Appendix M.2 – Hydrogeological Report

Kennedy Road Environmental Assessment between Steeles Avenue and Major Mackenzie Drive

REPORT

Hydrogeological Assessment Report

Class Environmental Assessment Study for Improvements to Kennedy Road from Steeles Avenue to Major Mackenzie Drive, Markham, Ontario

Submitted to:

HDR Inc.
100 York Boulevard, Suite 300
Richmond Hill, ON
L4B 1J8

Submitted by:

Golder Associates Ltd.
6925 Century Avenue, Suite #100, Mississauga, Ontario, L5N 7K2, Canada
+1 905 567 4444

Project No. 1664178 Rev1

August 13, 2020

Distribution List

1 eCopy - HDR Inc.

1 eCopy - Golder Associates Ltd.

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by HDR Inc. (HDR) to provide hydrogeological services in support of the Class Environmental Assessment for the proposed improvements to of Kennedy Road from Major Mackenzie Drive East to Steeles Avenue East in the City of Markham, Regional Municipality of York (Region), Ontario. Kennedy Road is a major north-south corridor in the Region of York and the need for capacity improvements are identified in the Region's transportation plans to accommodate growth and improve overall network connectivity.

As part of this project, hydrogeologic investigations were carried out for multiple structures along Kennedy Road, between Steeles Avenue and Major Mackenzie Drive, including the GO Rail Crossing at Clayton Drive, CN Rail Crossing, 407 Express Toll Route, Tributary Crossing, Rouge River Crossing, and GO Rail Crossing at Austin Drive. This report presents the results of the hydrogeological assessment.

The purpose of the investigation was to characterize existing groundwater conditions along Kennedy Road, assess potential impacts as part of the environmental assessment, and identify the potential need for a Permit to Take Water ("PTTW") or Environmental Activity and Sector Registry (EASR).

The investigation and reporting were carried out in general accordance with the scope of work provided in our Work Plan and Methodology, of the Subconsultant Agreement between Golder and HDR dated November 9, 2017. The scope of work was developed based on the requirements of the Request for Proposal outlined in The Regional Municipality of York 's Request for Proposal (P-16-167) dated November 3, 2016 and associated addenda.

The factual data, interpretations and preliminary recommendations contained in this report pertain to a specific project as described in the report and are not applicable to any other project or site location. This report should be read in conjunction with *"Important Information and Limitations of This Report"* in Appendix A, following the text of this report. The reader's attention is specifically drawn to this information, as it is essential for the proper use and interpretation of this report.

2.0 SITE DESCRIPTIONS

The study area for the proposed road improvements is located along Kennedy Road from Steeles Avenue to Major Mackenzie Drive East in the City of Markham, as shown in Figure 1. Within the study limits, Kennedy Road is a four lane north-south road. The current alignment intersects existing and future local roads and entrances across the city. Within the overall project limits, Kennedy Road crosses the main branch of the Rouge River. Notably, the confluence of Bruce Creek with the Rouge River is located 150 meters west of Kennedy Road and the Unionville Marsh Wetland Complex, a provincially significant wetland, is located 500 meters west of Kennedy Road, as shown in Figure 2. It is understood that the proposed Kennedy Road improvements will modify the existing roadway to meet the planning requirements for the City of Markham as set out in Places to Grow, the Big Move, Regional policy documents, such as Vision 2051, and the Regional Official Plan.

The following structures crossing Kennedy Road are identified within the study area are listed below and elaborated in the subsequent subsections.

- GO Rail Crossing at Clayton Drive – no existing structure, crossing at grade;
- CN Rail Crossing– Single span bridge over Kennedy, currently on spread footings;

- 407 Express Toll Route (407 ETR) – Double span bridge over 407 ETR;
- Tributary Crossing – Double CSP culvert;
- Rouge River – Bridge over Rouge River on steel piles; and,
- GO Rail Crossing at Austin Drive – Crossing currently at grade.

2.1 GO Rail Crossing at Clayton Drive

An existing GO Transit at-grade crossing (Stouffville Line) is present on Kennedy road approximately 700 m north of Steeles Avenue as shown on the Key Plan on Figure 3a. Kennedy Road consists of two lanes in each direction with a boulevard and sidewalk on each side of Kennedy Road. Residential developments are located to the west of the rail crossing and commercial developments are located to the north, east and south of the rail crossing. The grade of Kennedy Road in the vicinity of the GO Transit crossing is at about Elevation 201.7 m and the surrounding lands are generally flat.

2.2 CN Rail Crossing

The Kennedy Road and CN Rail bridge is located approximately 0.4 km south of the 407 ETR and Kennedy Road interchange as shown on the Key Plan on Figure 3b. The CN Rail bridge is approximately 11 m wide and approximately 22 m long. Kennedy Road consists of two lanes in each direction with a boulevard and sidewalk on each side of Kennedy Road.

The natural ground surface at the site slopes downward from south to north with ground surface elevations ranging from approximately Elevation 191 m to Elevation 187 m, being approximately Elevation 188 at the bridge location. The CN Rail bridge which crosses over Kennedy Road is at about Elevation 194 m. Commercial development is located south of the bridge and west of Kennedy Road. Residential development is located south of the bridge and east of Kennedy Road. Undeveloped lands are present north of the bridge that contain the Hydro One corridor and infrastructure which runs parallel to the CN rail.

2.3 407 ETR

The existing Kennedy Road Overpass at 407 ETR consists of a two-span integral abutment structure, approximately 107 m long and 30 m wide, carrying six lanes of traffic of Kennedy Road as shown on the Key Plan on Figure 3c. The Kennedy Road grade at the crossing location varies from about Elevation 188 m to 189 m and the grade of 407 ETR is at about Elevation 180 m. Commercial developments are located north of 407 ETR and agricultural land is located immediately south of 407 ETR with commercial and residential developments further south.

2.4 Tributary Crossing

The existing culvert structure at the Rouge River tributary is located about 190 m southwest of Unionville Gate and consists of twin 900 mm by 1430 mm corrugated steel pipe (CSP) arch culverts crossing beneath Kennedy Road in the City of Markham, in the Regional Municipality of York, Ontario, as shown on the Key Plan on Figure 3d. At the tributary culvert location, Kennedy Road consists of six lanes of traffic with four northbound lanes (one left turn lane, two through lanes and one right turn lane) and two southbound lanes. Wide boulevards are present along with sidewalks on both sides of Kennedy Road. Commercial developments surround the site. The grade of Kennedy Road in the vicinity of the culvert is about Elevation 175 m and the surrounding lands are general flat. Based on information provided by HDR, the existing culvert inverts are at about Elevation 173 m.

2.5 Rouge River

The existing Rouge River bridge at Kennedy Road consists of a single span structure carrying four lanes of vehicular traffic and sidewalks on both sides of Kennedy Road as shown on the Key Plan on Figure 3e. The pavement surface along Kennedy Road at the Rouge River bridge varies from Elevation 173.0 m to 172.4 m. The drawings referenced below were provided to Golder by HDR on August 23, 2018:

- The Regional Municipality of York Engineering, drawing titled, “Regional Road No 3 Realignment Rouge River Bridge, Rouge River, Town of Markham, General Arrangement, Drawing No. S-208-7A, Cont. No. 81-15, Sheet Nos. 27”, prepared by Totten Sims Hubicki Associates, dated March 1981.

The existing structure is approximately 30 m long and 19 m wide. Both abutments are supported by driven 324 mm diameter battered steel tube piles extending between 8.5 m and 9.1 m in length to reported Elevation 158.5 m. The undersides of the pile caps are reportedly at Elevation 167.6 m and 167.0 m at the north and south abutments, respectively. The above drawings indicate that the riverbed of Rouge River is at approximately Elevation 167 m and the river water level is at about Elevation 167.3 m, some 5 m below Kennedy Road. The Denby Valley Park is located east and west of the Rouge River bridge and there are residential developments located south of the park.

2.6 GO Rail Crossing at Austin Drive

An existing CN Rail at-grade crossing is present on Kennedy Road approximately 90 m north of Austin Drive, as shown on Figure 3f. The existing CN Rail line is also used as a GO Transit Rail line. For this project, this rail line is referred to as the GO Rail Crossing at Austin Drive. Kennedy Road consists of two lanes in each direction with a boulevard and sidewalk on each side of Kennedy Road. Residential developments are located northwest, northeast, and southeast of the crossing and landscaped park lands are located southwest of the crossing.

The grade of Kennedy Road in the vicinity of the GO Rail Crossing at Austin Dr. crossing is at about Elevation 175.6 m and the surrounding lands are generally flat.

3.0 EXISTING CONDITIONS

3.1 Previous Studies

Previous projects on Kennedy Road between Major Mackenzie Drive East and Steeles Avenue East have contributed to the current understanding of the conditions on the site. Studies reviewed to inform this report include:

- Geo-Canada Ltd., report titled “Report on subsurface investigation for Kennedy Road and Birchview Lane Intersection Improvements Regional Municipality of York”, Report No. G-06.0406, dated June 2006.
- Trow Associates Inc., report titled “Geotechnical Investigation Proposed Road Widening Kennedy and Birchview Lane Markham, Ontario”, Report No. BRGE00283621A, dated June 5, 2007.
- Coffey Geotechnics Inc., report titled “Hydrogeological Assessment Report for Application to Renew Permit to Take Water 1500-mm Diameter Kennedy Road Watermain”, Report No. ENVSETOB10389AA, dated March 25, 2014.
- North-South Environmental Inc., report titled “Natural Heritage and Hydrologic Study – Millken Secondary Plan Area”, dated December 12, 2016.

- URS Corp., report titled “Environmental Study Report – Miller Avenue Extension and Improvements from Woodbine Avenue to Kennedy Road”, dated September 2013.
- York Region Rapid Transit Plan, report titled “Highway 7 Corridor & Vaughan North-South Link Public Transit Improvements – Environmental Assessment Report”, Report No. PM1435, dated August 2005.
- Trow Associates Inc., report titled “Foundation Conditions Proposed Bridge Replacement Kennedy Road Over Beaver Creek South of Unionville”, Report No. 30M14-049, dated April 1968.
- Beatty and Associates Ltd., report titled “Groundwater and Engineering in the Town of Markham”, dated December 2001.
- MacViro Consultants Inc., report titled “Fill, Construction, Alteration to Waterways Application 16th Avenue Trunk Sewer Phase II York Durham Sewage System”, dated June 2003.
- Golder Associates Ltd., report titled “Preliminary Geotechnical Investigation Proposed Residential Development, 4134 16th Ave Markham, Ontario”, Report No. 1413472, dated September 29, 2016.
- R. J. Burnside and Associates Ltd., report titled “Hydrogeological Assessment and Water Balance of 4134 16th Ave Markham, Ontario”, Report No. 300038247.0000, dated September 2016.

3.2 Topography, Drainage and Geology

This section of Kennedy Road from Major Mackenzie Drive East to Steeles Avenue East straddles the boundary between two physiographic regions of Southern Ontario; the South Slope region and the Oak Ridges region (Chapman and Putnam, 1972) (Chapman and Putnam, 1973).

The Oak Ridges region is over 160 km in length, running from the Niagara Escarpment to the Trent River, dividing the streams of the Lake Ontario basin from those flowing into Georgian Bay and the Trent River. The surface is hilly, with the hills composed for the most part of sandy and gravelly materials. In some places, boulder clay protrudes above these soils.

The South Slope physiographic region covers portions of the Regional Municipalities of Peel, York and Durham. A surficial till sheet, which generally follows the surface topography, is generally present throughout much of this area. The till is typically comprised of clayey silt to silty clay, with occasional silt to sand zones and is mapped in this area as the Halton Till. Shallow, localized deposits of loose silt and sand and/or soft clay can overlie this uppermost till sheet, and these represent relatively recent deposits, formed in small glacial melt water ponds scattered throughout the Peel Plain and concentrated near river valleys. The recent sand, silt and clay and uppermost till deposits in this area overlie and are interbedded with stratified deposits of sand, silt and clay. The area is underlain by the grey Collingwood and Dundas shales.

3.3 Regional Geology

This section of Kennedy Road from Major Mackenzie Drive East to Steeles Avenue East straddles the boundary between two physiographic regions of Southern Ontario; the South Slope region and the Oak Ridges region (Chapman and Putnam, 1972) (Chapman and Putnam, 1973).

The Oak Ridges region is over 160 km in length, running from the Niagara Escarpment to the Trent River, dividing the streams of the Lake Ontario basin from those flowing into Georgian Bay and the Trent River. The surface is

hilly, with the hills composed for the most part of sandy and gravelly materials. In some places, boulder clay protrudes above these soils.

