Geotechnical Baseline Report
Proposed Trunk Sanitary Sewer
Moffat Creek Alignment – Station 0+000 to 0+750
East of Dundas Street to Franklin Boulevard
Cambridge, Ontario

Prepared for The City of Cambridge
c/o Conestoga-Rovers & Associates

Date: **May 30, 2008**	Reference: **T010052 (2)**

Reference No. T010052

May 30, 2008

Mr. Chris Hunter, P. Eng.
Conestoga-Rovers & Associates
651 Colby Drive
Waterloo, Ontario N2V 1C2

Re: Geotechnical Baseline Report
Proposed Trunk Sanitary Sewer
Moffat Creek Alignment – Station 0+000 to 0+750
East of Dundas Street to Franklin Boulevard
Cambridge, Ontario

Dear Mr. Hunter:

In accordance with your request, we have prepared the geotechnical baseline report for the above-captioned project and are pleased to present our report.

We trust that this information meets with your approval. Please do not hesitate to contact us, should any questions arise.

Yours very truly,
INSPEC-SOL INC.

Bruce Polan, M.A.Sc., P. Eng.
Manager, Waterloo

HG/jdh

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1.0 INTRODUCTION

1.1 GENERAL

The City of Cambridge, Ontario (the City) is planning to construct a trunk sanitary sewer along Moffat Creek alignment commencing from the proposed Wesley Boulevard to service the Greengate Subdivision (Station 1+178) and ending at the existing sanitary manhole S2J4 (Station 0+000) at Franklin Boulevard. A Site location map is provided on Figure 1.

The design of the sanitary sewer has been performed by Conestoga-Rovers & Associates (CRA), the prime consultants for the project. Inspec-Sol Inc. (Inspec-Sol) has been retained by Conestoga-Rovers & Associates (CRA) as the geotechnical engineer for the project.

1.2 PURPOSE AND LIMITATIONS

This Geotechnical Baseline Report (GBR) provides the geotechnical baseline for the construction of the proposed trunk sanitary sewer and is intended for use by bidders as an aid in the bid preparation. This report includes:

- A description of the project;
- An interpretation of the geologic and geotechnical data collected for the project;
- A summary of the anticipated subsurface conditions and how these conditions have been addressed in the design; and
- A discussion of construction baseline considerations that the Contractor will need to address during bid preparation and construction.

The results of the geotechnical investigations carried out along the proposed sewer alignment are presented in the Inspec-Sol report titled Geotechnical Data Report Proposed Trunk Sanitary Sewer, Moffat Creek Alignment – Station 0+000 to 0+750 (GDR) dated May 9, 2008. The GDR and GBR will be included as part of the Contract Documents.

This report presents Inspec-Sol's best judgment of the subsurface conditions expected to be encountered during construction of the proposed sanitary sewer. In order to develop geotechnical construction baselines, it was necessary to interpolate between exploratory borehole and test pit data along the Moffat Creek alignment. The actual conditions encountered along the alignment are anticipated to be within the range of the conditions discussed in the GBR; however conditions encountered may be more complex than presented in this report. In addition, the GBR is based on assumptions regarding construction methods likely to be used, and on the level of the Contractor's workmanship that can reasonably be expected during the construction of the sanitary sewer.

Descriptions and discussions of anticipated subsurface conditions contained in the GBR are intended to establish baselines for use by the City and the Contractor, in the bidding stage, and for evaluating the merits of a Differing Site Conditions (DSC) claim. The baselines provided in this GBR may change based on input from the City and the design team, and once further geotechnical information is obtained from additional test pits planned to be excavated along the alignment. Inspec-Sol should be informed of any differing conditions experienced from the baseline conditions so that we can provide advice and recommendations on the merits of the DSC claim, or other construction related issues arising from the subsurface conditions encountered during the micro-tunneling operations.

