of the proposed tunnel.

Based on this interpretation and the recorded borehole information it is unlikely that shale bedrock will be encountered during tunnelling for the proposed twin tunnel TBM construction or during underground station construction.

5 SOURCE DATA

Borehole information for the ECLRT alignment was collected from the TTC Library and includes work by Peto MacCallum Limited (PML), Trow Associates, Conestoga-Rovers & Associates (CRA), and Golder Associates. Geotechnical investigations were conducted along Eglinton Avenue for the at-grade sections from Renforth Drive to Weston Road and from Mount Pleasant Road to Kennedy Road by PML (2009) and from Chiltern Hill Road to Redpath Avenue by CRA (2009). Table 2 summarizes the work carried out by PML and CRA in previous investigations along the proposed LRT route.

Table 2: Summary of Field and Laboratory Tests

	Peto MacCallum (2009)	**CRA (2009)**
Borehole	42	7
Piezometer	12	7
Natural Moisture Content	All recovered samples	127
Particle Size Analysis	60	23
Atterberg Limits	44	21
Unit Weight	26	20
Rising Head Permeability	6	7

Borehole locations are shown in Drawings 1 to 36.

The groundwater conditions along the at-grade section of ECLRT were monitored by piezometers and are tabulated in Table 3.

Table 3: Groundwater Levels (Source PML 2009, CRA 2009)

Borehole No.	Station	Approximate Borehole Elevation (m)	Screen Depth (m)	Piezometric Groundwater Depth / Elevation (m)	
				Depth / Elevation / Date	Depth / Elevation / Date
E14	104+019	108.9	7.6 to 10.6	8.2 / 100.7 / 9-Oct-08	7.9 / 101.0 / 11-Nov-08
E15	104+264	105.2	4.9 to 7.9	5.2 / 100.0 / 7-Oct-08	5.0 / 100.25 / 26-Nov-08
E16	104+495	105.2	6.1 to 9.1	4.8 / 100.4 / 17-Oct-08	4.6 / 100.6 / 17-Nov-08
E17	104+775	106.6	7.0 to 10.0	5.3 / 101.3 / 28-Oct-08	5.3 / 101.3 / 2-Dec-08
E18	104+886	111.2	9.2 to 12.2	7.7 / 103.5 / 30-Oct-08	7.7 / 103.5 / 2-Dec-08
E27	114+057	157.9	17.4 to 20.4	8.7 / 149.2 / 23-Sep-08	8.6 / 149.2 / 11-Nov-08
E28	114+582	160.4	27.4 to 30.4	14.0 / 146.4 / 23-Sep-08	13.1 / 147.3 / 2-Dec-08
E29	115+096	142.7	12.2 to 15.2	2.6 / 140.1 / 27-Oct-08	2.6 / 140.1 / 11-Nov-08
E30	115+557	135. 5	19.8 to 22.8	18.7 / 116.8 / 23-Sep-08	18.6 / 116.9 / 6-Nov-08
E31	116+177	130.7	19.8 to 22.8	18.4 / 112.3 / 23-Sep-08	18.5 / 112.2 / 6-Nov-08
E32	116+757	114.6	15.2 to 18.2	17.4 / 97.2 / 16-Oct-08	17.4 / 97.2 / 6-Nov-08
E47	123+620	157.9	2.4 to 5.4	5.2 / 152.7 / 23-Sep-08	5.3 / 152.6 / 10-Nov-08
E21-08	110+691	168.5	16.8 to 19.8	11.7/ 156.8/ 29-July-08	N/A
E22-08	111+084	186.6	33.5 to 36.9	29.9/ 156.7/ 13-August-08	N/A
E23-08	111+530	166.9	18.3 to 21.3	11.6/ 155.3/ 27-July-08	N/A
E24-08	112+045	174.1	24.5 to 27.5	22.2/ 152.9/ 29-July-08	N/A
E25-08	112+605	161.8	20.0 to 23.0	9.8/ 152.1/ 29-July-08	N/A
E49-08	113+093	160.6	32.6 to 35.8	34.8/ 125.9/ 24-June-08	N/A
BH3-08	113+105	160.7	11.0 to 12.5	10.3/ 150.4/ 20-June-08	N/A
E-26-08	113+621	160.8	20.7 to 24.8	11.7/ 149.1/ 29-July-08	N/A

Rising head tests carried out for boreholes along the proposed route have yielded interpreted permeability values ranging from $6x10^{-8}$ m/s to $2x10^{-4}$ m/s for materials described as sands or silts. Test results are set out in Table 4 below.

