Kirby Road Widening Environmental Assessment (Jane Street to Dufferin Street)

Fluvial Geomorphological Assessment
Don River West Branch and East Humber River

Prepared for:
City of Vaughan
c/o HDR Inc.
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January 10, 2020 (Updated September 15, 2021)
PN19109

GEO MORPHIX
Geomorphology
Earth Science
Observations

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Appendices

1 Introduction

The City of Vaughan is undertaking Phases 3 and 4 of the Schedule C Municipal Class Environmental Assessment (EA) Study for the widening of Kirby Road between Jane Street and Dufferin Street from two lanes to four lanes, with active transportation facilities, the grade separation of the Barrie GO Rail Line at Kirby Road, and design of the intersection of Kirby Road and Jane Street. It is understood that the North Vaughan and New Communities Transportation Master Plan (NVNCTMP) satisfied Phases 1 and 2 of the Class EA process. Phases 3 and 4 are to develop a range of alternative design concepts for the preferred solution, identify impacts and mitigation measures, evaluate alternative concepts based on criteria established through the EA process, and identify the preferred design alternative.

GEO Morphix Ltd. has been retained as part of a multi-disciplinary team to provide fluvial geomorphological support to the Class EA process being led by the City of Vaughan and HDR Inc. Two regulated watercourse crossings were identified as part of this study and are within the jurisdiction of Toronto and Region Conservation Authority (TRCA):

- One tributary of the East Humber River crossing Kirby Road (Crossing 1), west of Jane Street
- One tributary of the Don River West Branch crossing Kirby Road (Crossing 2)

The activities listed below were completed in support of the fluvial geomorphological assessment:

- Review available background reports and mapping (e.g., soils, physiography, geology, and topography)
- Complete a historical assessment using aerial photographs to identify changes to the system due to land use and past channel modifications
- Delineate meander belt widths within the Kirby Road right-of-way (ROW)
- Conduct rapid geomorphological field assessments for portions of accessible channel upstream and downstream of each watercourse crossing to document channel conditions and verify the desktop assessment
- Provide recommendations regarding crossing structure spans and enhancements to be refined during subsequent design stages

2 Study Site History

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use/cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics. Aerial photographs from the National Air Photo Library (NAPL) for 1946 (scale 1:20,000) and from the York Region online interactive mapping tool specifically for the years 1978, 1999, 2009, 2014, and 2019 were reviewed to complete the historical assessment. Refer to **Appendix A** for copies of the imagery.

In 1946, the predominant land use was agricultural with a few rural residential homes along Kirby Road. The rail line west of Keele Street was present prior to 1946. All features upstream and downstream of both crossings flowed through agricultural fields with no observerable riparian zone. A swale feature was apparent downstream of both crossings. Upstream of both crossings, only depressional features were apparent through the agricultural fields. Due to the size and nature of the reaches at both crossings, other channel features were not discernable for all the aerial images assessed.

The overall land use remained agricultural by 1978. Highway 400 had since been built to the west of the study site. The upstream section of Crossing 1 appeared to have been straightened for agricultural proposes. No other changes were noted.

Between 1978 and 1999, the overall land use remained agricultural. However, east of Keele Street and south of Kirby Road, two residential blocks were in the process of development. South of Crossing 2, a weather station was built just to the east of the reach. More importantly, Kirby Road east of Keele Street was being reconstructed from Keele Street to Dufferin Road.

At Crossing 1, a swale feature was apparent both upstream and downstream of the crossing. Both reaches had grassy riparian zones; however, the upstream reach had a wider riparian buffer. At Crossing 2, both reaches consisted of poorly defined swales through agricultural fields with no riparian buffer. The downstream reach was less apparent in the aerial image than the upstream reach.