This GBR applies to the area between Station 0+000 at Franklin Boulevard, to Station 0+750, which is to the east of Dundas Street South, along the floodplain of Moffat Creek. The sanitary sewers will continue to the east to Station 1+178, using open cut installation techniques, however, this section of the sewers between Station 0+750 to 1+178 was not investigated as part of this geotechnical investigation report, and therefore this GBR does not pertain to the easterly section of the sanitary trunk sewer beyond Station 0+750.

The project dimensions provided in the GBR (i.e., pipe lengths, pipe alignments, etc.) are for the purposes of the GBR only, and must not be used for bidding or construction purposes.

The dimensions and quantities given in the contract documents and design drawings must be used for bidding and construction purposes.

2.0 PROJECT DESCRIPTION

CRA has prepared a report titled Preliminary Design Brief – Moffat Creek Trunk Sanitary Sewer (CRA Design Brief) dated April 2008. Based on the CRA Design Brief the construction of the proposed sanitary sewer will provide a gravity outlet for the sewage flows expected from the full development of the Southeast Galt Community. The proposed sanitary sewer will comprise a 675 mm diameter sanitary sewer pipe placed at a gradient of 0.3 percent. Future development will require two sanitary stubs along Dundas Street (one from the north and one from the south). The pipe material will consist of either Polycrete, Hobas centrifugally cast fiberglass reinforced polymer mortar (CCFRPM) pipe, concrete, or clay and will be detailed in the contract documents. The manholes will be 1500 mm diameter except at Dundas Street, where it will be 1800 mm in diameter.

The CRA Design Brief discusses the possible methods of sewer installation taking into consideration the existing soil and groundwater conditions, and has identified a combination of open cut and micro-tunneling as the optimal method of installation based on the minimum area of construction footprint and its least environmental impact. The proposed alignment of the trunk sanitary sewer is shown on Figure 2 of this report and on the CRA plan and Profile Drawings 37936-C01 to 37936-C03.

Open cut excavation will be used for the tie-in to the existing manhole MH-S2 at Franklin Boulevard, and for the manhole at Dundas Street and its stubs to the north and south. The remaining length will be installed using micro-tunneling techniques. A review of the CRA plan and Profile Drawings show that seven (7) manholes will be installed between Stations 0+000 to Station 0+750 at a spacing ranging from 75 m to 170 m. The manholes will also be installed using open cut or shored excavations. Except for the manhole at

Dundas Street, excavations for the remaining six manholes are expected to be used as launching and/or receiving pits for the micro-tunneling operations.

3.0 PROJECT GEOLOGIC SETTING

3.1 SOURCES OF GEOLOGICAL AND GEOTECHNICAL INFORMATION

Geologic and geotechnical data used for preparation for this GBR was obtained from the following sources:

1. Draft Geotechnical Data Report (GDR), Proposed Trunk Sanitary Sewer, Moffat Creek Alignment – Station 0+000 to 0+750, East of Dundas Street to Franklin Boulevard, Cambridge Ontario dated May 21, 2008 prepared by Inspec-Sol;
2. 'The Physiography of Southern Ontario' (1984) 3rd Edition by L. J. Chapman and D. F. Putnam, Ontario Geological Survey Special Volume 2 published by the Ontario Ministry of Natural Resources (MNR);
3. Karrow, P. F. (1987) Quaternary Geology of the Cambridge Area, Southern Ontario; Ontario Geological Survey, Map 2508, scale 1:50,000 published by Ministry of Northern Development and Mines (MNDM), Ontario; and
4. Miller, R. F., Farrell, Larrraine, and Karrow, P. F., (1979) Bedrock Topography of the Cambridge Area, Southern Ontario; Ontario Geological Survey, Preliminary Map P P.1983, Bedrock Topography Series, Scale 1;50,000, Geology 1978, published by Ontario Ministry of Natural Resources (MNR).

3.2 SITE PHYSIOGRAPHY

Based on 'The Physiography of Southern Ontario' (1984), the Site is located near the common boundaries of two physiographic regions; the Guelph Drumlin field and the Waterloo Hills at their southern limits, which are bounded by the physiographic region of Horseshoe Moraine.

