DURHAM – SCARBOROUGH

Bus Rapid Transit

Appendix L2 – Foundation

Prepared for Metrolinx
by IBI Group & Parsons

DRAFT TECHNICAL MEMORANDUM

DATE December 2, 2021 **Project No.** 21473923

TO Ms. Margaret Parkhill, P.Eng., Transportation Engineer, IBI Group

CC Mr. Ragavan Thuraisinganathan, P.Eng., Rail & Transit, Parsons

FROM Tom Zalucki, P.Eng.

DURHAM-SCARBOROUGH BUS RAPID TRANSIT
PRELIMINARY FOUNDATION RECOMMENDATIONS FOR CULVERTS, BRIDGES, AND BUS PLATFORMS
CITY OF TORONTO AND DURHAM REGION, ONTARIO

1.0 INTRODUCTION

Golder, a member of WSP ("Golder"), has been retained by IBI Group to provide foundation engineering services associated with the planning and preliminary design of the Durham-Scarborough Bus Rapid Transit (DSBRT) project.

This Technical Memorandum provides a desktop-level assessment of the subsurface conditions along the proposed DSBRT alignment based on existing subsurface information, and provides preliminary foundation recommendations for planning the proposed culvert extensions, bridge widenings/replacements, and construction of new bus platforms. This document also provides recommendations for future geotechnical subsurface investigations to support the preliminary and detail design.

This Technical Memorandum should be read in conjunction with the *Important Information and Limitations of This Report* attached following the text of this document. The reader's attention is specifically drawn to this information as it is essential for the proper use and interpretation of this document.

2.0 PROJECT AND SITE DESCRIPTION

2.1 Project Description

Metrolinx is collaborating with Durham Region, Durham Region Transit (DRT), City of Toronto, and the Toronto Transit Commission (TTC) to plan and design approximately 36 km of BRT infrastructure linking the City of Toronto and the Durham Region.

The proposed rapid transit corridor project includes:

- Improved connections/operations between TTC, DRT, and GO buses.
- Dedicated bus lanes, with smart signals along Highway 2.
- Transit stops with passenger amenities.
- New active transportation facilities such as, wider sidewalks and cycling infrastructure.

The proposed rapid transit corridor will also require extensions of existing culverts, widening and replacement of existing bridges, and construction of new bus platforms.

2.2 Site Description

As noted in Section 2.1, the proposed DSBRT alignment is proposed to connect the City of Toronto and the Durham Region. Specifically, the DSBRT alignment is proposed to extend from the Scarborough Town Centre (western terminus, located at the northwest quadrant of Ellesmere Rd. and McCowan Rd.), run easterly along Ellesmere Rd. up to Highway 401, continue easterly along Highway 2, and terminate in Downtown Oshawa (eastern terminus, located near Simcoe St. N). The proposed DSBRT alignment is shown below on Figure 1.

Figure 1: Proposed Durham-Scarborough BRT Alignment (Courtesy Metrolinx)

The DSBRT alignment is proposed to extend along existing roadways (i.e., Ellesmere Rd. and Kingston Road/Highway 2) which consist of two-lanes in each direction. The aforementioned roadways extend along an urban environment and cross major ravines/watercourse valleys such as, Highland Creek (also know as Ellesmere Ravine), Rouge River, Duffins Creek, and Oshawa Creek. Highway 2 also crosses under the Highway 401 corridor (in the City of Toronto), CN Rail tracks (in the City of Pickering), CP Rail tracks (in the Town of Whitby), and over Highway 412, which links Highway 401 and Highway 407 (in the Town of Whitby).

Given the length of the proposed DSBRT alignment, the existing ground surface elevation along the proposed rapid transit corridor varies between approximately Elevation 81 m and Elevation 168 m. It is further noted that minimal grade raise/lowering will be required along the proposed alignment to accommodate the bus lanes.

3.0 REGIONAL GEOLOGY

The alignment of the of the proposed DSBRT is located predominantly within the physiographic region known as the Iroquois Plain, as delineated in *The Physiography of Southern Ontario* [1]. However, west of the Ellesmere Ravine, the proposed alignment is located with the physiographic region know as the South Slope.

The soils in the area of the Iroquois Plain are typically comprised of glaciolacustrine clays, silts, and sands which are underlain by an extensive till deposit that is mapped in this area as the Bowmanville Till. More recent alluvial deposits of gravel, sand, silt, and/or clay are present along the watercourse valleys.

[1] Chapman, L.J. and Putnam, D.F. 1984. "The Physiography of Southern Ontario, 3rd Edition", Ontario Geological Survey, Special Volume 2, Ontario Ministry of Natural Resources.

The South Slope physiographic region is characterized by a smooth to drumlinized till plain that was formed as a result of glacial action and deposition of till material south of the Oak Ridges Moraine. The South Slope contains a variety of soil deposits that have developed over the till and the overburden soils can typically be more than 50 m thick. Similarly to the Iroquois Plain, more recent alluvial deposits are present along the watercourse valleys.

The overburden soils encountered along the DSBRT alignment are underlain by shale bedrock. Based on public information, the bedrock west of the Highway 401 / Highway 2 interchange is generally comprised of grey shale (with limestone, siltstone, and sandstone interbeds) of the Georgian Bay Formation and the bedrock encountered east of the Highway 401 / Highway 2 interchange is generally comprised of grey and black shale of the Whitby Formation.