By 2009, there were no changes to the overall land use. A small golf course had been built along the West Don River Tributary further upstream of Crossing 2. The features immediately upstream and downstream of each road crossing had remained consistent when 1999 and 2009 images were compared

Between 2009 and 2019, land use remained mostly agricultural. However, industrial buildings had been built at the northwest corner of Keele Street and Kirby Road in vicinity of a tributary of the Don River West Branch. The industrial buildings did not appear to result in the removal of any riparian vegetation or require realignment of the adjacent tributary. Also, the weather station south of Crossing 2 was removed during this time. Upstream of Crossing 1, more trees were noted within the riparian zone, likely improving local channel conditions by providing shade and coarse particulate organic matter to the channel. The remainder of the reaches have remained similar since 2009.

3 Watershed-Scale Characteristics

3.1 Geology and Physiography

Geology and physiography act as constraints to channel development and tendency. These factors determine the nature and quantity of the availability and type of sediment. Secondary variables that affect the channel include land use and riparian vegetation. These factors are explored as they not only offer insight into existing conditions, but also potential changes that could be expected in the future as they relate to a proposed activity.

The surficial geology surrounding both crossings consists of clay to silt textured till (OGS, 2010). Approximately 1 km east of Keele Street, the surficial geology changed to an ice-contact stratified deposit consisting of sand and gravel with minor silt, clay, and till (OGS, 2010). The till and ice-contact stratified deposit are separated with an ice-contact slope (OGS, 2010). This was apparent in the topography during field reconnaissance. This ice-contact slope marks the start of the Oak Ridges Moraine (ORM).

All of the watercourses delineated for the purpose of this study flow through the clay to silt textured till. No exposed till was encountered during field reconnaissance. Refer to **Section 5.1** for reach delineation information and **Section 5.1.1** for watercourse descriptions.

The study area is situated in the South Slope physiographic region. The South Slope originates from the southern flank of the ORM and extends south to the Peel Plain. The soils contain a high clay soil content underlain by glacial till, both impeding water infiltration. Unlike the ORM, the

South Slope was not hummocky, and runoff is generally relatively high while infiltration is generally relatively low (TRCA, 2008b).

4 Drainage Basin Characteristics

There are two watersheds located within the study area: the Humber River and the Don River. Specifically, the tributary west of Jane Street (Crossing 1) is within the East Humber River subwatershed and the tributary between Jane Street and Keele Street (Crossing 2) is within the West Don River subwatershed.

4.1 East Humber River

The East Humber River originates within the ORM, the northern boundary of the Humber River watershed, and extends over 60 km south to the Lower Humber River in Woodbridge, Ontario (TRCA, 2008a and 2008b). Land use is predominantly agricultural with settlements such as Oak Ridges, King City, Nobleton, and portions of Woodbridge. The East Humber River has the least amount of green space (approximately 6%) due to agricultural land use and limited public lands (TRCA, 2008a). The East Humber subwatershed has experienced high rates of urbanization over the last few decades and will continue to develop for the foreseeable future. The East Humber subwatershed contributes approximately 20% of the base flow to the Humber River watershed (TRCA, 2008a).

4.2 West Don River

The Don River covers approximately 36, 000 ha from the ORM to Lake Ontario (TRCA, 2009). The study area was within the north west extent of the Upper West Don subwatershed. The Upper West Don and the Don River watershed overall, are extensively urbanized. However, the study site was in a small rural area and one of the few locations within the Greenbelt Boundary. The Upper West Don contributes approximately 11% of overall baseflow to the Don River (TRCA, 2009).

5 Watercourse Characteristics

5.1 Reach Delineation

Reaches are homogeneous segments of channel used in geomorphological investigations. Reaches are studied semi-independently as each is expected to function in a manner that is at least slightly different from adjoining reaches. This method allows for a meaningful characterization of a watercourse as the aggregate of reaches, or an understanding of a reach, for example, as it relates to a proposed activity.

Reaches are typically delineated based on changes in the following:

- Channel planform
- Channel gradient
- Physiography
- Land cover (land use or vegetation)
- Flow, due to tributary inputs
- Soil type and surficial geology
- Historical channel modifications

Reaches are delineated following scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards et al. (1997), and the Toronto and Region Conservation Authority (2004).