Table 4: Hydraulic Conductivity (Source PML 2009, CRA 2009)

Borehole No.	Material in Screened Interval	Screening Depth (m)	Screen Length (m)	Hydraulic Conductivity (m/s)
E14	Partly in sandy silt fill, partly in clayey silt till and weathered shale	7.6 to 10.6	3.0	5.2×10^{-6}
E16	Sandy silt and silty clay	6.1 to 9.1	3.0	1.8×10^{-7}
E27	Very dense fine sand some silt trace clay	17.4 to 20.4	3.0	1.2×10^{-7}
E29	Dense silt trace sand trace clay	12.2 to 15.2	3.0	5.9×10^{-7}
E30	Very dense fine sand some silt trace clay	19.8 to 22.8	3.0	4.2×10^{-6}
E47	Sandy silt fill over loose sand and silt	2.4 to 5.4	3.0	6.0×10^{-8}
E21-08	Very dense silty sand	16.8 to 19.8	3.0	3.3×10^{-5}
E22-08	Very dense medium to coarse sand trace silt and gravel	33.5 to 36.9	3.4	1.0×10^{-5}
E23-08	Very dense sand	18.3 to 21.3	3.0	2.5×10^{-6}
E24-08	Very dense sand some silt	24.5 to 27.5	3.0	5.6×10^{-6}
E25-08	Very dense sand and silt trace clay	20.0 to 23.0	3.0	1.6×10^{-5}
E-26-08	Very dense silt, stratified sand and varved clay	20.7 to 24.8	4.1	2.1×10^{-4}
E49-08	Silty clay over very dense sandy silt	32.6 to 35.8	3.2	5.3×10^{-6}
BH3-08	Very dense sand	11.0 to 12.5	1.5	6.0×10^{-5}

6 GEOTECHNICAL CONDITIONS

The following sections discuss the geotechnical conditions which can be anticipated for the at grade sections at each end of the Eglinton Crosstown LRT and the conditions anticipated for the section to be construction below ground. An interpreted stratigraphic profile along the alignment is shown on Drawing Nos 37 to 95 based on borehole logs and background geological records.

6.1 West At-Grade Section – Commerce Boulevard to Black Creek Drive

Available borehole information shows that the overburden along section from Commerce Boulevard to Black Creek Drive includes fill, sandy silt till, clayey silt to silty clay till and lacustrine deposits of sand, silt and clay.

Lacustrine and alluvial soils can be expected to be encountered in the low lying Humber River floodplain within the lake deposits from about 400 m west of Scarlett Road to Keele Street. These soils are likely to be comparatively soft and measures may be required to manage settlement of the road embankment widening which will be required in this area. Shallow alluvial deposits can be expected in this area. Further investigation will be required to support design in these areas.

Fill material was encountered in all borehole locations. The thickness of the fill encountered in the boreholes typically vary from 1.0 to 3.0 m. High fills ranging from 4.8 to 9.5 m thick were encountered in the low lying areas near Jane Street (Boreholes E14, E15, E16 and E17).

Sandy silt to silty sand till was encountered in Boreholes E2, E3, E7, E11, E13 and E18. This deposit extends to 1.8 to 12.2 m below existing grade. Standard Penetration Tests have obtained N-values ranging from 27 to 85 blows per 0.3 m penetration, indicating a compact to very dense condition.

A clayey silt till deposit was encountered in Boreholes E5, E6, E9, E12 and E14, and extends to depths of 2.6 to 9.1 m below existing ground. N-values obtained from Standard Penetration Tests performed in this deposit are typically over 50 blows per 0.3 m which indicate this deposit is typically hard.

A silty clay till unit extending to depths of 2.3 to 9.6 m below existing grade was encountered in Boreholes E2 to E4, E7 , E8, E13 and E15. N-values from Standard Penetration Tests indicate that this layer is typically very stiff to hard in consistency (20 to 40 blows per 0.3 m penetration).

A silty sand to sand deposit was encountered in Boreholes E6, E8 to E11, and E18 to E20 and extends to 3.7 to 12.8 m below existing grade. This layer contains traces of clay and gravel. The Standard Penetration Test N-values from this layer typically range from 15 to 50 blows per 0.3 m penetration, indicating compact to dense condition.