4.0 EXISTING SUBSURFACE INFORMATION

In general, there is limited site-specific subsurface information available along the proposed DSBRT alignment. The geotechnical/foundation reports (not including the pavement reports) that were provided by the Durham Region or downloaded from MTO's public online Foundation Library (Geocres) are listed below.

- Highway 2 Bus Rapid Transit; Proposed Retaining Walls Between About Sta. 19+850 and Sta. 20+250; Town of Ajax, Ontario (Golder, November 16, 2017; Project No. 1780077).
- Pine Creek Culvert Extension; Kingston Road BRT – Dixie Road to Liverpool Road (D2021-001); The Regional Municipality of Durham, Pickering Ontario (Golder, November 20, 2018; Project No. 1893424).
- Watermain Replacement Kingston Road BRT – Dixie Road to Liverpool Road (D2021-001); The Regional Municipality of Durham, Pickering Ontario (Golder, May 6, 2020; Project No. 1893424-2-REV1).
- Hwy 401 and Hwy 2: MTO Geocres No. 30M14-023 (additional information available along Hwy 401 in the vicinity of Hwy 2: MTO Geocres Nos. 30M14-021, 30M14-022, 30M14-024, and 30M14-025).
- Hwy 401 and Hwy 2A: MTO Geocres Nos. 30M14-199 and 30M14-200.
- Rouge River and Hwy 2: MTO Geocres No. 30M14-016.
- Rouge River and Hwy 401: MTO Geocres No. 30M14-198.
- Area east and west of Rougemount Dr. and Hwy 401: MTO Geocres No. 30M14-190.
- CN Rail and Hwy 401: MTO Geocres No. 30M14-215.
- Grade Separation at CN Rail (Mile 1.92, York Subdivision); South of Hwy 401, between Whites Rd. and Liverpool Rd. – MTO Geocres No. 30M14-170.
- Duffins Creek and Hwy 2: MTO Geocres No. 30M14-003.
- Pringle Creek and Hwy 2: MTO Geocres No. 30M15-006.
- CP Rail and Hwy 2: MTO Geocres No. 30M15-005.

5.0 PRELIMINARY FOUNDATION RECOMMENDATIONS

The section provides general foundation recommendations for planning and preliminary design of the proposed culvert extensions, bridge widenings/replacements, and bus platforms.

The preliminary foundation recommendations provided herein are based on interpretation of the limited subsurface information/data obtained from the Durham Region and MTO (as noted in Section 4.0, geotechnical/foundation reports were not provided by other municipalities/regions). The closest available subsurface information to the site of the proposed new/rehabilitated structures was used to develop the preliminary foundation recommendations. It is noted that the available geotechnical information was not necessarily within or near the footprint of the proposed structures, and often up to 115 m away from the structure site at many locations.

Where preliminary comments are made on construction, they are provided to highlight those aspects that could affect the design of the project. Those requiring information on aspects for detail design and construction must make their own interpretation of the available factual information and supplement the available information as necessary, as such interpretation may affect detail design and equipment selection, proposed construction methods, scheduling, costing, and the like.

5.1 Culverts

Based on Table 1 appended to this Technical Memorandum, the DSBRT alignment will cross 22 culverts and one storm trunk sewer. The majority of the culverts and the storm trunk sewer will require an extension either on one end or both ends of the culverts to accommodate the rapid transit corridor, including sidewalks and cycling paths. The majority of the culverts have been identified as concrete box culverts, but details for many of the culverts have not been provided.

Limited subsurface information is available at the locations of the culverts. A subsurface investigation was carried in the vicinity of the Miller Creek site (City of Pickering) in June 2017 (Golder, Project No. 1780077), and a subsurface investigation was carried out at the Pringle Creek site (Town of Whitby) in February 1964 (MTO Geocres No. 30M15-006). Based on the existing investigations, the soils in the area generally consist of topsoil/organics overlying competent till soils. At some locations, a layer of compressible clayey soil is present between the organics and till deposit.

Based on the existing information, organic deposits and other deleterious materials encountered immediately below the footprint of the culverts will require sub-excavation and replacement with granular fill. Weak/soft clay deposits can also be expected and may require sub-excavation and replacement with granular fill, especially if proposed embankment widenings near the culverts will impose significant additional loads on the foundation soils resulting in large magnitudes of settlement. If deep excavations to remove unsuitable soils are not practical / feasible, other settlement mitigation measures will need to be assessed and implemented such as preloading or surcharging that will add additional time to the project schedule. However, site-specific subsurface investigations will need to be carried out first to identify the types and strength of soils encountered at the locations of the culverts.

It is not necessary to found the precast concrete box culverts and CSP culverts at or below the frost depth for this area (i.e., 1.3 m), as these types of culverts are tolerant of small magnitudes of movement related to freeze-thaw cycles. However, structural open footing culverts or cast-in-place culverts will need to be founded below the standard depth for frost protection.

Generally, the concrete box culverts should be founded on a 75 mm thick levelling course on a 0.3 m thick granular bedding layer placed on a properly prepared subgrade. These details will need to be confirmed during the detail design/design-build stage and will need to satisfy the respective municipal/regional standards, if applicable.