The South Slope physiographic region covers portions of the Regional Municipalities of Peel, York and Durham. A surficial till sheet, which generally follows the surface topography, is generally present throughout much of this area. The till is typically comprised of clayey silt to silty clay, with occasional silt to sand zones and is mapped in this area as the Halton Till. Shallow, localized deposits of loose silt and sand and/or soft clay can overlie this uppermost till sheet, and these represent relatively recent deposits, formed in small glacial melt water ponds scattered throughout the Peel Plain and concentrated near river valleys. The recent sand, silt and clay and uppermost till deposits in this area overlie and are interbedded with stratified deposits of sand, silt and clay. The area is underlain by the grey Collingwood and Dundas shales.

3.4 Overview of Subsurface Soils

The surficial geology of the area is summarized in Figure 4. The surficial geology of the study area includes carbonate derived silty to sandy till, massive well laminated deposits, foreshore-basinal deposits, and modern alluvial sediments. Between 407 ETR and Steeles Avenue, silty to sandy till is consistently observed. 407 ETR and Major Mackenzie Drive East, massive well laminated deposits, foreshore-basinal deposits, and silty to sandy till are found in sections. Rouge River and Bruce Creek, modern alluvial deposits are observed.

Sixty-three borehole records, six borehole plans, and a stratigraphic transect found in previous studies are included in Appendix C. Boreholes ranged in depth from 1 meter to 35 meters and generally showed agreement with the surficial soils mapping in Figure 3. Some coarser gravelly soils are observed near the Rouge River in the modern alluvial sediments. Silty to sandy till and clay till were encountered in most boreholes, with some sand deposits. Contacts between sand till, silt till, clay till, and sand units are often irregular, and many units are discontinuous.

3.5 Regional Hydrogeology

Generally, hydrostratigraphic units influencing groundwater flow in the study area include a shallow groundwater system (i.e., Halton Till and Oak Ridges Complex Aquifer) and a deeper groundwater system (i.e., Newmarket Till, Thorncliffe Aquifer, Sunnybrook Aquitard, Scarborough Aquifer and Weathered Bedrock) (TRCA, 2008). The characteristics of these hydrostratigraphic units that influence groundwater flow include the presence and configuration of bedrock valleys and tunnel channels, the thickness and lateral extent of the Newmarket Till, which separates the shallow and deep groundwater systems, and the thickness and lateral extent and nature of the sediments in the aquifer complexes (TRCA, 2008). Along Kennedy Road, there may be additional discontinuous layers and variation of the hydrostratigraphic units.

The shallow aquifer in the study area has been observed in hydrogeological and geotechnical studies. Depth to the water table varies throughout the study area, ranging from 31 metres below ground surface (mbgs) to -3.5 mbgs (Coffey, 2014). Some artesian conditions have been observed in shallow groundwater in the topographic lows and near the Rouge River. Observed groundwater levels in the shallow aquifer mimicked the topography (Beatty and Associates Ltd, 2001) from high elevations in the northern end of the study area to the low point in the study area, the Rouge River (Coffey, 2014). Shallow groundwater levels are influenced by infiltration at the ground surface contributing to recharge. Based on the annual precipitation, topography, and surficial soils, 100 millimetres per year (mm/yr) of recharge is estimated in the study area (North-South Environmental, 2016). Seasonality and recharge events also have an influence on the water level distribution in the shallow aquifer. Due to the heterogeneity of the shallow soils, perched water table conditions were observed near the intersection of Kennedy Road and Steeles Avenue.

The lower aquifer is found at the contact between the Scarborough Sands and the weathered shale Georgian Bay Formation bedrock. In the study area, a buried bedrock valley affects the groundwater flow (Beatty and Associates Ltd., 2001). A pumping test conducted using seven wells on 16th Avenue and Markham Road (2 km east of the study area) made observations of the baseline head distributions and estimated the hydraulic parameters (MacViro, 2003). The test showed that in the lower aquifers the typical direction of groundwater flow is from the Oak Ridges Moraine toward Lake Ontario, south-southeast.

3.6 Groundwater Use

Based on a review of the Ontario Ministry of Environment, Conservation and Parks (MECP) (formerly, Ministry of the Environment and Climate Change's (MOECC)) Water Well Information System (WWIS) database, there are 412 water well records and 7 Permits to Take Water (PTTW) within a 500 m radius of the study area. Figures 5 and 6 indicate the locations of these water well records and PTTW, respectively. Table B1 summarizes the well information and Table B2 summarizes the PTTW information, found in Appendix B.

These wells were drilled between 1950 and 2016 to depths of 1.8 to 100.6 metres below ground surface (mbgs). Some (97) of the water wells listed have been abandoned. A total of 160 water supply well records are listed and are primarily for domestic, livestock, and irrigation use (145) and monitoring/test holes/observation wells (99). Two municipal and two public wells were identified, completed in 1964, 1967, 1967, and 1994 respectively. The majority of the area is now municipally serviced and most of these water supply wells are assumed to be no longer active and may have been decommissioned.

Seven active Permits to Take Water (PTTW) were identified within 500 m of the site and are summarized in Table B2. Six of the permits are held by the Regional Municipality of York (RMOY), ranging from 135,000 L/day to 200,000 L/day. All six permits are used for construction dewatering. Five of the construction dewatering permits are near the Kennedy Road bridge over the Rouge River and the sixth is located on Kennedy Road north of the 407. The other permit is head by the Angus Glen Golf Club and is active until 2022 and are used for irrigation (392,775 L/day). The permit for the Angus Glen Golf Club is located at the northwestern extent of study area.

4.0 HYDROGEOLOGIC CONDITIONS

4.1 Groundwater Conditions

A total of five monitoring wells were installed as part of the geotechnical investigation carried out by Golder (2018a-f). Each of these wells were developed immediately following installation. The details of the monitoring well installations are described in the geotechnical report (Golder 2019a-f).

Groundwater level measurements were collected from stand pipe piezometers installed at each structure location (GO Rail Crossing at Austin Dr., Rouge River, Tributary Crossing, 407 ETR, CN Rail Crossing, and GO Rail Crossing at Clayton Dr.) immediately following drilling (November 29/30, 2018) and again after well development and recovery (December 13/14, 2018). The details of measured water levels are provided in Table 1 below.

Table 1: Groundwater Levels

Structure Location	Borehole Number	Screened Stratigraphy	Ground Surface Elevation (m)	Pre-Development (29/30-Nov-18)		Post-Development (13/14-Dec-18)	
				Water Level Depth (m)	Water Elevation (m)	Water Level Depth (m)	Water Elevation (m)
GO Rail Crossing at Clayton Dr.	CNR-202B	Gravelly Silty Sand	175.6	5.6	170.0	5.0	170.6
Rouge River	RR-1	Sandy Gravel	172.0	3.2	168.8	3.4*	168.6*
Rouge River	RR-2	Gravelly Silty Sand Fill	172.9	4.0	168.9	4.6	168.3
Tributary Crossing	TC-2	Sandy Silty Clay and Gravelly Silty Sand Till	174.9	5.7	169.2	4.6	170.3
407 ETR	ETR-2	Till / Silty Clay	188.5	10.8	177.7	10.8	177.7
CN Rail Crossing	CNR-102	Silty Sand Till	187.1	7.7	179.4	10.6	176.5
GO Rail Crossing at Austin Dr.	GO-2	Silt and Sand	201.6	1.3	200.3	1.4	200.2

*Water level collected on January 11, 2019

It should be noted that the groundwater measurements reflect the groundwater conditions encountered in the boreholes on the dates they were measured, and the levels are anticipated to fluctuate with seasonal variations in precipitation and snowmelt.

4.2 Hydraulic Testing

Golder estimated the bulk hydraulic conductivity (K) of the soil materials adjacent to the screened intervals at all monitoring wells. Single well response tests (SWRT) were carried out at monitoring wells installed in boreholes CNR-102, CNR-202B, ETR-2, GO-2, RR-1, RR-2, and TC-2 on December 13/14, 2018 and January 11, 2019 (location RR-1). The SWRT were performed by removing a known volume of water rapidly from the well column, using a bailer. Recovery of the water level in the well was subsequently monitored using a pressure transducer. Water levels were measured manually using a water level meter to 95% recovery where able. A summary of the analysis is provided in Appendix C. The hydraulic conductivity of the screened material was interpreted from the water level displacement using the Hvorslev method (Hvorslev, 1951) as follows:

$$K = \frac{r^2 \ln\left(\frac{L}{R}\right) \ln\left(\frac{h_1}{h_2}\right)}{2L\,(t_2 - t_1)}$$

where, K = hydraulic conductivity of the tested material;

r = radius of the well riser pipe;

R = radius of the sand pack;

L = length of screen and sand pack; and,

h_1, h_2, t_1, and t_2 - represent the slope of the recovery plotted on the head ratio (log scale) versus elapsed time plot.

Table 2: Hydraulic Conductivity Estimates

Structure Location	Borehole Number	Description of Soil Attendant at Screened Depth	Depth of Sand Pack Interval (mbgs)	Estimated Hydraulic Conductivity K (m/s)
CN Rail Crossing	CNR-102	(CI) SILTY CLAY to (SM) SILTY SAND (TILL)	13.0 – 15.7	1×10^{-6}
GO Rail Crossing at Austin Dr.	CNR-202B	(CI) SILTY CLAY to (SM) gravelly SILTY SAND	6.1 – 7.6	2×10^{-6}
407 ETR	ETR-2	(CL-ML/CL) CLAYEY SILT and SAND to SILTY CLAY (TILL) to (CL) SILTY CLAY	12.2 – 15.2	4×10^{-8}
GO Rail Crossing at Clayton Dr.	GO-2	(ML) SILT and SAND	11.3 – 12.8	2×10^{-7}
Rouge River	RR-1	FILL – (SM) gravelly SILTY SAND	11.3 – 12.8	1×10^{-4}
Rouge River	RR-2	(GP) sandy GRAVEL	5.5 – 7.0	7×10^{-5}
Tributary Crossing	TC-2	(CL) SILTY CLAY to (SM) gravelly SILTY SAND (TILL)	6.1 – 7.6	5×10^{-9}

4.3 Grain Size Analysis

Hydraulic conductivity estimates were derived from grain size samples collected from the elevations and stratigraphy relevant to the proposed dewatering excavations, using the Hazen Method (Hazen, 1911). Table 3 below provides a summary of hydraulic conductivity estimates derived from this analysis. The complete list of laboratory records of grain size curves can be found in the corresponding foundation reports (Golder, 2019a-f).

Table 3: Hydraulic Conductivity Results based on Grain Size Analysis

Borehole ID	Sample ID	Description of Soil Attendant at Sample Depth	Sample Elevation (m)	d_{10} (mm)	Estimated Hydraulic Conductivity K (m/s)
GO-2	2	Fill – (CL) Sandy SILTY CLAY	200.5	0.001	1.0×10^{-8}
GO-2	11	(ML) SILT and SAND to (CL-ML) CLAYEY SILT and SAND (TILL)	189.1	0.0024	5.8×10^{-8}
GO-2	13	(ML) SILT and SAND to (CL-ML) CLAYEY SILT and SAND (TILL)	186.0	0.001	1.0×10^{-8}
GO-1	12	(ML) SILT and SAND to (CL-ML) CLAYEY SILT and SAND (TILL)	187.9	0.0017	2.9×10^{-8}
GO-1	4	(ML) SILT and SAND to (CL-ML) CLAYEY SILT and SAND (TILL)	200.1	0.003	9.0×10^{-8}
GO-1	6	(ML) SILT and SAND to (CL-ML) CLAYEY SILT and SAND (TILL)	198.6	0.0015	2.3×10^{-8}
CNR-101	2	FILL – (CL) sandy SILTY CLAY	185.9	0.0003	9.0×10^{-10}
CNR-101	12	(SM) SILTY SAND (TILL) to (CL-ML) CLAYEY SILT and SAND (TILL)	173.1	0.003	9.0×10^{-8}
CNR-101	6A	(SM) SILTY SAND (TILL) to (CL-ML) CLAYEY SILT and SAND (TILL)	177.7	0.003	9.0×10^{-8}
CNR-102	12	(SM) SILTY SAND (TILL) to (CL-ML) CLAYEY SILT and SAND (TILL)	174.4	0.003	9.0×10^{-8}
CNR-102	9	(SM) SILTY SAND (TILL) to (CL-ML) CLAYEY SILT and SAND (TILL)	183.7	0.0008	6.4×10^{-9}
CNR-102	11	(CI) SILTY CLAY	174.7	<0.00001	$<1 \times 10^{-12}$
ETR-1	6	FILL – (ML) Silt and Sand	183.1	0.0015	2.3×10^{-8}
ETR-1	9	(SM) SILTY SAND (TILL) to (CL-ML) CLAYEY SILT and SAND (TILL)	178.5	0.0016	2.6×10^{-8}