A clayey silt to silty clay deposit was encountered in Boreholes E1, E15 to E17 and E20, which extends to depths of 4.6 to 12.8 m below existing grade. Standard Penetration tests conducted in this layer gave N-values between 5 to 19 blows per 0.3 m penetration, indicating firm to very stiff consistency.

A sandy silt deposit was encountered in Boreholes E9, E11, E12, E16 and E17. This deposit extends to 2.3 to 10.2 m below the existing grade. N-values from Standard Penetration Tests typically range from 9 to 11 blows per 0.3 m penetration, indicating a loose to compact condition.

Silt was encountered in Borehole E2 and extends to 5.2 m below existing ground. Standard Penetration Test N-value of this layer/lense was 60 blows per 0.3 m penetration, indicating a very dense condition.

Weathered shale was encountered in Borehole E13 and E14 and extends to 4.3 and 11.6 m below the existing ground level. N-values yielded by the Standard Penetration Tests conducted in the layer of weathered shale varied from 70 to 80 blows per 0.05 to 0.12 m penetration.

Structures over Black Creek and Mimico Creek will require widening to accommodate the ECLRT alignment.

6.2 East At-Grade Section – Brentcliffe Road to Kennedy Road

Lacustrine and alluvial soils can be expected to be encountered in the low-lying Don River floodplain within the lake deposits from about 300 m east of Brentcliffe Road to about 200 m west of Swift Drive. These soils are likely to be comparatively soft and measures may be required to manage settlement of the road embankment widening which will be required in this area. Bridge widening will be required for the bridges over East and West Don Rivers while the bridge structure at Wynford Drive will be removed. Wilson Brook culvert will also require extension. Shallow alluvial deposits can be expected in this area. Further investigation will be required to support design in these areas.

The overburden along the ECLRT East At-Grade Section alignment consists of fill, sandy silt till, clayey silt to silty clay till and lacustrine deposits (including sand, silt and clay).

Fill material was encountered at all borehole locations. The thickness of the fill material varies from 0.4 to 5.0 m.

Sandy silt till deposit was encountered in Boreholes E27, E28, E31, E34, E35 and E45 to E47. This deposit extends to 4.4 to 10.7 m below existing grade. Standard Penetration Tests recorded N-values ranging from 11 to 172 blows per 0.3 m, indicating a compact to very dense condition.

A clayey silt to silty clay till deposit was encountered in Boreholes E29 to E32, E34, E36, E38 to E44, E46 and E48 and extends to depths of 2.9 to 23.5 m below existing grade. N-values measured using Standard Penetration Tests range typically from 20 to 50 blows per 0.3 m, indicating a firm to hard consistency.

A sand deposit, extending from 3.8 to 26.4 m below existing ground, was encountered in Boreholes E27 to E30, E32 and E34. The sand deposit contains some silt and traces of clay and gravel. Typical N-values recorded by Standard Penetration Tests vary from 15 to 95 blows per 0.3 m which indicate a compact to very dense condition.

A clayey silt to silty clay deposit containing some sand and traces of gravel was encountered in Boreholes E28 to E30, E32, E34, E39, E40 and E46 and extends to depths of 2.2 and 21.4 m below existing ground level. Standard Penetration Tests conducted in this deposit gave typical N-values of 10-50 blows per 0.3 m penetration indicating the deposit is stiff to hard in consistency.

6.3 Underground Section – Black Creek Drive to Brenticliffe Road

Coffey understands that tunnel construction will be carried out using TBMs (tunnel boring machines). Tunnelling will pass through highly variable soil deposits ranging from loose sands to dense sands and hard silty clays possibly containing cobbles and boulders.

6.3.1 Bedrock

Bedrock in the exploratory boreholes was encountered only at the west side of the project area between approximately Keele Street and Richardson Avenue, where it was encountered at depths ranging between about 25 m and 35 m. Elsewhere, the 20 m to 40 m deep boreholes did not encounter the bedrock. Based on the results of available investigations it is unlikely that the shale bedrock would be encountered in the twin bored tunnels or in the excavations for the underground stations.