It is also noted that any wingwalls/retaining walls near the culverts may need to be extended/relocated as a result of the widenings and culvert extensions.

Temporary cofferdams at the culvert sites will be required to facilitate construction of the proposed culvert extensions. It is assumed that it may be possible to construct temporary cofferdams and divert the watercourse water using one of the following methods:

- Driven steel sheet piling;
- Small inflatable bladder cofferdams;
- Water dams consisting of industrial grade, impermeable, composite fabrics formed into flexible tubes containing one or more chambers; or,
- Multiple rows of large sand bags/yard bags ('super-bags' or 'bulk-bags') lined with an impermeable barrier (poly-material).

Given the relatively constrained access at some of the culvert sites, the use of smaller, and more modular or inflatable cofferdams may be preferred as these systems can be maneuvered by small equipment and/or by hand. However, the viability and effectiveness of such systems will depend on the watercourse water level and groundwater level at the time of construction as well as the available space between where the diversion structures/temporary cofferdams will be located relative to the excavation limits for the new culvert extensions.

If water levels in the creek are high, if the working area is restricted and/or if deeper sub-excavations are required to remove any weak/softened soils before bedding placement for the culvert extensions, it may be necessary to install a proper groundwater cut-off system (comprised of an interlocking driven steel sheet piles) to avoid excavation instability, a "boiling" or "quick" condition that would loosen/soften any granular soils and/or cause disturbance of the foundation subgrade within the footprint of the excavation area. If required, a more robust/watertight cofferdam system for these sites would likely consist of interlocking, steel sheet piles driven to a suitable depth – although the effectiveness of this type of cofferdam system will have to be evaluated during detail design/design-build stage.

Excavations at the culvert sites will extend below the watercourse levels, as such, some form of groundwater control will be required to allow for construction to be carried out in-the-dry conditions. The method and extent of groundwater control required at each site will ultimately depend on the type of temporary cofferdams and roadway protection (if required) selected by the contractor. Furthermore, if construction water pumping volumes are anticipated to exceed 50 m^3/day, an Environmental Activity Section Registry (EASR) will be required as per the changes to the Environmental Protection Act by the Ontario Ministry of Environment, Conservation and Parks (MECP). A Permit To Take Water (PTTW) will be required if water pumping volumes exceed 400 m^3/day.

5.2 Bridges

Based on Table 1 (appended to this Technical Memorandum), the DSBRT alignment will cross nine bridges, but only six bridges require widening/replacement and preliminary foundation input as follows:

- CN Rail over Kingston Rd./Highway 2 (City of Pickering): New rail bridge over the new BRT westbound lanes on the north side of the existing Kingston Rd. (Highway 2).
- Duffins Creek (Town of Ajax): Bridge widening on the west side by 2.5 m and on the east side by 6 m.
- Lynde Creek – Main (Town of Whitby): Full replacement of existing bridge, including increasing the span of the new bridge compared to the existing bridge.

- CP Rail over Dundas St. (Town of Whitby): Full replacement of existing bridge.
- Oshawa Creek at Bond St., westbound lanes (Town of Oshawa): Full replacement of existing bridge.
- Oshawa Creek at King St., eastbound lanes (Town of Oshawa): Full replacement of existing bridge.

Other bridge structures require only rehabilitation works – for example, removing and replacing asphalt and waterproofing.

For preliminary design, site-specific foundation recommendations are provided in Table 1 for each of the six bridge structures.

Construction of new foundations, whether shallow foundations or deep foundations, must be carried out without disturbing the existing foundations/structure. At bridge sites requiring an extension/widening of existing foundations, the new foundation type should generally match the existing foundation type for consistent performance. However, at some sites, consideration may need to be given to the installation of low disturbance / low vibration foundation options (e.g., micropiles) to support the new/extended foundations and reduce impacts to the existing structure. Micropiles are installed by methods that cause minimal disturbance to adjacent structures and soils and produce minimal vibration and noise. Hence, micropiles are often used to safely underpin existing structures, including bridges. Furthermore, micropile equipment is small and maneuverable and can be used at sites that have difficult or limited access.

5.3 Bus Platforms

It is understood that a total of 55 bus platforms (i.e., 14 curbside platforms and 41 centre-median platforms) will be constructed along the DSBRT alignment. Based on the architectural details provided by Parsons on August 23, 2021, the bus platforms are anticipated to be 40 m long and vary in width – that is, 3.6 m or 4.2 m wide. In addition to various passenger amenities proposed at each platform, the platforms are expected to include enclosed bus shelters (see Figure 2 below) or cantilevered, open canopies (see Figure 3 below).