Borehole ID	Sample ID	Description of Soil Attendant at Sample Depth	Sample Elevation (m)	d_{10} (mm)	Estimated Hydraulic Conductivity K (m/s)
ETR-2	8	(SM) SILTY SAND (TILL) to (CL-ML) CLAYEY SILT and SAND (TILL)	180.7	0.0016	2.6×10^{-8}
TC-2	7	(CL) Sandy SILTY CLAY	168.5	0.0003	9.0×10^{-10}
TC-1	8	(ML) SILT and SAND	167.3	0.0045	2.0×10^{-7}
TC-1	10	(SM) Gravelly SILTY SAND to (CL-ML) CLAYEY SILT and SAND (TILL)	164.2	0.0015	2.3×10^{-8}
TC-2	13	(SM) Gravelly SILTY SAND to (CL-ML) CLAYEY SILT and SAND (TILL)	160.1	0.009	8.1×10^{-7}
TC-2	8	(SM) Gravelly SILTY SAND to (CL-ML) CLAYEY SILT and SAND (TILL)	167.0	0.0031	9.6×10^{-8}
TC-1	12	(SP) Gravelly SAND	161.2	0.055	3.0×10^{-5}
RR-2	7	FILL – (SM) gravelly SILTY SAND	166.6	0.035	1.2×10^{-5}
RR-1	6	(CL) sandy SILTY CLAY	167.2	0.0001	1.0×10^{-10}
RR-2	10	(SM) SILTY SAND and GRAVEL to (GP) sandy GRAVEL	162.0	0.049	2.4×10^{-5}
RR-1	11	(SM) SILTY SAND and GRAVEL to (GP) sandy GRAVEL	159.6	1.5	2.3×10^{-2}
RR-2	12	(CL) SILTY CLAY	159.0	0.0005	2.5×10^{-9}
RR-1	12	(CL-ML) sandy CLAYEY SILT (TILL)	158.1	0.001	1.0×10^{-8}
RR-2	13	(SM) SILTY SAND	157.5	0.028	7.8×10^{-6}
CNR-201	2	FILL – (SP) gravelly SAND	174.6	0.07	4.9×10^{-5}
CNR-202	4	(CI) SILTY CLAY	173.0	0.0002	4.0×10^{-10}

Borehole ID	Sample ID	Description of Soil Attendant at Sample Depth	Sample Elevation (m)	d_{10} (mm)	Estimated Hydraulic Conductivity K (m/s)
CNR-201	5	(CI) SILTY CLAY	172.4	<0.0001	<1 x 10^{-10}
CNR-201	6	(SM) SILT SAND to (SM) gravelly SILTY SAND	170.7	0.02	4.0 x 10^{-6}
CNR-202B	7B	(SM) SILT SAND to (SM) gravelly SILTY SAND	169.2	0.02	4.0 x 10^{-6}
CNR-202	9	(CI) SILTY CLAY	166.2	0.00015	2.3 x 10^{-10}
CNR-202	13	(SP) SAND	160.1	0.065	4.2 x 10^{-5}

In summary, the results of the Hazen analysis showed a range of hydraulic conductivity values from <1.0 x 10^{-10} m/s to 2.3 x 10^{-2} m/s.

5.0 PROPOSED WATER TAKING PROGRAM

Water takings in excess of 50 m^3/day are regulated by the Ministry of Environment, Conservation and Parks (MECP). Certain construction dewatering activities up to 400 m^3/day may qualify for a self-registration process on the Environmental Activity Sector Registry (“EASR”). A Category 3 Permit to Take Water (“PTTW”) is required where the proposed water taking is greater than 400 m^3/day. Based on the information collected in the hydrogeological investigation, temporary dewatering of groundwater inflow and direct precipitation into the excavations will be necessary to maintain suitable conditions for the period of construction.

It is recommended that a licensed, specialist dewatering subcontractor supervise the installation, operation and decommissioning of all dewatering systems for this project, in accordance with applicable legislation. The method of construction dewatering is to be solely determined by the Contractor based on their own assessment of the Site-specific conditions, and likely by their specialist dewatering contractor.

Golder has assumed that dewatering will be carried out as follows:

- The required dewatering level is no more than 1 m below the invert of the proposed excavations;
- A seasonal groundwater high of 1 m above measured groundwater height has been assumed;
- A number of different alternatives are being considered for the various crossings to accommodate the proposed Kennedy Road widening. Details of the proposed alternatives are discussed further in the corresponding geotechnical reports (Golder 2019a-f). For the purposes of construction dewatering, the below alternatives are being considered:
  - GO Rail Crossing at Austin Dr) – Crossing currently at grade. An underpass construction is assumed (carrying Kennedy Road under the existing GO rail line). It is assumed that the lowest point of the

depressed corridor of Kennedy Road would be at a maximum depth of 8 m below the existing ground surface (i.e., at about Elevation 167.6 m) and spread footings would extend an additional 1.4 m.

- Rouge River – The current bridge over Rouge River is on steel piles. It is currently assumed that a full replacement of the existing Rouge River bridge will be needed. Four excavations to a lowest Elevation of 167.0 m will be required.
- Tributary Crossing – The preferred culvert alternative is the full replacement of the structure, box culvert(s) are considered feasible culvert option supported on shallow foundation. Two pre-cast 1.8 m span box culverts are assumed for the assessment founded at an assumed elevation of 172.5 m.
- 407 ETR – It is assumed that there will be two separate AT bridges constructed (one on either side of the existing bridge) for pedestrians and cyclists. Shallow foundations are anticipated to be above the measured depth of groundwater. (Elevation 177.7).
- CN Rail Crossing– It is assumed that the single span bridge over Kennedy, currently on spread footings, will be replaced. Lowest excavation depths will reach an invert Elevation of 183.6 m.
- GO Rail Crossing at Clayton Dr. – Crossing is currently at grade. An underpass construction is assumed (carrying Kennedy Road under the existing GO Transit rail line). It is assumed that the lowest point of the depressed corridor of Kennedy Road would be at a maximum depth of 8 m below existing ground surface (i.e., at about Elevation 193.6 m) and spread footings would extend an additional 1.4 m.

- Surface water runoff will be directed away from any open excavation; and
- Groundwater should be pumped in a manner to prevent loss of ground.

The complete range of hydraulic conductivity estimates from both single well response test analyses and grain size analyses were considered for the purposes of construction dewatering calculations. A conservative hydraulic conductivity was assigned based on these results but was weighted towards the single well responses tests.

Temporary dewatering of groundwater inflow and direct precipitation into the excavations will be necessary to maintain suitable conditions for the period of construction. The following sections provide information relevant to the estimation of dewatering volumes. The method of construction dewatering is to be solely determined by the Contractor based on their own assessment of the Site-specific conditions, and likely by their specialist dewatering contractor. The dewatering system is the Contractor’s responsibility and the rate and volume required for dewatering is dependent on the construction methods and staging chosen by the contractor.

5.1 Required Water Table Lowering

Based on available information provided by HDR, Table 4 below provides a list of excavation structures potentially requiring construction dewatering. Based on the measured groundwater levels at monitoring wells installed near each structure, a dewatering elevation/height was calculated for each structure. In the case of the 407 ETR and CN Rail Crossing, all excavations were above the seasonal high groundwater level and therefore, do not require dewatering.

Table 4: Dewatering Dimensions

Structure	Number of Excavations	Length (m)	Width (m)	Depth (m)	Approx. Grade Elevation (m)	Water Level Elevation (m)	Dewatering Elevation (m)***	Dewatering Height (m) **
GO Rail Crossing at Austin Dr.	1	200+	20+	9.5	175.6	170.2	165.1	6.1
Rouge River	4	5	3.5	3.0	170.0*	168.3	166.0	3.3
Tributary Crossing	2	20	3.6	0.7	173.2*	170.3	No Dewatering Required	
407 ETR	8	10	3	8.0	188.5	177.7	No Dewatering Required	
CN Rail Crossing	4	10	4.6	3.5	187.1	176.5	No Dewatering Required	
GO Rail Crossing at Clayton Dr.	1	200+	20+	9.5	201.6	200.2	191.1	10.1

*Assumed natural grade
**A metre is added to the dewatering height to account for seasonal high groundwater levels
+ These dimensions were assumed since design information was not available.
*** The Dewatering Elevation is 1 m below the invert.

5.2 Hydraulic Radius of Influence

The groundwater dewatering radius of influence (ROI) represents the lateral extent of water table drawdown in response to temporary construction dewatering activities. The dewatering ROI (summarized in Table 5) for the proposed excavations was assessed based on an estimated using the empirical Sichart and Kyrieleis relationship discussed in Powers (2007) and the Theis analysis (Theis, 1941) for coarser material, using available subsurface information for the site.

Table 5: Dewatering Radius of Influence

Structure	Approximate Grade Elevation	Assumed Groundwater Elevation **	Assumed Excavation Invert Elevation	Water Table Lowering (1 m below invert)	Estimated Hydraulic Conductivity	Dewatering ZOI
	(masl)	(masl)	(masl)	(m)	(m/s)	(m)
GO Rail Crossing at Austin Dr.	175.6	171.2	166.1	165.1	2×10^{-6}	**35**

Structure	Approximate Grade Elevation	Assumed Groundwater Elevation **	Assumed Excavation Invert Elevation	Water Table Lowering (1 m below invert)	Estimated Hydraulic Conductivity	Dewatering ZOI
	(masl)	(masl)	(masl)	(m)	(m/s)	(m)
Rouge River	170.0*	169.3	167.0	166.0	1×10^{-4}	**140**
Tributary Crossing	173.2*	171.3	172.5	171.5	5×10^{-9}	**N/A**
407 ETR	188.5	178.7	180.5	179.5	4×10^{-8}	**N/A**
CN Rail Crossing	187.1	176.5	183.6	182.6	1×10^{-6}	**N/A**
GO Rail Crossing at Clayton Dr.	201.6	200.2	192.1	191.1	2×10^{-7}	**35**

*Assumed natural grade

**A metre is added to the measured groundwater level to account for seasonal high groundwater levels

5.3 Construction Dewatering Rate

5.3.1 Initial Groundwater Storage Removal

The initial storage volume is the quantity of water stored in the pore space of the overburden that must be removed from the area before dry conditions can be maintained in the excavation (i.e. to 1 m below the base of the excavation) using steady state flow/ pumping rates. The volume of water in storage comprises a significant amount of the initial pumping rate, therefore the pumping rate will decrease when the initial storage has been removed.

At the start of dewatering, higher pumping rates will be required to remove water stored within the excavation and within the interconnected pore spaces in the overburden material. The volume of storage (Vs) can be estimated as follows:

$$V_s = (H - h)n\ [LW + (\frac{1}{3}\pi R^2) + LR]$$

Where

V_s = volume of storage (m^3)

L = excavation length (m)

W = excavation width (m)

H-h = drawdown (m)

n = porosity (0.1)

R = radius of influence (m)

The total storage removal, assuming a 14-day removal time is summarized in Table 6.

5.3.2 Steady State Inflow

Estimated groundwater steady state inflow into the proposed excavations as estimated using the modified Jacob non-equilibrium equation (Cooper and Jacob, 1946) for flow to an equivalent well in an unconfined system:

$$Q = \frac{K\pi(H^2 - h^2)}{\ln\left(\frac{R_0}{r_s}\right)}$$

Where:

Q = Steady-state pumping rate required to maintain the groundwater elevation at the target level (m^3/day);

K = Hydraulic conductivity (m/day);

H = Static groundwater level height above aquifer base (m);

h = Dewatering groundwater level height above aquifer base (m);

r_s = Equivalent radius based on excavation geometry (m); and,

R_o = radius of influence (m), estimated using the empirical Sichart and Kyrieleis relationship (Powers, 2007) and the Theis analysis (Theis, 1941).

For long and narrow excavations, the following modified Jacob's equation was applied to estimate radial flow and flow to a trench from a line source, under unconfined *(eqn 1)* aquifer conditions for the GO Rail Crossing at Clayton Dr. and the GO Rail Crossing at Austin Dr. locations, the equation under confined conditions *(eqn 2)* was used.

$$Q = \frac{K\pi(H^2 - h^2)}{\ln\left(\frac{R_0}{r_s}\right)} + 2\frac{xK(H^2 - h^2)}{2L} \qquad (eqn\ 1)$$

$$Q = \frac{2\pi KB(H - h)}{\ln\left(\frac{R_0}{r_s}\right)} + 2\frac{xKB(H - h)}{L} \qquad (eqn 2)$$

Where:

Q = Steady-state pumping rate required to maintain the groundwater elevation at the target level (m^3/day);

K = Hydraulic conductivity (m/day);

H = Static groundwater level height above aquifer base (m);

H = Dewatering groundwater level height above aquifer base (m);

r_s = Equivalent radius based on excavation geometry (m);

R_o = radius of influence (m), estimated using the empirical Sichart and Kyrieleis relationship (Powers, 2007) and the Theis analysis (Theis, 1941);

x = the length of the trench (m);

L = Line source distance from the center of the trench (m); and,

B = Thickness of the aquifer (m).