6.3.2 Soils

The overburden soils along the underground alignment of the ECLRT can be grouped into five major soil groups : **fill, sandy silt to silty sand till, clayey silt to silty clay till, sand and silt, and clay and silt**.

The characteristics of the various overburden soils are summarized as follows:

Fill

Beneath the road pavement, fill was generally encountered in the boreholes from 0.4 to more than 5.0 m below the existing grade at various locations throughout the tunnel alignment. This fill contains various soils but is typically sand, silt, and sand/silt mixtures.

Sandy silt to silty sand till

Till deposits consisting predominantly of sand and silt combined in assorted proportions were generally found at various depths below the existing grade throughout the tunnelled alignment where these deposits ranged from compact to very dense relative density based on the SPT. The recovered samples contained trace amounts of clay and gravel; however, cobbles and boulders were also noted in borehole logging.

Clayey silt to silty clay till

Clayey silt to silty clay tills were generally found at various depths below the existing grade throughout the tunnel alignment where these deposits ranged from firm to hard based on the SPT. The recovered samples contained some sand and gravel. As well, the presence of boulders and cobbles was also noted during the drilling operations, as noted on the borehole logs.

Sand and Silt

Sand and silt deposits were also found at various depths below the existing grade throughout the tunnel alignment where these deposits ranged from very loose to very dense relative density based on the SPT test. The recovered samples contained various amounts of gravel and trace amounts of clay size particles.

Clay and Silt

Clay and silt deposits combined in assorted proportions were generally located at various depths below the existing grade at various locations throughout the tunnel alignment where the deposits ranged from firm to hard, based on the SPT records. The recovered samples contained sand with a trace of gravel.

6.3.3 Soil Stiffness

Along the route till soils and consolidated inter-glacial deposits are typically compact to dense and as a result are not anticipated to be highly susceptible to settlement arising from lowering of the groundwater level during tunnelling or during construction of the underground stations.

Fill soils and post glacial soil deposits are for the most part less compact than till soils and inter-glacial soil deposits and will be more likely to settle under load or as a result of lowering of groundwater levels. Further investigation to address foundation conditions is recommended in the following areas where low SPT blow counts were recorded:

- Vicinity of Yarrow Road and Keele Street (proposed Keele Station location),
- Deep fill near Blackthorne Avenue at the site of the proposed Caledonia Station, and
- Deep fill in the vicinity of Spadina Road (proposed Chaplin Station location).

6.3.4 Tunnelling Conditions

Tunnelling will be required through highly variable soil deposits ranging from loose sands to dense sands and hard silty clays containing cobbles and boulders. Boulders, especially where relatively large size (i.e. nominal diameter in excess of 0.5 m), can create problems during tunnelling operations. Measured groundwater levels are up to 20 m above the proposed rail level indicating that water pressure at the face up to about 200 kPa can be anticipated.

Construction of the tunnel tubes for the underground rail will be carried out using tunnel boring machines (TBMs) with installation of precast segmental linings. Recent developments in TBM technology have brought about effective methods of building tunnels in various types of soil, rock and mixed face conditions. Typically a TBM consists of a rotating head which excavates the material and from there the spoil enters into a chamber from which the material is transported to the surface. The complete operation requires a crew to drive and run the cutting head, an excavation handling crew, and a segmental liner installation and storage crew. Three types of TBM technology are predominantly used in current practice. They are referred to as Open Face, Earth Pressure Balance (EPB), and Slurry Shield. The presence of elevated groundwater levels and the presence of sand in places means that open face machines would not be appropriate. The choice of tunnelling equipment will depend upon a range of factors including: ground conditions, economics of materials handling, programme requirements, timing and equipment availability.

6.3.5 Excavations

Excavations will be made beneath and adjacent to Eglinton Avenue for the following purposes:

- Construction of the underground stations,
- Provision of a chamber for launching of the tunnel boring machines,

- Provision of chambers to allow rail lines to cross over,
- Provision of chambers for locations where three tracks are required, and
- To house variety of service and access facilities including ventilation facilities, machine rooms, emergency access etc.

Major excavations for the underground stations are expected to be constructed using cut and cover methods. These methods are similar to those which are routinely employed for excavation of deep basements in Toronto except that a cover will need to be provided to allow Eglinton Avenue to continue to operate. The sides of the excavations will be supported using slurry walls.