The Moffat Creek floodplain is enclosed in a glacial spillway valley draining towards the Grand River. The 7 m to 8 m high valley slopes and its floor are generally covered by a dense growth of young and mature trees, except for the creek channel itself. Another smaller creek which flows between Azores Crescent and the townhouse development on Franklin Boulevard joins Moffat Creek at about station 0+125. A steel-wire fence mounted on steel posts, covering the whole valley width is located immediately east of the point of confluence of this small creek with Moffat Creek.

Residential developments occupy the tableland above the northern southern valley slopes between Dundas Street and Franklin Boulevard. The access to the proposed alignment, between Franklin Boulevard and Dundas Street alignment is difficult due to the dense tree growth, the relatively steep southern valley slopes, existing residential developments, the creek merging into Moffat Creek at Station 0+125 and the Dundas Street embankment slopes.

3.3 REGIONAL GEOLOGY

The general landform pattern in the two adjoining physiographic regions consists of drumlins and other topographic highs separated by valleys used by glacial melt waters as spillways. These spillway valleys are covered with glacio-fluvial outwash materials consisting of sand and gravel deposits typically containing cobbles and boulders. Presently, small tributaries of the Grand River, such as Moffat Creek, flow in these melt water stream valleys. Some of the tributaries are poorly drained due to human development and/or natural changes in geomorphology and their floodplains within the valleys are covered by wetlands and swampy areas.

A review of the Quaternary Geology Map 2508 shows that the soils outside the glacial spillways, in the valley slopes and table lands are comprised of Wentworth Till consisting of

gravel, sand and silt materials. Glacial till materials also typically contain cobble and boulder sized inclusions.

The bedrock topography Map P.1983 shows that the bedrock in the area consists of the Guelph Formation which is comprised of massive and thick bedded, brown and grey dolostone. Based on the information available on the map, the bedrock along the Moffat Creek alignment is expected to range from elevations 262 m above mean sea level (amsl) to 260 m amsl, corresponding to depths of some 20 to 24 m below the Moffat Creek ground elevations of 279 m to 284 m amsl.

4.0 SUMMARIZED SUBSURFACE SOIL AND GROUNDWATER BASELINE CHARACTERIZATION

The Site stratigraphy mainly consists of a surficial topsoil layer underlain by recent alluvial silty sand to sandy silt deposits. The silty sand/sandy silt deposits are underlain by glacio-fluvial deposits predominantly consisting of sandy gravel and cobble sized particles and containing variable fractions of sand and silt sized particles, and intermittent boulders. The glacio-fluvial deposits are inferred to lie above the glacial till deposits at the valley slopes and either directly on the bedrock or on a veneer of till covering the bedrock in the valley floor footprint.

For the purposes of baseline conditions, a simplified subsurface profile should be assumed along the entire length of the micro-tunneling horizon that consists of sand and gravel/gravelly sand at the depth of the sewer installation. Based on the boreholes installed, only two exceptions were noted: BH/MW3-08, where silty sand soils were contacted at the sewer installation depths, and BH/MW6-08, where cobbles and boulders were contacted at the sewer installation depths. The subsurface data is summarized on the CRA Plan and Profile Drawings C-01 to C-03.

4.1 LABORATORY TESTING

A laboratory testing program was performed to characterize the Site soils in order to develop geotechnical parameters for design and construction of the proposed sanitary sewer. The laboratory test results are summarized in the GDR. The baselines determined from the laboratory test results are discussed in the following sections.

4.1.1 GRAIN SIZE DISTRIBUTION

A total of thirteen grain size distribution analyses were carried out on the two most dominant units encountered along the Moffat Creek alignment. Nine of the grain size analyses were performed on samples obtained from split-spoon samples (limited to 50 mm particle size), and four grain size analyses were carried out on bulk samples from the test pits. The range of gradations and baseline values are produced in the following table, which can be used to assess excavation and tunneling requirements through these deposits.