The steady state inflow represents the daily pumping rate required for maintaining suitable working conditions after initial groundwater storage has been removed. The steady state dewatering rates are summarized in Table 6.

5.3.3 Incident Precipitation

In addition to groundwater inflows, the dewatering rate for all open excavations will need to consider removal of stormwater accumulation from direct precipitation. Direction precipitation volumes were estimated for a large precipitation event (i.e., a one in five year, 24-hour event) resulting in 64 mm of precipitation over the open excavation. Assuming the area is graded away from the excavation, an additional pumping capacity corresponding to direct precipitation on the excavation should be considered as part of the total dewatering rate from the removal of the storm water within 24 hours. Based on the above assumptions, incident precipitation dewatering rates were calculated for each excavation and are shown in Table 6.

5.3.4 Estimated Total Dewatering Rate

Based on the preceding assumptions, the removal of initial storage, steady state inflows and incident precipitation accumulation within each excavation under normal conditions (i.e. dry and/or typical rainfall intensities up to the 5-Year Return Period Event) are presented for the proposed excavations in Table 6. A factor of safety of 2 was applied to the steady state groundwater flow estimate.

Table 6: Dewatering Estimate Summary

Structure	ROI (m)	Steady State Ground water Flow (m^3/day)	Steady State with Factor of Safety (2)	Initial Storage (m^3/day)	Precipitat ion (m^3/day)	Total Per Excavation (m^3/day)	Number of Excavations	Total All Excavations (m^3/day)*
GO Rail Crossing at Austin Dr	35	45	90	580	256	926	1	926
Rouge River	140	149	289	508	1	797	4	3,188
Tributary Crossing	N/A	No Dewatering Required						
407 ETR	N/A	No Dewatering Required						
CN Rail Crossing	N/A	No Dewatering Required						
GO Rail Crossing at Clayton Dr.	35	90	180	713	256	1,149	1	1,149

* Note: Other design options may require lower construction dewatering rates or minimal to no dewatering. Case presented is for maximum invert depth option.

Total maximum construction dewatering rates were calculated to range between approximately 16 m^3/day to 3,188 m^3/day for the structures. It should be noted that this calculation is based on maximum observed conditions, and that subsurface conditions may change due to the amount of historical construction operations in the area of interest (conduits, etc.), and that dewatering volumes may be higher in some areas.

It is expected that the GO Rail Crossing at Austin Dr., Rouge River and GO Rail Crossing at Clayton Dr. crossings work will likely require a PTTW as the construction dewatering estimates for the three cases all exceed the threshold of 400 m^3/day or 400,000 L/day.

It should be noted that for the cases of the GO Rail Crossing at Austin Dr. and GO Rail Crossing at Clayton Dr., an overpass (carrying Kennedy road over the existing rail line) alternative and hybrid underpass/overpass (for the CN Rail crossing) alternative are also being considered for design alternatives. The overpass alternative would require shallower excavations for the overpass foundations that would likely be above, or just under, seasonal high groundwater elevations. This would likely result in minimal to no dewatering.

With regards to the hybrid overpass/underpass alternative proposed at GO Rail Crossing at Austin Dr., it is assumed that the road grade would be lowered about 4 m below existing grade to an Elevation of 171.6 m. Therefore, dewatering would be required; however, the dewatering rates would be less than the underpass alternative.

5.3.5 Estimated Long-Term Dewatering Rate

Following regrading and completion of construction, permanent dewatering will be required at the GO Rail Crossing at Austin Dr. and GO Rail Crossing at Clayton Dr. crossing underpasses. Therefore, a long-term dewatering strategy is required.

The table below summarizes the expected long-term groundwater seepage, based on this preliminary investigation and assumptions, that will require long term management. Recommendations for methods to manage long-term dewatering are discussed in Golder’s respective foundations report (Golder, 2019a and 2019f).

Table 7: Long-Term Dewatering Estimate Summary

Excavation	Steady State Groundwater Flow (m^3/day)*	Steady State with Factor of Safety (2)
GO Rail Crossing at Austin Dr.	45	90
GO Rail Crossing at Clayton Dr.	90	180

* Note: This assumes drainage is the same elevation assumptions as for construction

6.0 POTENTIAL IMPACTS

As described in Section 5.2, the dewatering zone of influence is expected to extend up to 35 m (GO Rail Crossing at Austin Dr./GO Rail Crossing at Clayton Dr.), or 140 m (Rouge River Crossing) from each dewatering source based on dewatering estimates. The following discusses potential impacts during construction dewatering.

6.1 Impacts to Groundwater Users

Based on the review of the MECP Water Well Information System (WWIS) database within a 500 m radius of the study area, summarized in section 3.6, there does not appear to be any water supply wells within the estimated zone of influence for dewatering activities. There are other water supply wells listed for domestic use are mapped in the MECP database within 500 m of the proposed excavations, but are generally outside of the zone of influence, and therefore, there are no potential impacts anticipated to these surrounding water wells.

6.2 Surface Water and Natural Environment Effects

There are two surface water bodies of interest crossing Kennedy Road including the Rouge River and the Rouge River Tributary. Upon review of the Ministry of Natural Resources and Forestry's (MNRF) online database, there are no provincially significant wetlands within the zone of influence of any of the crossings along Kennedy Road.

6.3 Geotechnical Considerations

The lowering of groundwater levels can induce ground settlements. At the proposed excavations, ground settlements associated with the dewatering activities should be reviewed at the detailed design stage.

7.0 RECOMMENDATIONS FOR INVESTIGATION AT DETAILED DESIGN

It is recommended that the construction dewatering, and long-term dewatering estimate calculations be revisited during the detailed design phase, when a design alternative is specified, in order to refine the dewatering estimates and update the impact assessment and permitting requirements. Further, geotechnical considerations such as settlement impacts should also be revisited based on revised dewatering estimates and zones of influence.

Additional hydrogeological investigations are recommended during the detailed design stage in particular for the GO Rail Crossing at Austin Dr. and GO Rail Crossing at Clayton Dr. if the underpass alternative is selected. The additional hydrogeological investigations are recommended to include:

- Further hydraulic testing at multiple well locations;
- Collection of additional water level measurements and groundwater sampling; and,
- Review of potential impacts to the natural environment and surface water features and detailed monitoring and mitigation plans.

8.0 CLOSURE

This Report was authored under a Subconsultant Agreement between HDR and Golder for the Regional Municipality of York's ("Owner") projects. The Report is provided to HDR and Regional Municipality of York for their use, utilizing their judgment, in fulfilling a portion of HDR's particular scope of work. No other party may rely upon this report, or any portion thereof, without Golder's express written consent and any reliance of the reports by others will be at that user's sole risk and liability, notwithstanding that they may have received this Report through an appropriate user. In addition, Golder shall not be liable for any use of the Report for any purpose other than that for which the same was originally prepared or provided by Golder, or any improper use of this Report, or to any party other than HDR.

We trust that this submission meets your current requirements. If you have any questions regarding the contents of this report, please contact the undersigned.

Signature Page

Golder Associates Ltd.

Amanda Malatesta M.Sc.	John Piersol M.Sc., P.Geo
Geoscientist	*Associate, Senior Hydrogeologist*

AM/JP/ll/mp;mes

https://golderassociates.sharepoint.com/sites/32372g/deliverables/hydrogeology report/3 - final report /rev 1/1664178 rep 2020'08'13 hdr class ea kennedy rd hydrog r1.docx

REFERENCES

Chapman, L.J., and Putnam, D.F. 1972. Map 2226 – Physiography of the south central portion of Southern Ontario in The physiography of Southern Ontario. 2nd ed. Toronto: Ontario Dept. of Mines and Northern Affairs.

Chapman, L.J., and Putnam, D.F. 1973. The physiography of Southern Ontario. 2nd ed. Toronto: University of Toronto Press. pp. 174-175, 276-280, 287-292.

Cooper, H.H. and C.E. Jacob, 1946. A generalized graphical method for evaluating formation constants and summarizing well field history, Am. Geophys. Union Trans., vol. 27, pp. 526-534.

Golder Associates Ltd., 2019a. DRAFT report titled Foundation Investigation and Preliminary Design Report., Kennedy Road and GO Transit Grade Separation, Class Environmental Assessment Study for Improvements to Kennedy Road from Steeles Avenue to major Mackenzie Drive, Markham, Ontario. Dated April 2019.

Golder Associates Ltd., 2019b. DRAFT report titled Foundation Investigation and Preliminary Design Report., Kennedy Road and Canadian National Rail Bridge (South), Class Environmental Assessment Study for Improvements to Kennedy Road from Steeles Avenue to major Mackenzie Drive, Markham, Ontario. Dated April 2019.

Golder Associates Ltd., 2019c. DRAFT report titled Foundation Investigation and Preliminary Design Report. Kennedy Road Overpass at Highway 407, Class Environmental Assessment Study for Improvements to Kennedy Road from Steeles Avenue to Major Mackenzie Drive, Markham, Ontario. Date April 2019.

Golder Associates Ltd., 2019d. DRAFT report titled Foundation Investigation and Preliminary Design Report. Kennedy Road and Rouge River Tributary Crossing, Class Environmental Assessment Study for Improvements to Kennedy Road from Steeles Avenue to major Mackenzie Drive, Markham, Ontario. Dated: April 2019

Golder Associates Ltd., 2019e. DRAFT report titled Foundation Investigation and Preliminary Design Report. Rouge River Bridge at Kennedy Road, Class Environmental Assessment Study for Improvements to Kennedy Road from Steeles Avenue to Major Mackenzie Drive, Markham, Ontario. Dated: April 2019.

Golder Associates Ltd., 2019f. DRAFT report titled Foundation Investigation and Preliminary Design Report. Kennedy Road and Canadian National Rail Crossing (North), Class Environmental Assessment Study for Improvements to Kennedy Road from Steeles Avenue to major Mackenzie Drive, Markham, Ontario. Dated: April 2019.

Toronto and Region Conservation Authority (TRCA), 2008: Rouge River Watershed Plan Towards a Healthy and Sustainable Future – Report of the Rouge Watershed Task Force 2007.

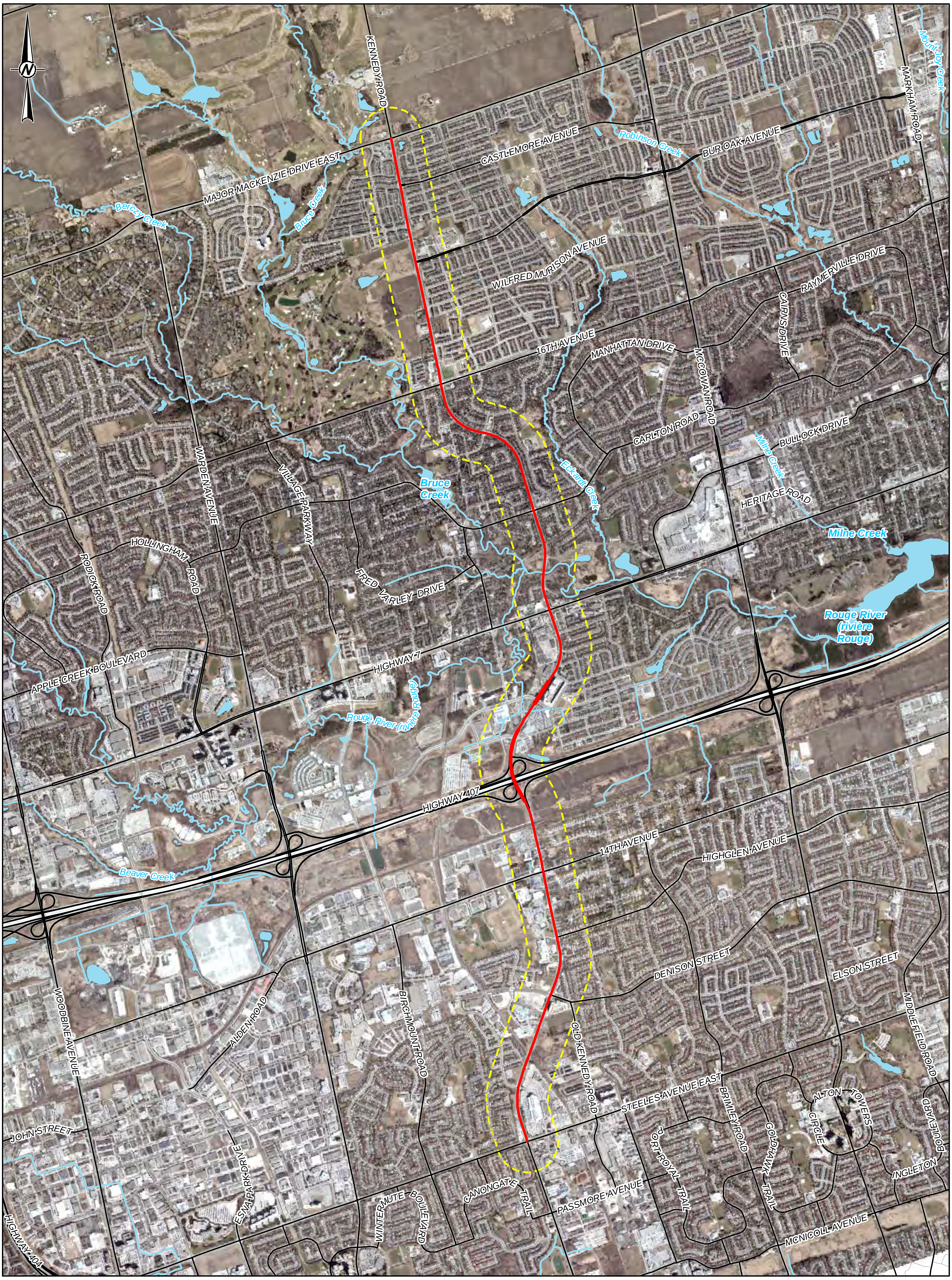
Ministry of Natural Resources (MNR), Land Information Ontario. 2010. Make a Map Tool. Retrieved from http://www.lio.ontario.ca/imf-ows/imf.jsp?site=makeamap_en on July 7, 2017.