Detailed assessment of local conditions at each excavation will be required to identify the nature of the foundation soils though the following general comments are expected to apply to most of the excavations:

- Bearing pressures required for support rail station structures will be modest and typically well within the capacity of the native materials.
- Groundwater levels are typically above the base levels for excavations and in most cases positive control of groundwater will be required to prevent heave and boiling at the base of the excavation.
- Some lateral movement of the walls supporting the excavation can be expected. The magnitude of the movement will depend upon the nature of the ground and the construction methods employed though lateral movement at the surface of the order of 2mm for each metre of excavated depth may occur. The zone of influence of these lateral movements is expected to be limited to twice the depth of the excavation. Assessment of potential impact of structures flanking the tunnel route will be required.
- Shoring design will need to take account of groundwater conditions and the nature of adjacent structures.

7 LIMITATIONS

The assessment presented in this report is based upon background geotechnical investigation studies and assessments carried out by others. The results of this background work have been assumed to be reliable. The interpretations presented are based on limited borehole coverage and departures from the interpreted conditions can be expected. For this reason further investigation will be required to provide detailed test results to support design of excavations, foundations and embankment construction and widening. It will also be necessary to carry out inspection and testing during construction works to allow identification of areas where ground conditions depart from the interpreted conditions so that the construction process and if necessary the design can be revised to accommodate the changed interpretation.

8 REFERENCES

Barenco Inc., Geo-Environmental Report Proposed Passenger Elevators Contract A45-4 TTC Eglinton Avenue West, Toronto, Ontario, 2001

Coleman, A.P. (1913), "Glacial Phenomena of Toronto and Vicinity", International Geological Congress Guide Book No. 6

Conestoga-Rovers & Associates (2009), "Preliminary Geotechnical Investigation – Eglinton Avenue LRT, Ciltern Hill Road to Redpath Avenue": February 2009

Conestoga-Rovers and Associates, Fire Ventilation Upgrade Project Geo-Environmental Investigation, Eglinton Station

Southwest Corner of Yonge and Eglinton Contract No. G60-109, 1999

Dillon Consulting Engineers & Planners, Toronto Transit Commission Eglinton Station Bus Transfer Slab Investigation Preliminary, 1986

Geo-Canada, Geotechnical Investigation, Black Creek Corridor, Feasibility Study, City of York, 1987

Golder Associates, Geotchnical Design Summary Report for Sewer Relocation Allen Station Area Report No. E-GIR4-A-2 RTEP Eglinton Avenue West Subway, 1994

Golder Associates, Geotechnical Baseline Report for Eglinton Avenue Subway Allen Station - Sewer (Tunnel) Relocation, Report No. E-GIR4-A-2, 1994

Golder Associates, Geotechnical Baseline Report for Twin Tunnels Report No. E-GIR4-C-1 RTEP Eglinton Avenue West Subway, 1995

Golder Associates, Geotechnical Design Report for Twin Tunnels Report No. E-GIR3-C-1 RTEP Eglinton Avenue West Subway, 1994

Golder Associates, Geotechnical Design Report for York City Centre Station Report No. E-GIR3-B-1 RTEP Eglinton Aveue West Route, 1995

Golder Associates, Geotechnical Design Summary Report for Sewer Relocation Allen Station Area Report No. E-GIR4-A-2 RTEP Eglinton Area West Subway, 1994

Golder Associates, Geotechnical Investigation, Keele Street Interceptor Sewer, Cities of North York and York, Ontario, 1990

Golder Associates, Preliminary Design Report for York City Centre Station Area Report No. E-GIR2-B-1 RTEP Eglinton Avenue West Subway, 1993

Golder Associates, Preliminary Geotechnical Design Report for Allen Road Station Area Report No. E-GIR2-A-1 RTEP Eglinton Avenue West Subway, 1993

Golder Associates, Preliminary Geotechnical Design Report for Caledonia Station Report No. E-GIR2-E-1 RTEP Eglinton Avenue West Route, 1995

Golder Associates, Preliminary Geotechnical Design Report for Keele North Station Report No. E-GIR2-D-1 RTEP Eglinton Avenue West Route, 1995

Golder Associates, Preliminary Geotechnical Design Report for Twin Tunnels Report No. E-GIR2-C-1 RTEP Eglinton Avenue West Subway, 1993

Golder Associates, RTEP Draft Report on Soil and Groundwater Management Strategy for Eglinton West Subway, 1994