Crossing 1 was located approximately 250 m west of Jane Street. Since Crossing 1 may be impacted by the realignment of the Kirby Road and Jane Street intersection a field assessment was completed. The tributary at Crossing 1 was divided into two reaches, Reach **HT2-1** downstream and Reach **HT2-2** upstream of Kirby Road.

The tributary of the West Don River was divided into five reaches and crossed both Kirby Road and Keele Street. From downstream to upstream the reaches were delineated as **WDT1-1** (downstream of Kirby Road), **WDT1-2** (upstream of Kirby Road), **WDT1-3**, **WDT1-4** (downstream of Keele Street), and **WDT1-5** (upstream of Keele Street). Reaches **WDT1-1** and **WDT1-2** were assessed at Crossing 2. Reach delineation is provided in **Appendix B**.

For this study, the full length of each reach was not verified due to site access limitations. Each reach was assessed within the road ROW. However, it was deemed unnecessary to obtain further access as the tributaries consisted of swale features with limited erosion.

5.1.1 General Reach Observations

Field investigations were completed within the ROWs on November 28, 2019 and included the following:

- Descriptions of riparian conditions
- Estimates of bankfull channel dimensions
- Bed and bank material composition and structure
- Observations of erosion, scour, or deposition
- Collection of photographs to document the overall observations

These observations and measurements are summarized below. The descriptions are supplemented and supported with representative photographs, which are included in **Appendix C**. Reach characteristics field sheets are provided in **Appendix D**. The Rapid Geomorphological Assessment (RGA; MOE, 2003) and the Rapid Stream Assessment Technique (RSAT; Galli, 1996) were not applicable due to the poorly defined nature of the features.

Humber River Tributaries

Reach **HT2-1** extended downstream (south) of Kirby Road through an agricultural field. The reach was unconfined with a low gradient. The riparian vegetation consisted of grasses and was continuous but narrow. Although bankfull indicators were generally absent, a low flow channel within the wider swale feature was observed at the fence line. The width and depth of the low flow channel were 0.4 m and 0.15 m, respectively. The swale was extensively encroached with grasses and no erosion was observed. The feature was dry at the time of assessment. The crossing consisted of a Corrugated Steel Pipe (CSP) with a diameter of 2.0 m and was stable at the time of assessment.

Reach **HT2-2** extended upstream (north) of Kirby Road through an agricultural field. The reach was unconfined with a low to moderate gradient. The reach appeared moderately entrenched upstream of the ROW, but no erosion was observed. The riparian buffer zone consisted of grasses with scattered trees that formed a continuous buffer. Grasses heavily encroached the reach. Similar to upstream, a low flow channel was observed within the wider swale feature. The width and depth of the low flow channel were 0.35 m and 0.10 m, respectively. The feature was dry at the time of assessment, however standing water was noted within the CSP.

West Don River Tributary

Reach **WDT1-1** extended downstream (south) of Kirby Road. There was no defined feature (no swale or flow path) apparent through the agricultural field. There was also no riparian vegetation. The feature was dry at the time of assessment. The crossing consisted of double CSPs with a diameter of 0.6 m and was stable at the time of assessment.

Reach **WDT1-2** extended upstream (north) of Kirby Road. A defined feature was only apparent for a few metres between Kirby Road and the edge of the agricultural field. The defined feature within the ROW had a width of 0.8 m and a depth of 0.25 m. There was no defined feature upstream through the agricultural field, however a shallow depression was observed from a distance through the agricultural field. There was also no riparian vegetation through the ploughed agricultural field. The feature was dry at the time of assessment.

6 Meander Belt Width Delineation

Most watercourses in southern Ontario have a natural tendency to develop and maintain a meandering planform, provided there are no spatial constraints. A meander belt width, or erosion hazard assessment, estimates the lateral extent that a meandering channel has historically occupied and will likely occupy in the future. This assessment is therefore useful for determining, for example, the potential limit of an activity (e.g., development) adjacent to a watercourse or the floodplain width required to restore a stream.

Since the watercourses are heavily vegetated swales with limited drainage area, they do not have the force to form a meandering channel. Therefore, these watercourses do not have a true erosion hazard. For the purpose of this study, a theoretical meander belt width is provided for context. However, these theoretical meander belt widths should be considered conservative and for reference purposes only.