Powers, J.P., Corwing, A.B., Schmall, P.C., Kaeck, W.E. 2007. Construction Dewatering and Groundwater Control: New Methods and Applications, 3rd Edition: Chapter 6 – Dewatering Design Using Analytical Methods. pp. 66-83.

Theis, C.V., 1941. The Effect of a Well on the Flow of a Nearby Stream. Transactions-American Geophysical Union, V.22, pt.3, pp. 734-738.

FIGURES

S:\Clients\Region_of_York\Kennedy_Road\99_PROJ\1664178_HDR\40_PROD\0002_Hydrogeology_Desktop_Study\1664178-0002-CH-0001.mxd



LEGEND

STUDY CORRIDOR

STUDY AREA

REFERENCE(S)

1. BASE DATA: MNRF LIO, OBTAINED 2016
2. IMAGERY: REGION OF YORK WMS, 2016
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

0 1,000 2,000

1:30,000 METRES

CLIENT

HDR CORPORATION

PROJECT

HYDROGEOLOGY DESKTOP STUDY
KENNEDY ROAD, STEELES AVENUE TO MAJOR MACKENZIE DRIVE
CITY OF MARKHAM, REGIONAL MUNICIPALITY OF YORK

TITLE

STUDY SITE

CONSULTANT

GOLDER

YYYY-MM-DD	2019-03-14
DESIGNED	JT
PREPARED	PR/JT
REVIEWED	AM
APPROVED	JP

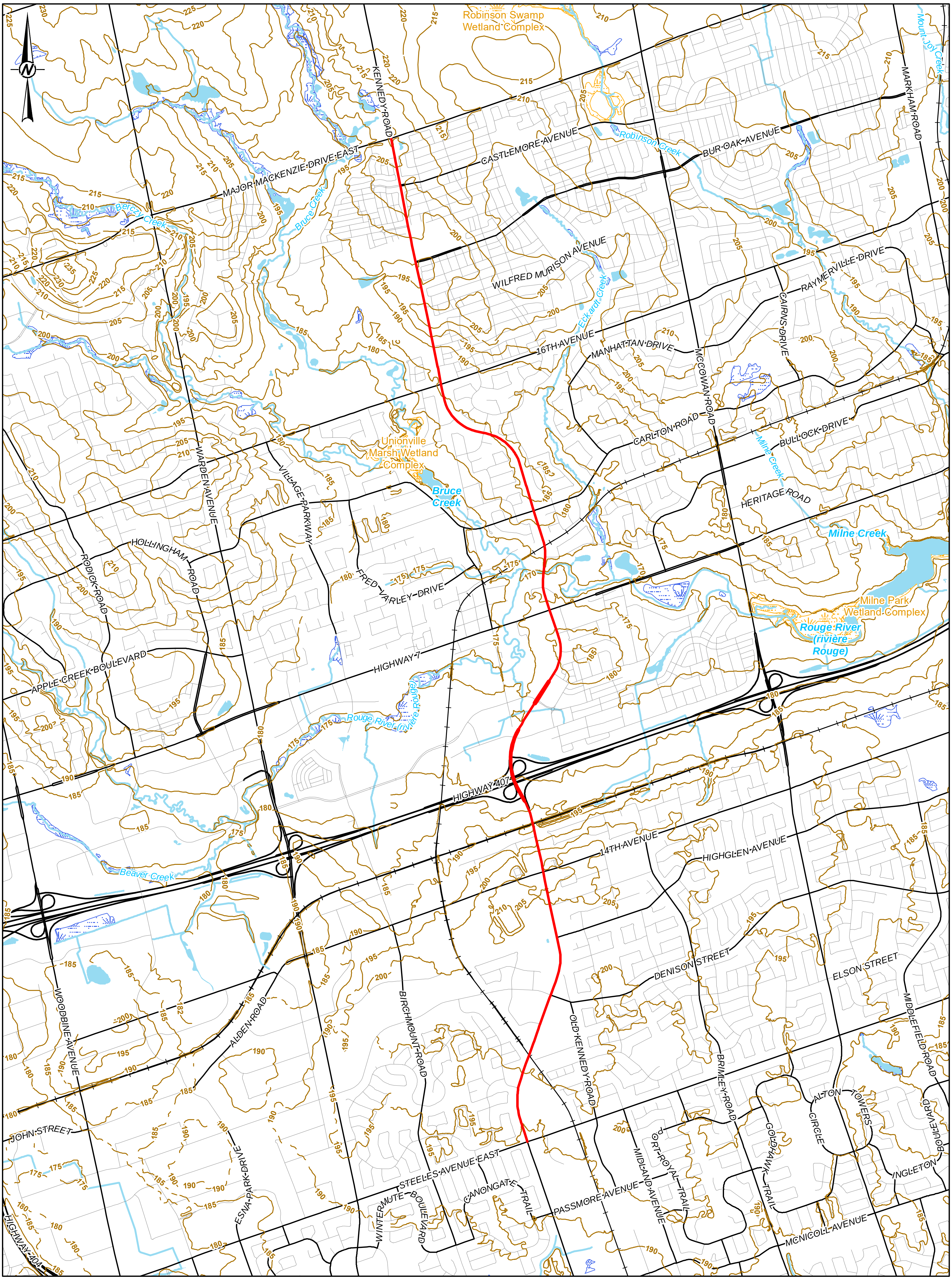
PROJECT NO.	CONTROL	REV.	FIGURE
1664178	0002	1	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

25mm

0

S:\Clients\Region_of_York\Kennedy_Road\99_PROJ\1664178_HDR\40_PROD\0002_Hydrogeology_Desktop_Study\1664178-0002-CH-0002.mxd



LEGEND

- STUDY CORRIDOR
- CONTOUR (5 M)
- RAILWAY
- ROAD
- WATERCOURSE
- WATERBODY
- NOT EVALUATED WETLAND
- PROVINCIALLY SIGNIFICANT WETLAND

REFERENCE(S)

1. BASE DATA: MNRF LIO, OBTAINED 2016
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

0 1,000 2,000

1:30,000 METRES

CLIENT
HDR CORPORATION

PROJECT
HYDROGEOLOGY DESKTOP STUDY
KENNEDY ROAD, STEELES AVENUE TO MAJOR MACKENZIE DRIVE
CITY OF MARKHAM, REGIONAL MUNICIPALITY OF YORK

TITLE
ELEVATION AND DRAINAGE

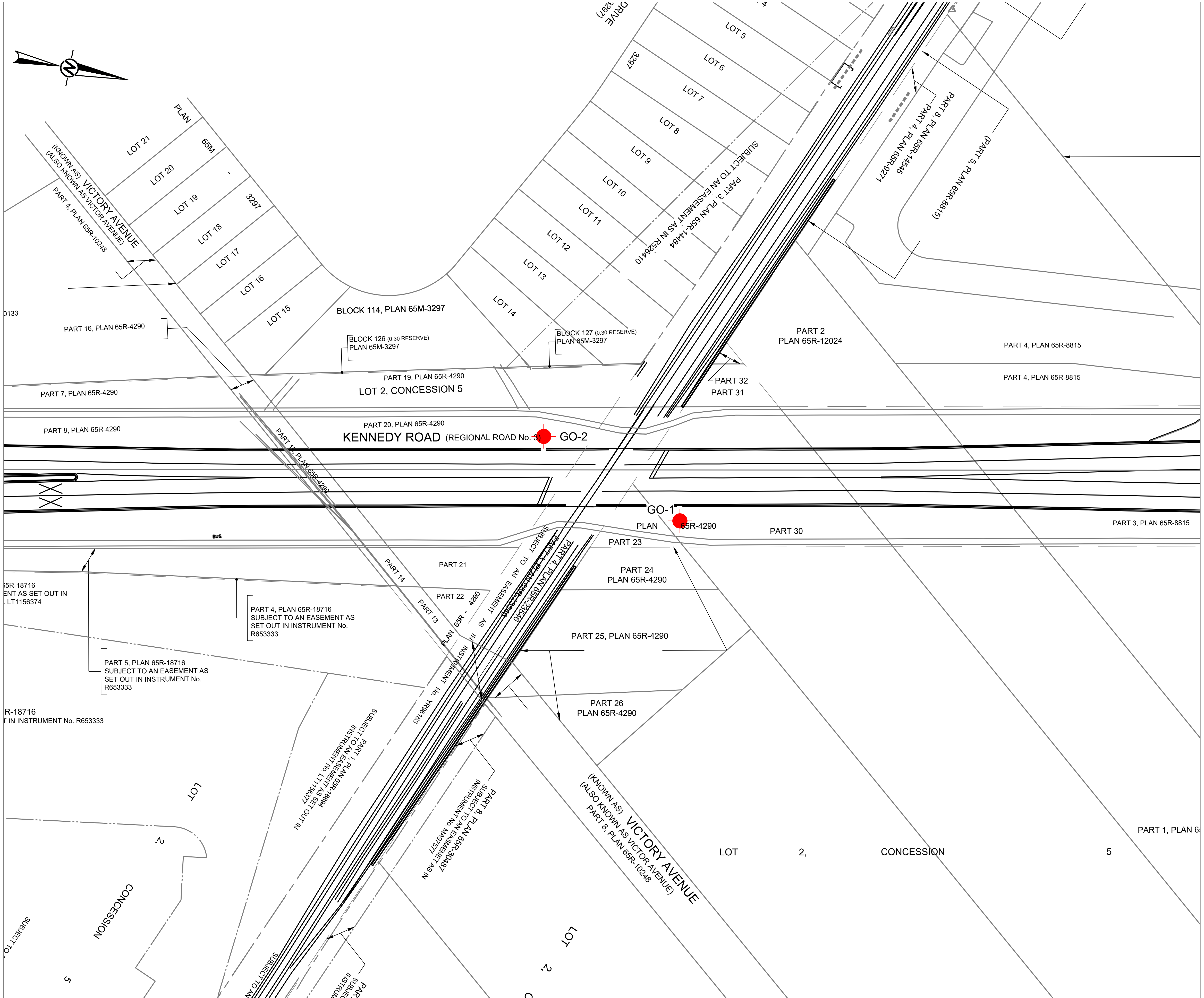
CONSULTANT

GOLDER

YYYY-MM-DD	2019-03-14
DESIGNED	JT
PREPARED	PR/JT
REVIEWED	AM
APPROVED	JP

PROJECT NO.	CONTROL	REV.	FIGURE
1664178	0002	1	2

25mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:



LEGEND

BOREHOLE LOCATION

0 25 50

1:1,000 METRES

REFERENCE(S)

BASE DATA PROVIDED BY HDR CORPORATION, THAM SURVEYING LIMITED ONTARIO LAND SURVEYORS, OBTAINED DECEMBER, 2018.

PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2018

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT

HDR INC.