Golder Associates, RTEP Eglinton Avenue West Project Geotechnical Overview Report Phase I Investigation, 1993

Golder Associates, RTEP Eglinton Avenue West Project, Geotechnical Design Report for East Tailtrack Allen Station Area Report No. E-GIR3-A-1, 1994

Golder Associates, RTEP Eglinton Avenue West Project, Preliminary Geotechnical Design Report for Allen Road Station Area, 1993

Golder Associates, RTEP Eglinton Avenue West Subway Project Geotechnical Design Report for Allen Station, WYE Connection and Associated Works Report No. E-GIR3-A-3, 1995

Golder Associates, RTEP Geotechnical Baseline Report No. E-GIR4-A-1 for East Tailtrack (Contract EW-55-C1) Eglinton West Subway, 1994

Golder Associates, Subsurface Investigation Existing Sanitary Sewer Northwest Metro Arterial Road Eglinton Avenue, Borough of York, Ontario, 1980

Golder Associates, Volume 1 - Report on Investigation - Geotechnical Investigation, Lower Keele Trunk Relief Sewer, Cities of North York and York, Ontario, 1991

Golder Associates, Volume II - Interpretation of Results - Geotechnical Investigation, Lower Keele Trunk Relief Sewer, Cities of North York and York, Ontario, 1998

Jacques Whitford Consulting Engineers, Geotechnical Investigation and Design Report, Bus Loop Expansion Kennedy Station, Toronto, Ontario, Contract No. F3-20, 2001

Jacques Whitford Consulting Engineers, Geotechnical Investigation and Design Report, Kennedy Station, Toronto, Ontario, Contract No. F3-20, 2001

Jacques Whitford Consulting Engineers, Geotechnical Investigation and Pavement Design Report, Commuter Parking Lot Expansion Kennedy Station, Toronto, Ontario, Contract F3-19, 2001

Jacques Whitford Consulting Engineers, Pavement Investigation Report, Bus Loop Rehabilitation Kennedy Station, Toronto, Ontario, Contract No. F3-22, 2004

Jacques Whitford Consulting Engineers, Pavement Investigation Report, Bus Loop Eglinton West Subway Station, Toronto, Ontario, Contract No. A9-8, 1997

Karrow, P.F. (1967), "Pleistocene Geology of the Scarborough Area", Geological Report 46, Ontario Geological Survey

MTO, Foundation Investigation Report for Design of Relocated Baseball Diamond Light Pole Bases, Northwest Metro Asterial, 1979

MTO, Foundation Investigation Report for Hwy 401, 27 and Richview Expressway Interchange, 1968

MTO, Foundation Investigation Report for Hwy 401, 27 and Richview Expressway Interchange, 1968

MTO, Foundation Investigation Report for NWMA Road Between Eglinton Avenue and Weston Road (Feasibility Study), 1978

MTO, Foundation Investigation Report for Retaining Walls at Kidak Access Road, South of Eglinton Avenue, Parallel to CPR, 1979

MTO, Foundation Investigation Report for the Proposed Retaining Walls at the site of Hwy 401, 27 and Richview Expressway Interchange, 1967

MTO, Foundation Investigation Report for the Proposed Sub-Tunk Sewer at Hwy 401 and Hwy 27 Interchange, 1967

MTO, Foundation Investigation Report for the Proposed Tunk Sewer Project at Hwy 401 and Hwy 27, 1967

MTO, Hwy 401 and Richview Expressway Under Renforth Drive - Borehole Locations and Soil Strata Drawings, 1967

MTO, Preliminary Foundation Investigation Report (In Connection with Functional Study) For Future Extension of Hwy 400 from Jane Street to Eglinton Avenue, 1965

Peto Maccallum Ltd., Appendix C-1 Complete Chemical Test Results Phase 3 (Series EBT) Report No. E-GR3-5 York City Centre, Bus Terminal Eglinton Avenue West Subway, 1995

Peto Maccallum Ltd., Decommissioning of Boreholes, Eglinton West Subway, City of York, Ontario, 1996

Peto Maccallum Ltd., Geotechnical Phase 3 (Series E-PT) Report No. E-GR3-4C Black Creek Pumping Test Eglinton Avenue West and Black Creek Drive Eglinton Avenue West Subway, 1995