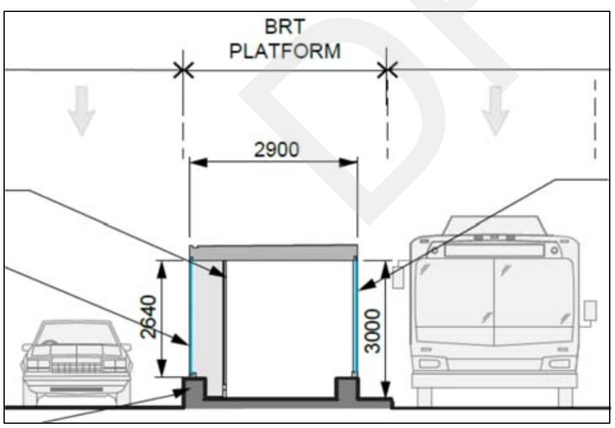

Figure 2: *Centre-Median Platform with Enclosed Bus Shelter*

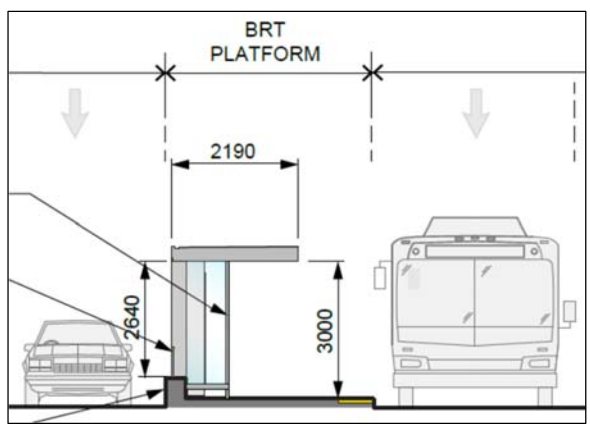

Figure 3: *Centre-Median Platform with Open Canopy*

Based on discussions with Parsons, the enclosed bus shelters and the open canopies are expected to be founded on caissons (bored piles) with a centre-to-centre spacing of about 3 m. It is further understood that each caisson supporting the enclosed bus shelter and the open canopy will need to resist a vertical compression loads of about 50 kN and 100 kN, respectively.

The subsurface conditions along the DSBRT alignment, including the proposed bus platforms, are expected to be variable. However, assuming a compact native granular deposit or granular fill, preliminary estimates of the diameter and minimum length of the caissons as well the respective geotechnical resistances are provided below in Table 2.

Table 2: *Bus Platforms - Preliminary Caisson Dimensions and Geotechnical Resistances*

Diameter	Length [1]	Factored ULS	Factored SLS for 25 mm of Settlement
0.45 m	3.0 m	125 kN	75 kN
0.60 m	3.0 m	225 kN	125 kN

Notes:
1. The length of the caissons assumes that the upper 1.3 m of the foundation element will include a bond breaker to prevent adfreezing and frost heaving of the caissons. Alternatively, the caissons can be founded at a greater length below ground surface.
2. Depending on the final design of the bus shelters and open canopies, wind (i.e., uplift) loads will need to be considered and additional length may be required to resist uplift forces.

The exterior slabs-on-grade for the bus platforms that are placed directly on the existing ground surface will be subject to seasonal vertical movements due to frost and thawing effects. In order to minimize the vertical movements, several mitigation measures can be considered as follows:

1) Sub-excavate the native soils and fills to a depth of 1.3 m below grade (estimated frost penetration depth along the DSBRT alignment) and replace with compacted, granular fill (i.e., non frost-susceptible soil).

2) Install a void form below the concrete platform. The void form should extend beyond the perimeter of the concrete platform to ensure the soils/fills below the concrete platform are not exposed to freezing temperatures.

3) Support the bus platforms on short caissons extending below the frost penetration depth. A bond breaker should be applied to the wall of the caissons (up to a depth of 1.3 m below grade) to prevent adfreezing and frost heaving of the foundation elements. A void form should also be placed below the concrete platform for added insulation from freezing temperatures.

The first alternative, which involves excavations along the existing roadways, would likely require the installation of temporary protection systems (i.e., shoring) to allow motorists to continue using the existing lanes during construction. The second alternative would involve shallower excavations; however, the excavations would occupy a larger footprint considering that the void forms would need to extend beyond the perimeter of the proposed bus platforms. The third alternative involving installation of caissons and placement of a void form directly below the footprint of the platform is likely the most economical and least disruptive alternative.

The latter alternative has also been successfully implemented on similar rapid transit corridor projects in urban environments.

6.0 RECOMMENDATIONS FOR FUTURE WORK

The preliminary foundation recommendations provided in this Technical Memorandum (and the appended table) are based on a desktop review of limited subsurface information. At many locations, site-specific subsurface information is not available. Consequently, site-specific subsurface investigations are recommended to be carried out during detail design/design-build stage to confirm soil, bedrock, and groundwater conditions (including artesian conditions) at the locations of the proposed culvert extensions, bridge widenings, bridge replacements, embankment widenings, any associated retaining walls, and bus platforms.

In areas where foundations are expected to be founded on bedrock, additional subsurface investigation should focus on identifying the transition/boundaries between weathered bedrock and slightly weathered to fresh bedrock, and the properties of the weathered and less weathered bedrock. Information on the weathering degree, quality and strength of the bedrock will affect the founding levels and geotechnical resistances of the preferred foundations.

The future subsurface field investigations should also satisfy the requirements stipulated by respective municipalities and third-parties affected by the proposed works (e.g., Toronto and Region Conservation Authority (TRCA)), the guidelines provided in the *Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6-19* [2], and Railway Authority (e.g., CN Rail/CP Rail or American Railway Engineering and Maintenance-of-Way Association (AREMA)) requirements, as applicable.