PROJECT

KENNEDY ROAD AND GO TRANSIT GRADE SEPARATION
CLASS ENVIRONMENTAL ASSESSMENT STUDY FOR IMPROVEMENTS TO KENNEDY ROAD FROM STEELES AVENUE TO MAJOR MACKENZIE DRIVE, MARKHAM, ONTARIO

TITLE

BOREHOLE LOCATION PLAN

CONSULTANT

GOLDER

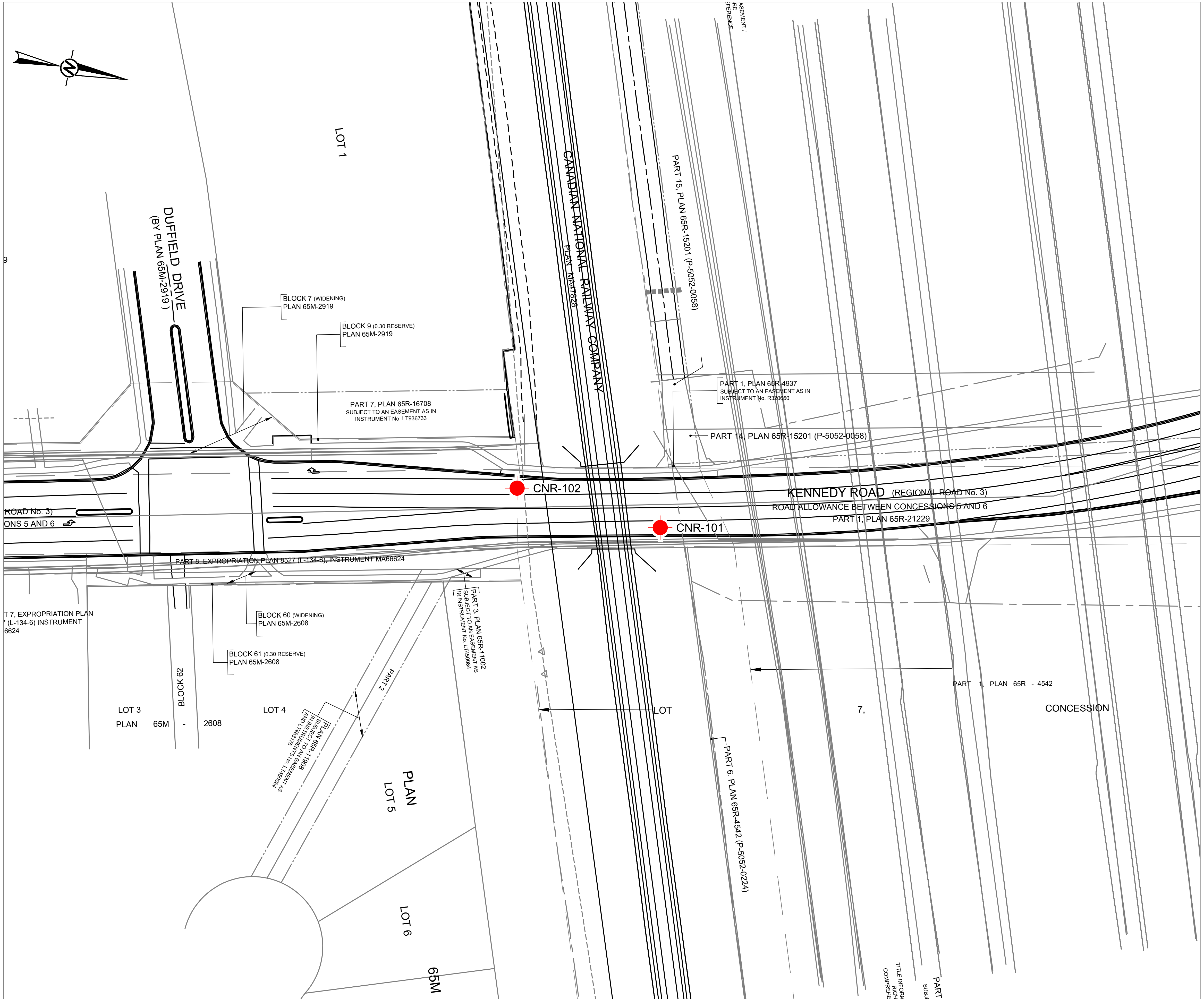
YYYY-MM-DD	2019-03-21
DESIGNED	
PREPARED	STB
REVIEWED	AMP
APPROVED	SEMP

PROJECT NO.	CONTROL	REV.	FIGURE
1664178 (2000)	0006	A	3A

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25 mm

Path: \\golder.gds\gal\mississauga\gis\Clients\Region_of_York\Kennedy_Road\99_PROJ\1664178_HDR\40_PROD\0006_GeotechFoundations\ | File Name: 1664178-0006-BG-0012.dwg | Last Edited By: sbowerman Date: 2019-03-21 Time:10:58:20 AM | Printed By: Sbowerman Date: 2019-03-21 Time:11:01:49 AM



LEGEND

BOREHOLE LOCATION

0 25 50

1:1,000 METRES

REFERENCE(S)

BASE DATA PROVIDED BY HDR CORPORATION, THAM SURVEYING LIMITED ONTARIO LAND SURVEYORS, OBTAINED DECEMBER, 2018.

PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2018

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT

HDR INC.

PROJECT

KENNEDY ROAD AND CANADIAN NATIONAL RAIL BRIDGE (SOUTH)
CLASS ENVIRONMENTAL ASSESSMENT STUDY FOR IMPROVEMENTS TO KENNEDY ROAD FROM STEELES AVENUE TO MAJOR MACKENZIE DRIVE, MARKHAM, ONTARIO

TITLE

BOREHOLE LOCATION PLAN

CONSULTANT

GOLDER

YYYY-MM-DD	2019-02-22
DESIGNED	
PREPARED	STB
REVIEWED	AMP
APPROVED	SEMP

PROJECT NO.	CONTROL	REV.	FIGURE
1664178 (2000)	0006	A	3B

LEGEND

BOREHOLE LOCATION

0 25 50

1:1,000 METRES

REFERENCE(S)

BASE DATA PROVIDED BY HDR CORPORATION, THAM SURVEYING LIMITED ONTARIO LAND SURVEYORS, OBTAINED DECEMBER, 2018.

PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2018

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT

HDR INC.

PROJECT

KENNEDY ROAD OVERPASS AT HIGHWAY 407

CLASS ENVIRONMENTAL ASSESSMENT STUDY FOR IMPROVEMENTS TO KENNEDY ROAD FROM STEELES AVENUE TO MAJOR MACKENZIE DRIVE, MARKHAM, ONTARIO

TITLE

BOREHOLE LOCATION PLAN

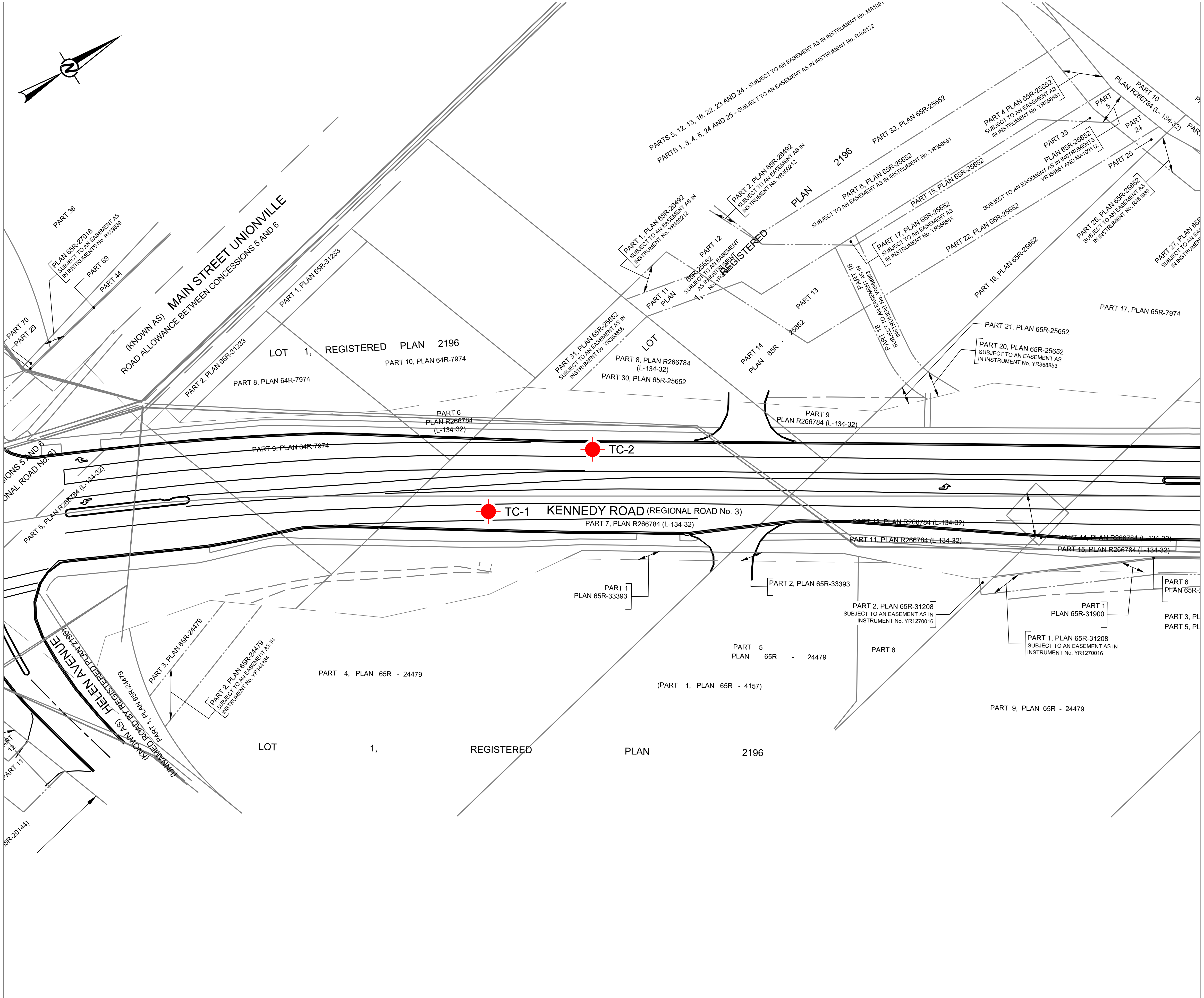
CONSULTANT

GOLDER

YYYY-MM-DD	2019-03-21
DESIGNED	
PREPARED	STB
REVIEWED	AMP
APPROVED	SEMP

PROJECT NO.	CONTROL	REV.	FIGURE
1664178 (2000)	0006	A	3C

25 mm IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



LEGEND

BOREHOLE LOCATION

0 25 50

1:1,000 METRES

REFERENCE(S)

BASE DATA PROVIDED BY HDR CORPORATION, THAM SURVEYING LIMITED ONTARIO LAND SURVEYORS, OBTAINED DECEMBER, 2018.

PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2018

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT
HDR INC.