Due to the size and nature of the watercourses, meander amplitudes could not be measured using the historical aerials. A modelling approach is used where the channel cannot be measured using aerials or when the channel has been previously modified. These models are scientifically defensible and have been verified in past projects as suitable for use in southern Ontario. Theoretical meander belt widths at both crossings were calculated using a suite of empirical models, with a summary of the results outlined in **Table 1**.

The empirical relations from Williams (1986) were modified to include channel area and width, and applied using the bankfull channel dimensions such that:

$$B_w = 18A^{0.65} + W_b \quad \text{[Eq. 1]}$$

$$B_w = 4.3{W_b}^{1.12} + W_b \quad \text{[Eq. 2]}$$

where *Bw* is meander belt width (m), *A* is bankfull cross-sectional area (m^2), and *Wb* is bankfull channel width (m). An additional 20% buffer, or factor of safety, was applied to the computed belt width values. This addresses issues of under prediction and provides a factor of safety.

The Ward et al. (2002) model was also used to estimate belt widths using a modified approach that incorporates bankfull channel width, such that:

$$B_w = 6{W_b}^{1.12} \quad \text{[Eq. 3]}$$

where *Bw* is meander belt width (ft) and *Wb* is bankfull channel width (ft). An additional 20% buffer, or factor of safety, was applied to the computed values. The bankfull channel dimensions observed during field reconnaissance were used to inform both the Williams (1986) and Ward (2002) models.

Table 1 below provides theoretical meander belt widths. Given the type and size of the features, there is no "true" erosion hazard associated with these features. In addition, little to no erosion was observed during the completion of field investigations. It should be noted that these theoretical meander belt widths should only be considered within the road allowance.

Table 1: Modelled theoretical meander belt widths for Humber River and West Don River tributaries

Crossing No.	Reach	Theoretical Meander Belt Width (m)		
		*Williams – Area (1986)	*Williams – Width (1986)	*Ward et al. – Width (2002)
1	HT2-1	4	2	3
	HT2-2	3	2	3
2	WDT1-1	No defined channel		
	WDT1-2	9	5	7

* Includes a 20% factor of safety

7 Crossing Recommendations

Crossings can have significant impacts on valley and stream corridors. Rivers and streams are dynamic systems and can easily migrate across their floodplains over time, impacting crossing infrastructure. Therefore, it is important to recognize and account for natural hazards in association with watercourse crossings. The assessment outlined herein is based on the guidance and recommendations outlined by the Toronto Region Conservation Authority (TRCA) Crossings Guideline for Valley and Stream Corridors (2015), Credit Valley Conservation (CVC) Technical Guidelines for Watercourse Crossings (2019) and CVC Fluvial Geomorphic Guidelines (2015). These are standard and accepted approaches for crossing design and implementation.

From a fluvial geomorphological perspective, watercourse crossings should be designed to minimize the probability of channel contact with crossing infrastructure while accounting for natural channel adjustment (i.e., migration, erosion, scour) (TRCA, 2015 and CVC, 2017). In general, it is recommended that any proposed crossings address the following fluvial geomorphological considerations, where appropriate:

- Potential channel erosion and/or migration
- Account for any local or upstream meanders
- Cross the watercourse at a reasonably straight and stable section of channel
- Cross the watercourse at a perpendicular angle
- Maintain sediment transport processes
- Maintain velocity differentials for frequent storm events

A structure that spans three times the bankfull channel width is typically recommended from a fluvial geomorphic perspective; however, due to the relatively small size of these swale features, crossings spanning three times the bankfull width are deemed unnecessary.