7.0 CONSLUSION

We trust that this document satisfies your immediate requirements for planning and preliminary design purposes. Please contact us if you have and questions.

Golder Associates Ltd.

Tomasz Zalucki, P.Eng.
Geotechnical Engineer

Kevin J. Bentley, M.E.Sc., P.Eng.
Associate, Senior Geotechnical Engineer

TZ/KJB/tz

Attachments: Important Information and Limitations of This Report
Table 1: Summary of Preliminary Foundation Recommendations at Bridges and Culverts

https://golderassociates.sharepoint.com/sites/148821/project files/6 deliverables/foundations/draft memo-revc/21473923-tm-revc-dsbrt-preliminary foundation recommendations-20211202.docx

[2] Canadian Standards Association (CSA). 2019. Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6-19. CSA Special Publication, S6.1-19.

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder cannot be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Ground Water Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report. The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

DURHAM-SCARBOROUGH BRT

TABLE 1 – SUMMARY OF PRELIMINARY FOUNDATION RECOMMENDATIONS AT BRIDGES AND CULVERTS

Structure No.	Structure Type	Crossing (West to East)	Municipality	Preliminary Structural Design Recommendations	Preliminary Foundation Recommendations
1	Bridge	Highland Creek - Miliken Branch	Toronto	No bridge widening required. Remove and replace asphalt and waterproofing. Reconstruct sidewalks and increase width.	Not applicable, bridge widening not required.
2	Culvert	Highland Creek - Unknown Tributary	Toronto	Not applicable.	Not applicable; culvert replacement/extension not required.
3	Storm Trunk	Centennial Creek	Toronto	Extend the existing storm trunk on the north side, relocate the inlet structure to connect to the extended portion of the storm trunk.	Extend storm trunk sewer. A site-specific subsurface investigation will be required during detail design/design-build stage to provide geotechnical / foundation design recommendations associated with the extension of the storm trunk sewer.
4	Bridge	Hwy 401 over Kingston Rd.	Toronto	No impact to existing bridge. Proposed design will include placement of additional fill on the south side.	Bridge widening not required; however, widening of the paved slope in front of the existing east bridge abutment is required to accommodate the proposed Multi-Use Path (MUP). The widening of the existing paved slope is not anticipated to impact the stability and settlement of the east bridge abutment and the bearing capacity of the existing spread footing supporting the east abutment for the following reasons: 1) The proposed widening of the existing front slope is minimal, and the additional fill will not be placed directly over the existing spread footing. The additional fill will be placed about 4 m from the east abutment wall and about 3 m from the front edge of the spread footing. Furthermore, the widening is anticipated to be about 1 m wide, and the existing front slope is approximately 2 m high. Consequently, the additional loading stress imposed on the foundation soils/fills in front and below the existing spread footing will be relatively small. 2) The existing spread footing supporting the east bridge abutment is founded on competent soils. The General Arrangement (GA) Drawing (Site 37-902; dated October 1970), indicates that the existing spread footing at the east bridge abutment is founded at about Elev. 114.8 m. Based on founding elevation and the existing subsurface information available at this bridge site (MTO Geocres No. 30M14-199), the existing spread footing is generally founded on hard glacial till classified as a heterogenous mixture of clayey silt to silt with sand, trace gravel, with occasional cobbles, boulders, and silty sand zones. A detailed foundation assessment (and potentially a site-specific subsurface investigation) may be required during detail design/design-build stage to confirm if the placement of additional fill will impact the geotechnical resistance of existing foundation and to assess the stability/settlement of the east bridge abutment.
5	Bridge	Rouge River	Toronto	No bridge replacement required. Remove asphalt and waterproofing. Reconstruct sidewalks and increase width.	Not applicable, bridge widening not required.
6	Culvert	Petticoat Creek	Pickering	Extend the existing concrete box culvert by 7.95 m on each end.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
7	Culvert	Petticoat Creek - Unknown Tributary	Pickering	Extend the existing 2.4 m x 2.4 m concrete box culvert on south end by approximately 14 m.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
8	Culvert	Amberlea Creek - West Branch	Pickering	Extend the existing 1.8 x1.5 m concrete box culvert on each end by approximately 13 m. Designed by others.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
9	Culvert	Amberlea Creek - Unknown Tributary	Pickering	Extend the existing 1.5 mx2.4 m concrete box culvert on each end by approximately 15 m. Construct a new 1.2 m culvert. Designed by others.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
10	Culvert	Amberlea Creek - East Branch	Pickering	Extend the existing 1.2 mx1.2 m concrete box culvert on the south end by approximately 12 m. Designed by others.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
11	Culvert	Dunbarton Creek	Pickering	Extend the existing 1.8 mx3.0 m concrete box culvert on the north side by approximately 30 m with culvert end treatment.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
12	Bridge	CN Rail over Kingston Rd.	Pickering	New rail bridge over the new BRT westbound lanes on the north side of the existing Kingston Rd. (Highway 2).	The existing structure consists of a single span bridge with a total span length of about 29 m and carries a CN railway track over Kingston Rd. (Highway 2). It is understood that the bridge was constructed in 1963 and there is no record of rehabilitation of this structure. A foundation report addressing the subsurface investigation carried out the CN Rail and Highway 2 site is not available. However, a subsurface investigation comprised of eight boreholes was carried at the CN Rail and Highway 401 site – about 90 m to 250 m southeast of the subject site. Boreholes 1 and 2 were advanced about 90 m southeast of the existing south bridge abutment at Highway 2. Based on the foundation report (MTO Geocres No. 30M14-215) the subsurface conditions generally consist of fill underlain by a cohesive glacial till deposit which in turn is underlain by a deposit of silty sand to sandy silt and/or shale bedrock. The composition of the fill ranges from stiff to hard clayey silt to silty clay or loose to compact?