Soil Unit (particle size)	***Silty Sand***		***Sand and Gravel/Sandy Gravel***	
	Data Range	***Baseline(1)***	***Data Range***	***Baseline(1)***
Silt (<0.074 mm)	30% to 31%	25%	4% to 27%	10%
Sand (0.074 mm to 4.74 mm)	50% to 55%	50%	15% to 39%	25%
Gravel (4.74 mm to 75 mm)	15% to 19%	15%	10% to 68%	30%
Cobbles (75 mm to 300 mm)	-	5%	19% to 45% (2)	30%
Boulders (>300 mm)	Not Assessed	0%	0% to 5% (3)	5%

(1) Particle Distribution by dry mass

(2) Based on grain size analyses of the test pit spoil piles

(3) Based on visual assessment of the test pit spoil piles

4.1.2 UNCONFINED COMPRESSIVE STRENGTH

One rock boulder of about 400 mm in size was collected from each of the test pits TP1 and TP2 and were tested for their compressive strength. The test results are provided in the GDR. The compressive strength (qu) of the boulder samples was found to be 103.8 MPa and 104.4 MPa, respectively.

A baseline value of boulder compressive strength of 110 MPa is to be used for selecting the micro-tunneling equipment.

4.2 GROUNDWATER

Groundwater level monitoring data is provided in the GDR. In general, groundwater was measured at depths ranging from 0.3 m below ground surface (BH/MW1-06) to 2 m below ground surface (BH/MW4-08).

A review of the subsoil conditions along the Moffat Creek alignment indicates that the piezometric surface represent an unconfined aquifer, and is under a direct influence of Creek water levels, seasonal conditions, weather events, and other factors. A blockage of the culvert under Dundas Street caused flooding in the Creek to the east of Dundas during the geotechnical investigation and pumping tests.

In-Situ testing for this project comprised SWRTs at four selected borehole and two pumping tests, one each at the two extraction wells. The test results are provided in the GDR. Based on the SWRTs results, the measured permeabilities of the soil deposits at the Site range from 1×10^{-2} cm/sec to 6×10^{-5} cm/sec.

4.3 LAUNCH AND RECEIVING PIT DEWATERING

Shored excavations will be required for the launch and receiving pits for the tunnel boring machine (TBM), for construction of the manholes, and for shored excavations at the Dundas

Street crossing and tie-in to Franklin Boulevard. The shored excavations required for the proposed sanitary sewer and its structures are expected to be approximately 4 m to 6 m deep below the existing ground surface, except at the Dundas Street crossing where it will be approximately 9 m deep.

It is anticipated that open cut excavations with supported (trench box or shoring system) side slopes will be carried out at the Franklin Boulevard tie-in and Dundas Street crossing. The manhole pits used as receiving and launching pits will be supported using an engineered shoring system.

4.3.1 SHORED EXCAVATIONS

The shored excavations will be located along the toe of the 6 m to 8 m or higher southern slope of the valley, potentially causing slope instability issues. Therefore vertical walls supported by an engineered shoring system are recommended. The support systems should be designed to resist lateral earth pressures, and must meet Occupational Health and Safety Act (OHSA) requirements.

The following baseline soil parameters must be used for the design of the engineered shoring system:

Soil	***Bulk Density Γ (kN/m³)***	***Undrained Shear Strength (kPa)***	***Effective Strength Parameters***	
			Cohesion c' (kPa)	***Angle of internal friction Φ' (degrees)***
Clayey Silt	22	60	5	26
Silty Sand	19	-	0	30
Sand & Gravel	19	-	0	33

The impact of the shored excavations on the stability of the existing slopes must be evaluated by a detailed slope stability analyses by the Geotechnical Engineer prior to proceeding with construction, to avoid potential instabilities and slope failures.