Following completion of the fluvial geomorphic assessment in 2020, the Project Team has explored alternative crossing designs as part of the Class EA process. It is understood that Crossing No. 1 is to be retained and the limit of proposed works is located east of the East Humber River tributary. No additional guidance is therefore provided for Crossing No. 1. With regard to Crossing No. 2, which conveys flows of the West Don River tributary, a single concrete box culvert (3.9 m span and 1 .2 m rise) or twin concrete box culverts (3.9 m span and 1.2 m rise) are being considered to address ecological passage and hydraulic capacity requirements. Each crossing type would be installed perpendicular to the road and would be approximately 29 m in length. This approach minimizes the length of the replacement crossing, which is favourable from both ecological and geomorphological perspectives.

As noted in **Section 5**, Reach **WDT1-1** (downstream of Kirby Road) did not contain a discernable flow path through an agricultural field and lacked natural riparian vegetation. Reach **WDT1-2** (upstream of Kirby Road) was defined within the ROW, where it had a width and depth of 0.8 m and 0.25 m, respectively. There was no defined feature upstream of the crossing through the agricultural field, although a shallow depression was observed from a distance through the agricultural field. The proposed crossing span of 3.9 m exceeds three times the bankfull width measured within the ROW along Reach **WDT1-2** (i.e., 2.4 m). In addition, given the limited channel definition and limited evidence of erosion, the proposed crossing span is adequate from a fluvial geomorphological perspective.

As the existing crossing is skewed, localized realignment of the drainage feature will be required to accommodate the perpendicular replacement crossing. To ensure long-term stability, it is recommended that stone core wetland features be implemented at the crossing inlet and outlet. In addition, bioengineered bank treatments such as brush mattress or vegetated buttresses should be installed at the crossing inlet and outlet to provide flow training. Given the existing drainage feature has limited form and is vegetation controlled, it is recommended that the realigned feature be replicated as a vegetated swale positioned within the ROW.

To ensure proper implementation of the realigned drainage feature, the following additional recommendations are provided for the detailed design stage:

- Confirm the gradient and upstream and downstream tie-in locations for the realigned drainage feature
- Design a formalized low flow channel with natural substrates through the crossing
- Complete hydraulic sizing for any stone to be used within the crossing, upstream and downstream wetlands and bioengineered bank treatments
- Develop a native planting plan for the realigned drainage feature that will complement bioengineered treatments and wetland features
- Establish site access routes, staging and storage areas for construction
- Prepare an erosion and sediment control plan
- Complete instream works during periods of limited to no flow

8 Summary

A fluvial geomorphological assessment was completed for two watercourse crossings, one tributary of the East Humber River (Crossing 1) and one tributary of the West Don River (Crossing

2) to support a Class EA Study for the widening of Kirby Road between Jane Street and Dufferin Street. The assessment included a review of previously completed studies, topographic and geologic mapping, a historical assessment using aerial photographs, field reconnaissance within the ROW to document channel conditions, meander belt width calculations, and crossing recommendations.

Land use within the study area largely remained agricultural over the period assessed (1946 to 2019), especially within the immediate vicinity of both crossings. The channel form for both tributaries has also remained consistent over the period examined. The tributary of the East Humber River remained as a swale feature with a narrow grassy riparian zone. The tributary of the West Don River remained as a poorly defined swale feature with no riparian zone. Results of the field assessments indicated that both crossings were stable with little to no erosion.

Theoretical meander belt widths were calculated using a modelling approach due to poor channel definition (i.e., absence of a meandering planform). The calculated meander belt widths are considered theoretical as there is limited erosion potential associated with swale features and little to no erosion was observed during field reconnaissance.

The existing twin 0.6 m CSP culverts at Crossing No. 2 are proposed to be replaced with either a 3.9 m wide, 29 m long single concrete box culvert or twin 3.9 m wide, 29 m long concrete box culverts. As the West Don River tributary had limited form, with bankfull width measured within the ROW to be 0.8 m, the proposed crossing span of 3.9 m more than adequately addresses the erosion hazard from a geomorphological perspective.