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12	Bridge	CN Rail over Kingston Rd.	Pickering	New rail bridge over the new BRT westbound lanes on the north side of the existing Kingston Rd. (Highway 2).	sandy silt to silty sand. Shale bedrock was encountered in six boreholes at elevations ranging between approximately 75.6 m and 74.1 m. Groundwater level was encountered at shallow depth – between about 0.2 m and 2.3 m below ground surface (between about elevations 83.7 m and 81.4 m). The foundation report (MTO Geocres No. 30M14-215) indicates that the original bridge structure at the Highway 401 site (i.e., prior to the widening of Highway 401) is founded on shallow foundations. The spread footings are 6.7 m wide by 12.2 m long. It is understood that the original foundations were designed for 380 kPa and founded at the following elevations: east abutment – Elev. 81.4 m ; pier – Elev. 81.7 m ; west abutment – Elev. 82.0 m. As for the most recent foundation elements proposed as a result of Highway 401 widening, the report recommends strip footings founded on native soil at the following elevations (which are consistent with the original founding elevations): east pier – Elev. 81.0 m ; west pier – Elev. 81.5 m ; west abutment – Elev. 82.0 m. The report recommends a factored bearing capacity at ULS of 900 kPa and a bearing capacity at SLS (for 25 mm of settlement) of 350 kPa. The size of the spread footings was not provided. Alternatively, the report recommends end-bearing piles driven to the following elevations: east pier – between Elev. 78 m and Elev. 75 m; west pier – between Elev. 79 m and Elev. 77 m ; west abutment – Elev. 81 m and Elev. 79 m. The pile tip elevations are variable as a result of variable subsurface conditions. The report recommends the following pile capacities: HP 310x110: Factored ULS = 1,600 kN ; Factored SLS for 25 mm of Settlement = 1,150 kN ; HP 310x79: Factored ULS = 1,150 kN ; Factored SLS for 25 mm of Settlement = 825 kN Based on a preliminary assessment, spread footings may be founded on hard clayey silt till deposit below Elev. 81.0 m (based on Boreholes 1 and 2). However, it is noted that an approximately 0.8 m thick deposit of compact silty sand, some gravel to silty sand with gravel was encountered at about Elev. 82.0 m or just below Elev. 82.0 m. Given the relatively high groundwater level measured at the site, it will be necessary to ensure the groundwater level is lowered at least 0.5 m below the founding elevation. The following geotechnical resistances may be used for 4 m wide footings founded on hard clayey silt till below Elev. 85.0 m: Factored ULS = 700 kPa ; Factored SLS for 25 mm of Settlement = 350 kPa Alternatively, consideration can be given to steel H-piles driven to shale bedrock or “100-blow” sandy silt to silty sand deposit. Based on a preliminary assessment (stratigraphy based on Boreholes 1 to 4 – that is, boreholes closest to the existing south bridge abutment), the following geotechnical resistances may be used for HP 310x110 piles driven into shale bedrock or “100-blow” sandy silt to silty sand deposit between approximately Elev. 80 m and Elev. 74.5 m, assuming the piles are at least 5 m long: Factored ULS = 1,200 kN ; Factored SLS for 25 mm of Settlement = Does not govern (assuming piles are driven into “100-blow till deposit) Factored ULS = 1,600 kN ; Factored SLS for 25 mm of Settlement = Does not govern (assuming piles are driven into shale bedrock) A site-specific subsurface investigation and a detailed foundation assessment will be required during detail design/design-build stage to confirm the preferred foundation alternative, founding elevations, and associated geotechnical resistances. Foundation recommendations will need to meet CN Rail and/or AREMA requirements.
13	Culvert	Pine Creek	Pickering	Extend existing 2.4 mx6.1 m concrete box culvert on each end by approximately 15 m. Designed by others.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
14	Bridge	Duffins Creek	Ajax	Bridge widening on the west side by 2.5 m and on the east side by 6 m.	Based on the existing General Arrangement (GA) Drawings (May 1968), the structure consists of a three-span bridge with a total span length of about 64 m and carries 5 lanes of traffic. It is understood that the bridge was rehabilitated in 1996. A major component of the rehabilitation works involved removing the concrete deck and sidewalk on the north side of the bridge. Consequently, the travelled portion of the road across the bridge was increased from about 16.5 m to 18.0 m. Based on the existing foundation report (MTO Geocres No. 30M14-003), the subsurface conditions consist of a deposit of silty sand underlain by a glacial till deposit comprised of sandy silt to silty sand (with shale fragments) which in turn is underlain by probable bedrock (rock coring was not carried out) between approximately Elev. 71.3 m and Elev. 70.8 m. The water level in the creek was measured at approximately Elev. 78.7 m on January 11, 1967. The GA Drawing indicates that the existing bridge abutments and piers are founded on steel H-piles (12 BP 74; metric designation: HP 310x110) driven to bedrock and the design load is 95 tons per pile. However, given that in places the sandy silt to silty sand till deposit is up to about 6.1 m thick and the SPT ‘N’-values measured within this glacial till deposit are generally 100 blows for less than 0.3 m of penetration, it is not known if the existing steel piles were driven to bedrock or if preaugering was required to drive the steel piles into bedrock. Based on a preliminary assessment, the following geotechnical resistances may be used for HP 310x110 piles driven to bedrock (below approximately Elev. 70.5 m): Factored ULS = 1,600 kN ; Factored SLS for 25 mm of Settlement = Does not govern A site-specific subsurface investigation (including rock coring and UCS testing) and a detailed foundation assessment will be required during detail design/design-build stage to confirm the geotechnical resistances of steel H-piles driven to bedrock, unless other foundation alternatives are deemed to be preferred.
15	Culvert	Miller's Creek	Ajax	Extend the culvert on the north end by approximately 5.4 m.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
16	Culvert	Carruthers Creek	Ajax	Extend the existing 1.9 mx5.5 m concrete box culvert by 16 m on the north end.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
17	Culvert	Unknown Tributary	Ajax	Extend the existing concrete box culvert and construct new headwall with handrail on south end.	Extend culvert – refer to Section 5.1 of Technical Memorandum.