PROJECT
KENNEDY ROAD AT TRIBUTARY CROSSING
CLASS ENVIRONMENTAL ASSESSMENT STUDY FOR IMPROVEMENTS TO KENNEDY ROAD FROM STEELES AVENUE TO MAJOR MACKENZIE DRIVE, MARKHAM, ONTARIO

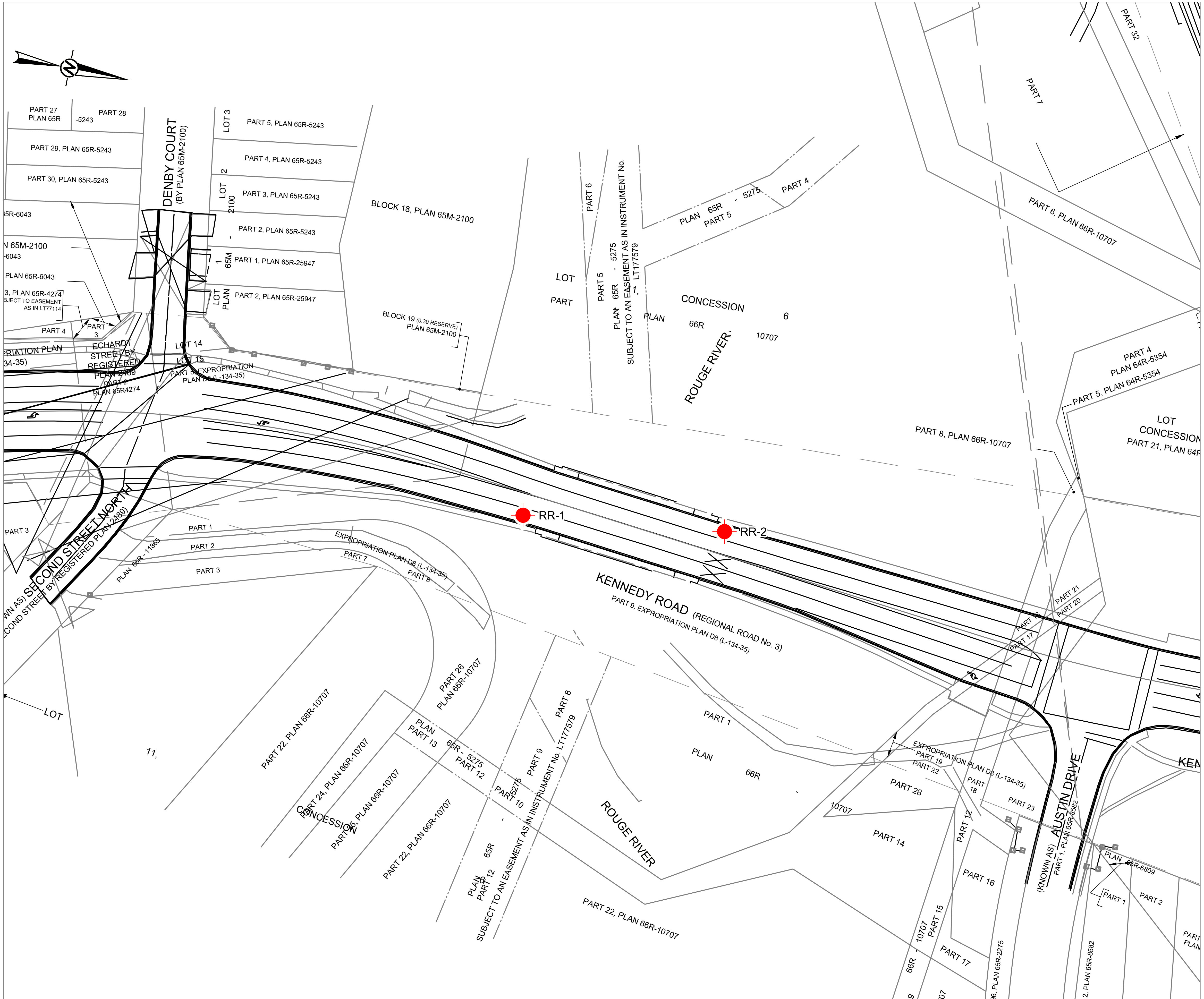
TITLE
BOREHOLE LOCATION PLAN

CONSULTANT

GOLDER

YYYY-MM-DD	2019-03-21
DESIGNED	
PREPARED	STB
REVIEWED	AMP
APPROVED	SEMP

PROJECT NO.	CONTROL	REV.	FIGURE
1664178 (2000)	0006	A	3D



LEGEND

BOREHOLE LOCATION

0 25 50

1:1,000 METRES

REFERENCE(S)

BASE DATA PROVIDED BY HDR CORPORATION, THAM SURVEYING LIMITED ONTARIO LAND SURVEYORS, OBTAINED DECEMBER, 2018.

PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2018

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT

HDR INC.

PROJECT

KENNEDY ROAD CROSSING ROUGE RIVER
CLASS ENVIRONMENTAL ASSESSMENT STUDY FOR IMPROVEMENTS TO KENNEDY ROAD FROM STEELES AVENUE TO MAJOR MACKENZIE DRIVE, MARKHAM, ONTARIO

TITLE

BOREHOLE LOCATION PLAN

CONSULTANT

GOLDER

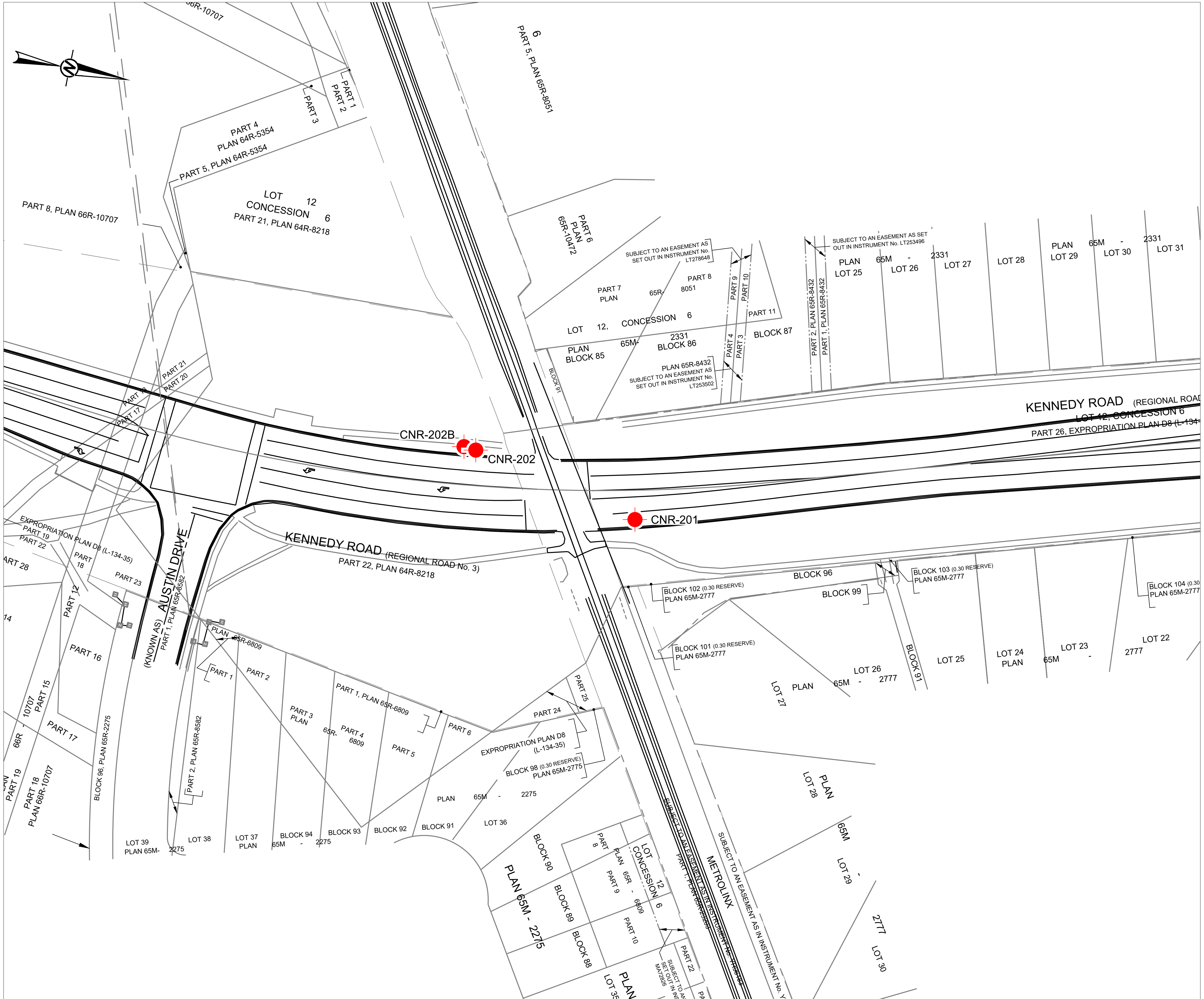
YYYY-MM-DD	2019-03-21
DESIGNED	
PREPARED	STB
REVIEWED	AMP
APPROVED	SEMP

PROJECT NO.	CONTROL	REV.	FIGURE
1664178 (2000)	0006	A	3E

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25 mm

Path: \\golder.gds\gal\mississauga\sim\Clients\Region_of_York\Kennedy_Road\99_PROJ\1664178_HDR\40_PROD\0006_GeotechFoundations\ | File Name: 1664178-0006-BG-0004.dwg | Last Edited By: sbowerman Date: 2019-03-21 Time:9:22:35 AM | Printed By: Sbowerman Date: 2019-03-21 Time:9:25:36 AM



LEGEND

BOREHOLE LOCATION

0 25 50

1:1,000 METRES

REFERENCE(S)

BASE DATA PROVIDED BY HDR CORPORATION, THAM SURVEYING LIMITED ONTARIO LAND SURVEYORS, OBTAINED DECEMBER, 2018.

PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENSE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2018

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT

HDR INC.

PROJECT

KENNEDY ROAD CROSSING CANADIAN NATIONAL RAIL (NORTH)
CLASS ENVIRONMENTAL ASSESSMENT STUDY FOR IMPROVEMENTS TO KENNEDY ROAD FROM STEELES AVENUE TO MAJOR MACKENZIE DRIVE, MARKHAM, ONTARIO

TITLE

BOREHOLE LOCATION PLAN

CONSULTANT

GOLDER

YYYY-MM-DD	2019-03-21
DESIGNED	
PREPARED	STB
REVIEWED	AMP
APPROVED	SEMP

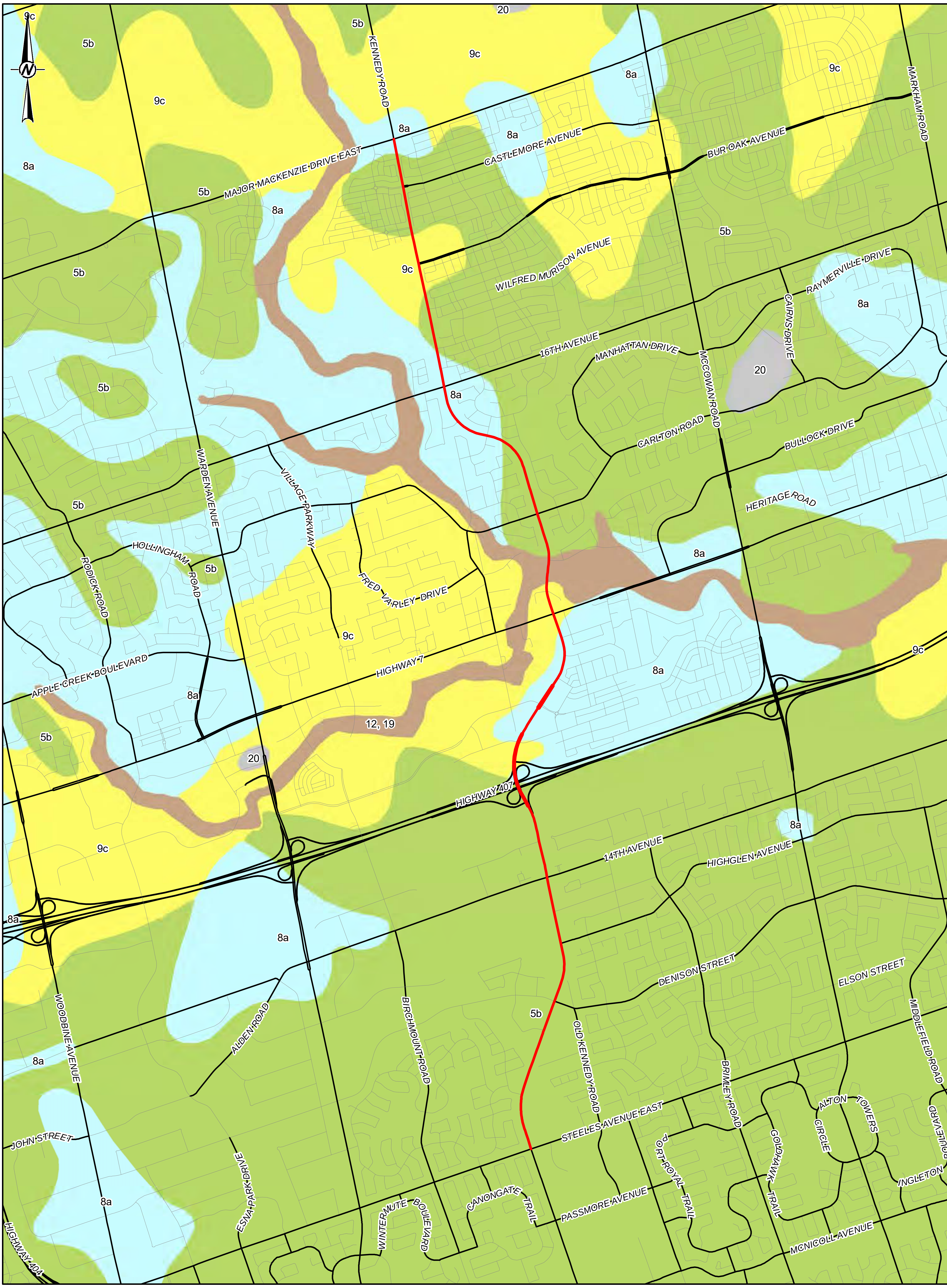
PROJECT NO.	CONTROL	REV.	FIGURE
1664178 (2000)	0006	A	3F