While the existing structure at Crossing No. 2 was installed at a skew, the replacement crossing is proposed to be installed perpendicular to Kirby Road. This approach is consistent with TRCA (2015) and CVC (2015 and 2019) crossing guidelines. A local feature realignment will be required to accommodate the proposed replacement crossing. Recommendations for consideration at the detailed design stage include providing a formalized low flow channel through the crossing, installing stone cored wetland treatments at the crossing inlet and outlet, and installing bioengineered bank treatments at the crossing inlet and outlet to provide flow training. All stone to be used within the crossing, upstream and downstream wetlands and bioengineered bank treatments should be hydraulically sized to remain stable over a range of flow events.

We trust this report meets your requirements at this time. Should you have any questions please contact the undersigned.

Respectfully submitted,

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Director, Principal Geomorphologist

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Suzanne St Onge, M.Sc.
Senior Environmental Scientist

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Appendix A
Historical Aerial Imagery

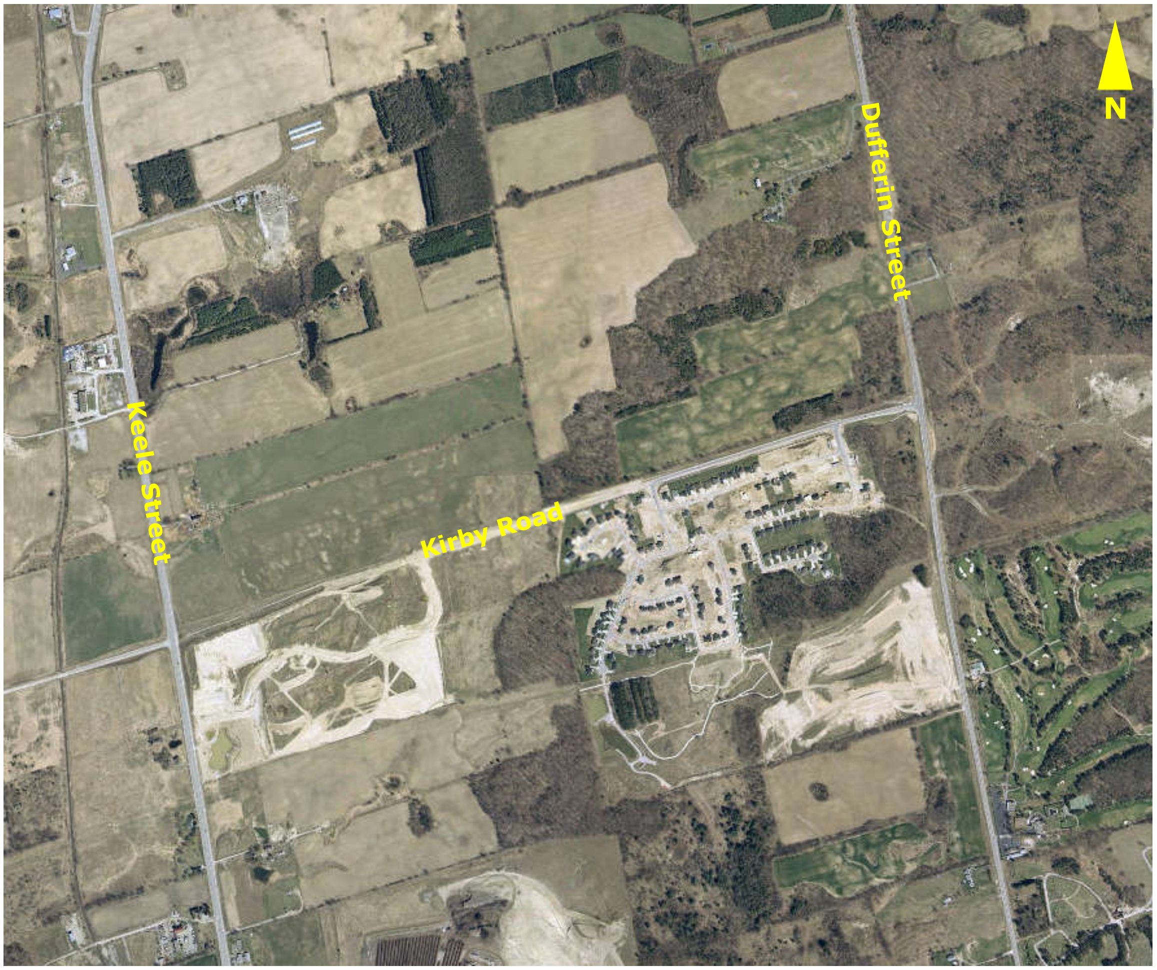
Location: Kirby Road (west)
Year: 1946
Scale: 1:20,000
Source: NAPL