Peto Maccallum Ltd., Geotechnical Report Phase 3 (Series 300) Report No. E-GR3-1 Allen Road Station Eglinton on Avenue West West Subway, City of York, Ontario, 1994

Peto Maccallum Ltd., Geotechnical Report Phase 3 (Series 300) Report No. E-GR3-4B Additional Boreholes Twin Tunnels Section Eglinton Avenue West Subway, 1995

Peto Maccallum Ltd., Geotechnical Report Phase 3 (Series 300) Report No. E-GR3-5 Twin Tunnel Section East to Keele Street Eglinton Avenue West Subway, City of York, Ontario, 1994

Peto Maccallum Ltd., Geotechnical Report Phase 3 (Series 300) Report No. E-GR3-6 Kodak Property Eglinton Avenue West Subway, City of York, Ontario, 1995

Peto Maccallum Ltd., Geotechnical Report Phase 3 (Series 300) Report No. E-GR3-7 Keele North Station Eglinton Avenue West Subway, 1995

Peto Maccallum Ltd., Geotechnical Report Phase 3 (Series 300) Report No. E-GR3-8 Calendonia Station Eglinton Avenue West Subway, 1995

Peto Maccallum Ltd., Geotechnical Report Phase 3 (Series 300) Report No. E-GR3-9 Dufferin Station Eglinton Avenue West Subway, 1995

Peto Maccallum Ltd., Geotechnical Report Phase 3 (Series EBT) Report No. E-GR3-5 York City Centre, Bus Terminal Eglinton Avenue West Subway, 1995

Peto Maccallum Ltd., Menard Pressue Meter Tests Report Eglinton West Subway, 1995

Peto Maccallum Ltd., Water Levels and Vapour Monitoring Results Observation Wells and Pirzometers Phase (Series 100) Phase 2 (Series 200) and Phase 3 (Series 300) Eglinton West, 1996

Peto MacCallum Ltd (2009), "Geotechnical Investigation – Eglinton Avenue LRT, Renforth Drive to Weston Road, Mount Pleasant Road to Kennedy Road": February 2009

Sharpe, D.R. (1980), "Quaternary Geology of Toronto and Surrounding Area", Preliminary Map P. 2204, Ontario Geological Survey

Soils Report, Eglinton to Lawrence, Yonge Street Subway Extension

Soils Section, Engineering Department, T.T.C., Yonge Subway Northern Extension, Engineering Report on Soil and Groundwater Conditions, Contract Y1 Eglinton Avenue to Orchard View Blvd., 1969

Soils, Subway Construction, TTC, East Extension Warden to Kennedy F2-2 Soils Investigation, 1975

T.T.C. Soils Section, Engineering Department, Spadina Subway Engineering Report on Soil and Groundwater Conditions, Eglinton Avenue to Wilson Avenue A9-1; A10-1; A11-1; A13-1; A15-1, 1974

Terrapex Environmental, Environmental Considerations, York Community Centre, Black Creek Drive and Eglinton Avenue West, Toronto, Ontario, 2006

Terrapex Environmental, Phase II Environmental Site Assessment , Keelesdale Park, Southeast Corner of Black Creek Drive and Eglinton Avenue West, Toronto, Ontario, 2006

Terrapex Environmental, Preliminary Geotechnical Evaluation, Proposed Community Centre, Black Creek Drive and Eglinton Avenue West, Toronto, Ontario, 2006

Trow Consulting Engineers Ltd., Geotechnical Report Kennedy Station Bus Bay Expansion Kennedy Rd. and Eglinton Ave. E. Scarborough, Ontario, Contract F3-12, 1993

Trow Consulting Engineers Ltd., Geotechnical Report Proposed Elevators Kennedy Subway Station Kennedy Road and Eglinton Aveune East, Ontarion, Contract G45-14**C, 1993

Trow Consulting Engineers Ltd., Preliminary Design Evaluation Excavation Support Systems, Keele North Station Eglinton West Subway, 1995

William Trow Associates, Subsoil Investigation, Yonge Street Subway Extension, Eglinton to Lawrence Avenue Y1, Y2, Y3, 1967

For and on behalf of Coffey Geotechnics Inc.

for **Ross Best, MIEAust, CPEng**

Senior Principal

Ramon Miranda, P. Eng.

Manager, Transportation Division

Drawings