25 mm

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

Path: \\golder.gds\gal\mississauga\gis\Clients\Region_of_York\Kennedy_Road\99_PROJ\1664178_HDR\40_PROD\0006_GeotechFoundations\ | File Name: 1664178-0006-BG-0002.dwg | Last Edited By: sbowerman Date: 2019-03-19 Time:3:04:28 PM | Printed By: Sbowerman Date: 2019-03-21 Time:9:24:35 AM

S:\Clients\Region_of_York\Kennedy_Road\99_PROJ\1664178_HDR\40_PROD\0002_Hydrogeology_Desktop_Study\1664178-0002-CH-0003.mxd



LEGEND

- STUDY CORRIDOR
- 5B: STONE-POOR, CARBONATE-DERIVED SILTY TO SANDY TILL
- 8A: MASSIVE WELL-LAMINATED
- 9C: FORESHORE-BASINAL DEPOSITS
- 19: MODERN ALLUVIAL DEPOSITS
- 20: ORGANIC DEPOSITS

REFERENCE(S)

1. BASE DATA: MNRF LIO, OBTAINED 2016
2. SURFICIAL GEOLOGY: ONTARIO GEOLOGICAL SURV EY 2010. SURFICIAL GEOLOGY OF SOUTHERN ONTARIO; ONTARIO GEOLOGICAL SURV EY, MISCELLANEOUS RELEASE--DATA 128.
3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

0 1,000 2,000

1:30,000 METRES

CLIENT
HDR CORPORATION

PROJECT
HYDROGEOLOGY DESKTOP STUDY
KENNEDY ROAD, STEELES AVENUE TO MAJOR MACKENZIE DRIVE
CITY OF MARKHAM, REGIONAL MUNICIPALITY OF YORK

TITLE
SURFICIAL GEOLOGY

CONSULTANT

GOLDER

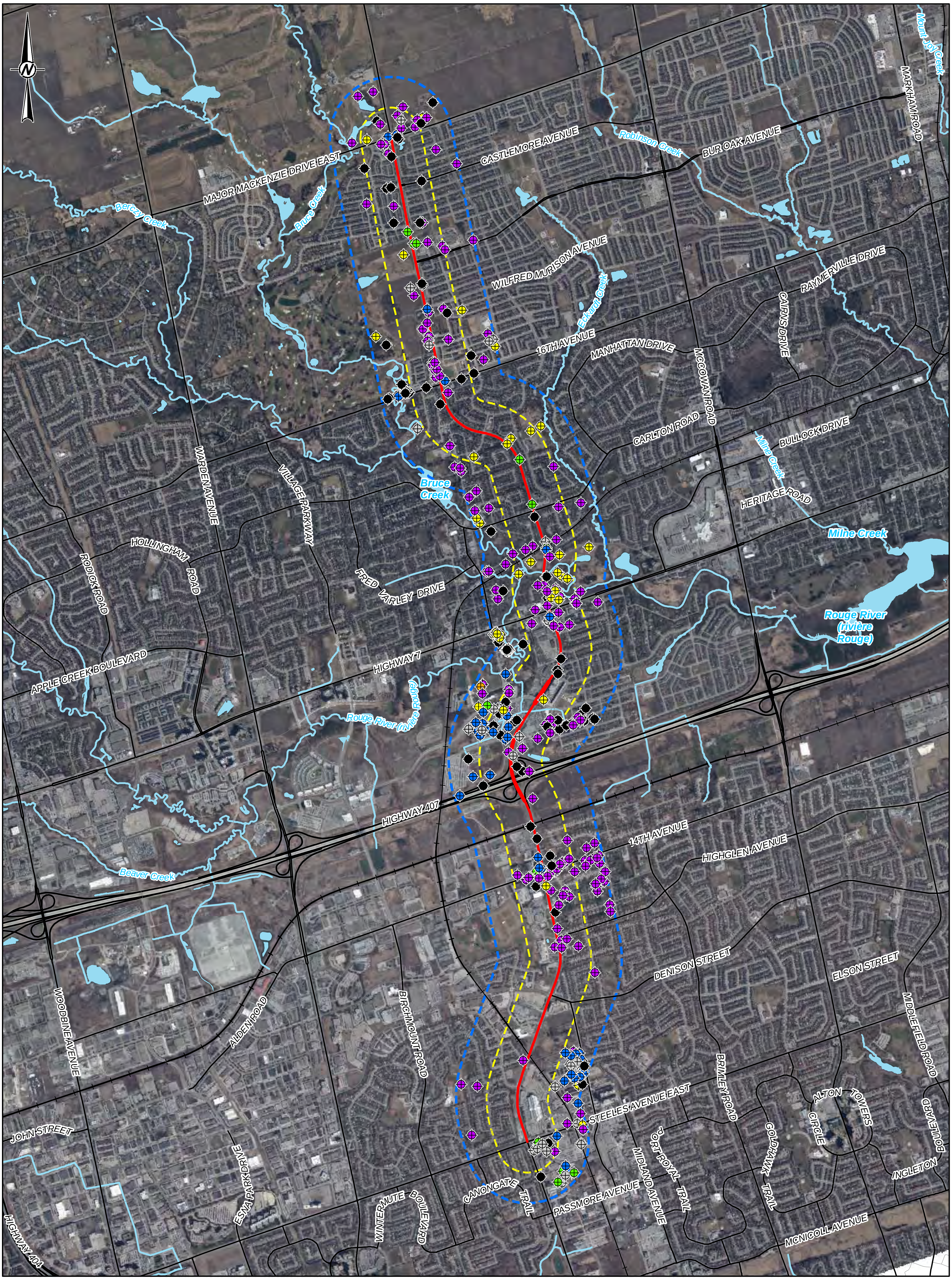
YYYY-MM-DD	2019-03-14
DESIGNED	JT
PREPARED	PR/JT
REVIEWED	AM
APPROVED	JP

PROJECT NO.	CONTROL	REV.	FIGURE
1664178	0002	1	4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

25mm

S:\Clients\Region_of_York\Kennedy_Road\99_PROJ\1664178_HDR\40_PROD\0002_Hydrogeology_Desktop_Study\1664178-0002-CH-0004.mxd



LEGEND

MOECC WATER WELL USE

- ABANDONED
- DEWATERING
- MONITORING AND TEST HOLE
- NOT IDENTIFIED
- OBSERVATION WELLS
- TEST HOLE
- WATER SUPPLY

- STUDY CORRIDOR
- RAILWAY
- WATERCOURSE
- WATERBODY
- BUFFER (500 M)

REFERENCE(S)

1. BASE DATA: MNRF LIO, OBTAINED 2016
2. MOECC WATER WELLS: WWIS MOECC, 2017
3. IMAGERY: REGION OF YORK WMS, 2016
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

0 1,000 2,000

1:30,000 METRES

CLIENT
HDR CORPORATION

PROJECT
HYDROGEOLOGY DESKTOP STUDY
KENNEDY ROAD, STEELES AVENUE TO MAJOR MACKENZIE DRIVE
CITY OF MARKHAM, REGIONAL MUNICIPALITY OF YORK

TITLE
MOECC WATER WELLS

CONSULTANT

GOLDER

YYYY-MM-DD	2019-03-14
DESIGNED	JT
PREPARED	PR/JT
REVIEWED	AM
APPROVED	JP

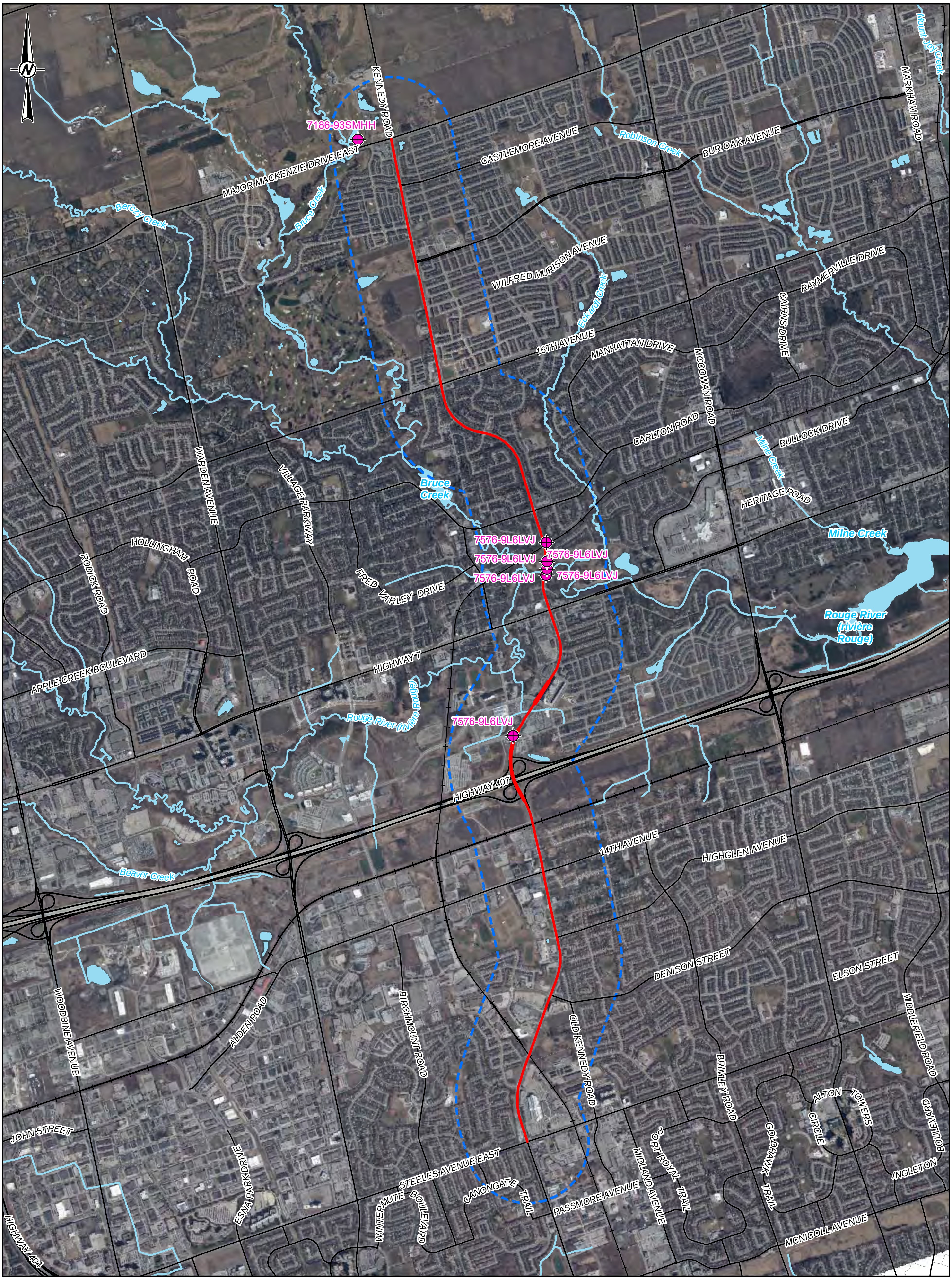
PROJECT NO.	CONTROL	REV.	FIGURE
1664178	0002	1	5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

25mm

0

S:\Clients\Region_of_York\Kennedy_Road\99_PROJ\1664178_HDR\40_PROD\0002_Hydrogeology_Desktop_Study\1664178-0002-CH-0005.mxd



LEGEND

- PERMIT TO TAKE WATER
- STUDY CORRIDOR
- RAILWAY
- WATERCOURSE
- WATERBODY
- BUFFER (500 M)

REFERENCE(S)

1. BASE DATA: MNRF LIO, OBTAINED 2016
2. MOECC PERMIT TO TAKE WATER LOCATIONS, MOECC 2017
3. IMAGERY: REGION OF YORK WMS, 2016
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

0 1,000 2,000

1:30,000 METRES

CLIENT
HDR CORPORATION

PROJECT
HYDROGEOLOGY DESKTOP STUDY
KENNEDY ROAD, STEELES AVENUE TO MAJOR MACKENZIE DRIVE
CITY OF MARKHAM, REGIONAL MUNICIPALITY OF YORK

TITLE
MOECC PERMITS TO TAKE WATER (PTTW)

CONSULTANT

GOLDER

YYYY-MM-DD	2019-03-14
DESIGNED	JT
PREPARED	PR/JT
REVIEWED	AM
APPROVED	JP

PROJECT NO.	CONTROL	REV.	FIGURE
1664178	0002	1	6

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:

25mm

0