4.3.2 DEWATERING

Due to the relatively shallow groundwater depth relative to the proposed invert levels, and free draining nature of the Site soils, a continuous dewatering system will be required for open cut excavations and at the launching and receiving pits. The following table provides baseline dewatering parameters for the proposed shored excavations for sewer pipe and launching and receiving pits:

Structure/ Component	***Location (Station)***	***Assumed Baseline Permeability K (cm/sec)***
Franklin Boulevard Tie-in	0+000	5×10^{-4}
Receiving Pit/MH1A	0+035	5×10^{-4}
Launching Pit/MH2A	0+185	5×10^{-4}
Receiving Pit/MH3A	0+272	5×10^{-3}
Launching Pit/MH4A	0+400	5×10^{-3}
Receiving Pit/MH5A	0+562	5×10^{-3}
Dundas Street Crossing/MH6A	0+600 to 0+700	5×10^{-2}
Launching Pit/MH7A	0+731	5×10^{-2}

The dewatering parameters provided in the above table are based on the hydraulic conductivities determined by CRA using the single well response tests. The actual dewatering rates/quantities will be a function of the dewatering approach selected by the Contractor, and the dewatering design parameters may vary from the baseline permeabilities tabulated here. Methods for dewatering are to be determined by the Contractor and discharge of water must be completed in accordance with the contract documents.

An Ontario Ministry of Environment (MOE) Permit to Take Water (PTTW) is required for the dewatering. The City will obtain the PTTW.

The dewatering system must fulfill the following requirements:

- The stability of the sides and bottom of the excavation must be maintained at all times during the construction, and fluctuations in the groundwater table which may cause excavation instability must be avoided;
- Effective filters must be provided to prevent migration of soil fines and subsequent loss of ground;
- Adequate pumping and standby pumping must be provided;
- Pumped water must be discharged such that it will not interfere with the excavation;
- The groundwater table must be maintained at least 0.6 m below the base of the progressively rising trench backfill during its placement, to prevent 'pumping' of the base due to the construction traffic/ compaction effort;
- Adequate monitoring of groundwater levels by observation standpipes must be provided; and
- On completion of construction activities, the dewatering system must be gradually shut down to prevent the creation of transient critical exit gradient conditions, which may result in migration of fines.

4.4 MICRO-TUNNELING

Micro-tunneling is a trenchless construction method and can be subdivided into two major groups; slurry method and auger method. Due to the predominantly cohesionless nature of the Site soils and shallow groundwater table, the slurry method is specified for this project. The technique must employ the earth pressure balance (EPB) method to minimize

dewatering requirements. The possible presence of boulders up to 60 percent of the pipe diameter must be considered when selecting the micro-tunneling machine for this project.

The jacking force required to push the pipe forward should be calculated taking into account the penetration resistance, frictional resistance and Site overburden and hydrostatic pressures.

The jacking force and thrust block/abutment can be designed using the soil parameters provided in Section 4.3.1 above.

The slurry used for the micro-tunneling project can be bentonite or other suitable material selected by the contractor provided the additive used in the slurry mix is environmentally friendly.

The micro-tunneling will be carried out primarily in the sand and gravel deposits. Frequent cobbles and boulders up to 30 percent of the pipe diameter will be encountered. Provisions must be made in accordance with the Contract Documents to remove large boulders if encountered. The micro-tunneling machine selected for this project should meet the following minimum requirements:

- The machine will encounter cobbles and boulders of various sizes, therefore the machine cutting head must be equipped with disc cutters capable of coring through boulders;
- To avoid clogging of the soil removal system, the machine should be equipped with an injection system that can inject water, foam or another lubricant at the face; and
- In order to overcome cutterhead resistance and to assist in freeing the cutterhead following downtime periods, the cutterhead is required to have either two rotational speeds or a variable speed drive system and to deliver high torque at start-up. The cutterhead should also be capable of reverse rotation (i.e., turning in either direction).

We trust that the above noted report suits your purposes at this time. However, should you have any questions or concerns, please feel free to contact the undersigned at your convenience.

Sincerely,

INSPEC-SOL INC.

Hassan Gilani, M.Sc., P.Eng.

Bruce Polan, M.A.Sc., P. Eng.
Branch Manager