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18	Culvert	Lynde Creek - Kinsale	Whitby	Extend the existing concrete box culvert by 10 m on each end.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
19	Culvert	Lynde Creek - Kinsale	Whitby	Extend the existing structural culvert by 7.8 m on the north side and by 5 m on the south side.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
20	Culvert	Hwy 412 over Dundas St.	Whitby	Remove and replace asphalt and waterproofing. Reconstruct sidewalks. Replace the existing parapet wall and railing to meet CHBDC height requirement for cyclist use.	Not applicable.
21	Culvert	Hwy 412 Road Ditch	Whitby	Extend the existing culvert by 3 m on north end and 6 m on south end.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
22	Culvert	Hwy 412 Ramp Ditch	Whitby	No bridge widening required. Extend the existing culvert by 6 m on each end.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
23	Culvert	Des Newman Blvd. Road Ditch	Whitby	Extend the existing culvert by 16 m on each side.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
24	Culvert	Lynde Creek - Main	Whitby	Extend the existing CSP on the north end by 10 m.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
25	Bridge	Lynde Creek – Main (0.75 km west of Cochrane Street)	Whitby	Full replacement of existing bridge, including increasing the span of the new bridge compared to the existing bridge.	The existing structure consists of a single span bridge with a total span length of about 21.3 m and carries Dundas St. (four lanes of traffic) over Lynde Creek. It is understood that the bridge was constructed in 1972. Based on an existing GA Drawing (November 1971; Structure Site No. 22-153), the original foundations are comprised of spread footings founded on overburden soil at about Elev. 75.7 m. The design bearing pressure is 7 ksf (about 335 kPa). The existing GA Drawing also provides inferred soil stratigraphy based on two boreholes advanced at the bridge site. The stratigraphy consists of: fill of unknown composition (measured SPT 'N'-values of 5 blows per 0.3 m of penetration); silty clayey sand (measured SPT 'N'-values ranging from 3 blows to 7 blows per 0.3 m of penetration); sandy gravel (measured SPT 'N'-value of 14 blows per 0.3 m of penetration); silty sand (measured SPT 'N'-values ranging from 20 blows to 43 blows per 0.3 m of penetration); silty sand till (measured SPT 'N'-values ranging from 60 blows to 100 blows per 0.3 m of penetration); and shale bedrock. Based on the founding elevation of the spread footings, the footings appear to be founded on the very dense silty sand till. Based on a preliminary assessment, the following geotechnical resistances may be used for 4 m wide spread footings founded on very dense silty sand till below approximately Elev. 75.5 m (stratigraphic/geological conditions and founding elevations to be confirmed): Factored ULS = 900 kPa ; Factored SLS for 25 mm of Settlement = 350 kPa Given the presence of competent glacial till and shallow bedrock at this site, deep foundations are not considered practical. However, if perched pile caps are founded within the fill, consideration may be given to steel H-piles driven to bedrock. A site-specific subsurface investigation (including rock coring and UCS testing) and a detailed foundation assessment will be required during detail design/design-build stage to confirm the preferred foundation alternative, founding elevations, and associated geotechnical resistances.
26	Culvert	Pringle Creek - Unknown Tributary	Whitby	Culvert extension on the north side by 8.2 m and by 9.5 m on the south side.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
27	Bridge	CP Rail over Dundas St.	Whitby	Full replacement of existing bridge.	The existing structure consists of a three-span bridge with a total span length of about 50 m (estimated from aerial imagery) and carries a CP railway track over Dundas St. (Highway 2). It is understood that the bridge was constructed in the mid to late 1960's. Based on the original foundation report (MTO Geocres No. 30M15-005) the subsurface conditions consist of 2.6 m to 4.4 m of very stiff clayey silt underlain by generally very dense (SPT 'N'-values greater than 100 blows per 0.3 m of penetration) glacial till comprised of a heterogenous mixture of silt, sand, and gravel. The "100-blow" material was generally encountered below Elev. 85.3 m. Shale bedrock was encountered in one borehole at a depth of about 13.1 m below original grade, corresponding to Elev. 76.5 m. Groundwater level was encountered between about elevations 89.0 m and 86.6 m. Furthermore, artesian groundwater conditions were encountered in the borehole advanced at the location of the southeast abutment. The artesian conditions were observed in the till deposit at a depth of about 6.1 m and the observed head was 0.6 m above original ground surface. The foundation report (MTO Geocres No. 30M15-005) recommends strip footings founded at Elev. 86.3 m with a safe bearing load of 3 tons/ft^2 (287 kPa). It is noted that a memo from the MTO Foundations Office was also appended to the report. The memo indicates that the abutments should be founded on steel H-piles (12 BP 74; metric designation: HP 310x110) driven to "100-blow" till deposit between about elevations 83.8 m and 82.9 m. The recommended design load is 95 tons per pile. Based on this discrepancy between the foundation report and the memo, it is not known if the abutments are founded on shallow or deep foundations. Based on a preliminary assessment, the following geotechnical resistances may be used for 4 m wide spread footings founded on the "100-blow" till deposit below Elev. 85.0 m: Factored ULS = 900 kPa ; Factored SLS for 25 mm of Settlement = 300 kPa