Location: Kirby Road (east)
Year: 1946
Scale: 1:20,000
Source: NAPL

Location: Kirby Road (west)
Year: 1978
Scale: N/A
Source: York Region

Location: Kirby Road (east)
Year: 1978
Scale: N/A
Source: York Region

Location: Kirby Road (west)
Year: 1999
Scale: N/A
Source: York Region



Location: Kirby Road (east)
Year: 1999
Scale: N/A
Source: York Region

Location: Kirby Road (west)
Year: 2009
Scale: N/A
Source: York Region

Location: Kirby Road (east)
Year: 2009
Scale: N/A
Source: York Region

Location: Kirby Road (west)
Year: 2019
Scale: N/A
Source: York Region

Location: Kirby Road (east)
Year: 2019
Scale: N/A
Source: York Region

Appendix B
Reach Delineation

Legend

- Crossing Location
- Reach Break and ID
- Watercourse

Kirby Road Widening EA (Jane Street to Dufferin Street)

Reach Delineation

Vaughan, Ontario

1:12,500

N

0 125 250 500

Metres

GEO MORPHIX

Imagery: City of Vaughan, 2018.
Watercourse: TRCA, 2019.
Reach Break and ID and Crossing Location: GEO Morphix Ltd., 2019.
Print Date: January 2020. PN19109. Drawn By: W.B., C.H., S.S.

Appendix C
Photographic Record

Photo 1 Crossing 1: Humber River Tributary, Reach HT2-1	
	Photograph taken facing downstream (south) of Kirby Road. The swale feature flowed through an active agricultural field.
Photo 2 Crossing 1: Humber River Tributary, Reach HT2-1	
	Photograph taken facing downstream (south) of Kirby Road. A defined low flow feature was observed only at the fence line.

Photo 3
Crossing 1: Humber River Tributary, Reach HT2-2

Photograph taken facing upstream (north) of Kirby Road.
The swale feature flowed through an active agriculture field.

Photo 4
Crossing 1: Humber River Tributary, Reach HT2-2

Photograph taken facing upstream (north) of Kirby Road.
A defined low flow feature within the wider swale was observed.

Photo 5
Crossing 2: West Don River Tributary, Reach WDT1-1

Photograph taken facing downstream (south) of Kirby Road.
No defined feature was observed.

Photo 6
Crossing 2: West Don River Tributary, Reach WDT1-1

Photograph taken facing downstream (south) of Kirby Road.
Double CSPs were noted crossing Kirby Road.

Photo 7 **Crossing 2: West Don River Tributary, Reach WDT1-2**		
	Photograph taken facing upstream (north) of Kirby Road. No defined feature was observed through agricultural field. However, a small depression further upstream was noted.	
Photo 8 **Crossing 2: West Don River Tributary, Reach WDT1-2**		
	Photograph taken facing downstream (south) towards the double CSPs at Kirby Road. There was a small defined channel between the agricultural field and the CSPs.	

Appendix D
Field Reconnaissance

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code: PN19109

Date:	Nov 28, 2019	**Stream/Reach:**	HT2-1 (D/S or S of Kirby Rd)
Weather:	Sun + 2°C	**Location:**	Kirby Rd, Vaughan
Field Staff:	CH	**Watershed/Subwatershed:**	Humber River
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1) 3 **Valley Type** (Table 2) 1 **Channel Type** (Table 3) 12 **Channel Zone** (Table 4) 1 **Flow Type** (Table 5) 3 ☐ Groundwater Evidence: None