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					Alternatively, the following geotechnical resistances may be used for HP 310x110 piles driven into the "100-blow till deposit below Elev. 83.5 m, assuming the piles are at least 5 m long (a more detailed assessment will be required to confirm the piles will not bee too short): Factored ULS = 1,400 kN ; Factored SLS for 25 mm of Settlement = Does not govern A site-specific subsurface investigation (including confirmation of artesian groundwater conditions) and a detailed foundation assessment will be required during detail design/design-build stage to confirm the preferred foundation alternative, founding elevations, and associated geotechnical resistances. The composition of the fill on the north side of Highway 2 will also need to be investigated. For planning purposes, it should be assumed that dewatering / depressurization of the confined aquifer will be required during construction.
28	Culvert	Corbett Creek	Oshawa	Culvert extension on both ends by 15 m with end treatment.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
29	Culvert	Corbett Creek	Oshawa	Culvert extension on the south end by 12 m with end treatment.	Extend culvert – refer to Section 5.1 of Technical Memorandum.
30	Culvert	Goodman Creek	Oshawa	No work.	Not applicable.
31	Bridge	Oshawa Creek at Bond St. (westbound lanes)	Oshawa	Full replacement of existing bridge.	The existing structure consists of a two-span bridge with a total span length of about 20 m (estimated from aerial imagery) and carries four lanes of traffic over the Oshawa Creek. The bridge was constructed in 1951. A foundation report addressing the subsurface investigation carried out at the Bond St. and Oshawa Creek site is not available. Based on an existing GA Drawing (February 1972), the original foundations are comprised of spread footings founded on bedrock between approximately elevations 97.7 m and 97.6 m. Based on a preliminary assessment, the following geotechnical resistances may be used for 4 m wide spread footings founded on unweathered shale bedrock below approximately Elev. 97.5 m (stratigraphic/geological conditions and founding elevations to be confirmed): Factored ULS = 1,200 kPa ; Factored SLS for 25 mm of Settlement = Does not govern Given the presence of shallow bedrock at this site, deep foundations are not considered practical. A site-specific subsurface investigation (including rock coring and UCS testing) and a detailed foundation assessment will be required during detail design/design-build stage to confirm the preferred foundation alternative, founding elevations, and associated geotechnical resistances.
32	Bridge	Oshawa Creek at King St. (eastbound lanes)	Oshawa	Full replacement of existing bridge.	The existing structure consists of a single span, earth filled arch structure with a total span length of about 20 m and carries four lanes of traffic over the Oshawa Creek. The bridge was constructed in 1921. A foundation report addressing the subsurface investigation carried out for the King St. and Oshawa Creek site is not available. GA Drawings are also unavailable, and it is not known if the structure is founded on shallow or deep foundations. However, considering that the bridge is located about 115 m south of the bridge which carries Bond St. over the Oshawa Creek, and the foundations associated with the latter bridge are comprised of spread footings founded on bedrock, it is assumed that the proposed bridge will also be founded on spread footings (on bedrock). Based on a preliminary assessment, the following geotechnical resistances may be used for 4 m wide spread footings founded on unweathered shale bedrock (stratigraphic/geological conditions and founding elevations to be confirmed): Factored ULS = 1,200 kPa ; Factored SLS for 25 mm of Settlement = Does not govern Given the likely presence of shallow bedrock at this site, deep foundations are not considered practical. A site-specific subsurface investigation (including rock coring and UCS testing) and a detailed foundation assessment will be required during detail design/design-build stage to confirm the preferred foundation alternative, founding elevations, and associated geotechnical resistances.