Riparian Vegetation

Dominant Type: (Table 6) 3
Species: ______

Coverage:
- ☐ None
- ☐ Fragmented
- ☑ Continuous

Channel widths
- ☑ 1-4
- ☐ 4-10
- ☐ > 10

Age Class (yrs):
- ☑ Immature (<5)
- ☐ Established (5-30)
- ☐ Mature (>30)

Encroachment: (Table 7) 5

Aquatic/Instream Vegetation

Type (Table8) None Coverage of Reach (%) /

Woody Debris
- ☐ Present in Cutbank
- ☐ Present in Channel
- ☑ Not Present

Density of WD:
- ☐ Low
- ☐ Moderate
- ☐ High

WDJ/50m:

Water Quality

Dry

Odour (Table 16) /

Turbidity (Table 17) /

Channel Characteristics

Sinuosity (Type) (Table 9) 1
Sinuosity (Degree) (Table 10) 1
Gradient (Table 11) 1
Number of Channels (Table 12) 1

Entrenchment (Table 13) 1
Type of Bank Failure (Table 14) None
Downs's Classification (Table 15) S

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☑	☐	☐	☐	☐	☐	☐
Pool Substrate	☐	☐	☐	☐	☐	☐	☐
Bank Material	☑	☐	☐	☐	☐	☐	☐

Feature ~~Bankfull~~ **Width (m)**	0.40	/	/	**Wetted Width (m)**	Dry	/	/
Feature ~~Bankfull~~ **Depth (m)**	0.15	/	/	**Wetted Depth (m)**	/	/	/

Riffle/Pool Spacing (m) NA **% Riffles:** NA **% Pools:** NA **Meander Amplitude:** NA

Pool Depth (m) NA **Riffle Length (m)** NA **Undercuts (m)** NA **Comments:** ▷ CSP 2m

Velocity (m/s) NA / / **Wiffle ball / ADV / Estimated** ▷ Swale

Bank Angle
- ☑ 0 – 30
- ☐ 30 – 60
- ☐ 60 – 90
- ☐ Undercut

Bank Erosion
- ☑ < 5%
- ☐ 5 – 30%
- ☐ 30 – 60%
- ☐ 60 – 100%

Notes:

Completed by: CH Checked by: ______

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code: PN19109

Date:	Nov 28, 2019	**Stream/Reach:**	HT2-2 (U/S or N of Kirby Rd)
Weather:	Sun + 2°C.	**Location:**	Kirby Rd, Vaughan
Field Staff:	CH	**Watershed/Subwatershed:**	Humber River
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 3 — **Valley Type** (Table 2): 1 — **Channel Type** (Table 3): 12 — **Channel Zone** (Table 4): 1 — **Flow Type** (Table 5): 3 — ☐ Groundwater — Evidence: None

Riparian Vegetation

- **Dominant Type:** (Table 6) 3
- Species: ____________
- **Coverage:** ☐ None ☐ Fragmented ☑ Continuous
- **Channel widths:** ☐ 1-4 ☑ 4-10 ☐ > 10
- **Age Class (yrs):** ☑ Immature (<5) ☐ Established (5-30) ☐ Mature (>30)
- **Encroachment:** (Table 7) 4

Aquatic/Instream Vegetation

- **Type** (Table8): None — Coverage of Reach (%): 0
- **Woody Debris:** ☐ Present in Cutbank ☐ Present in Channel ☑ Not Present
- **Density of WD:** ☐ Low ☐ Moderate ☐ High — WDJ/50m: ____

Water Quality

mostly Dry

- **Odour** (Table 16): 1
- **Turbidity** (Table 17): 1

Standing water inside CSP

Channel Characteristics

- **Sinuosity (Type)** (Table 9): 1
- **Sinuosity (Degree)** (Table 10): 1
- **Gradient** (Table 11): 1
- **Number of Channels** (Table 12): 1
- **Entrenchment** (Table 13): *
- **Type of Bank Failure** (Table 14): None
- **Downs's Classification** (Table 15): S

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
~~Riffle Substrate~~	☐	☐	☐	☐	☐	☐	☐
~~Pool~~ Substrate	☑	☐	☐	☐	☐	☐	☐
Bank Material	☑	☐	☐	☐	☐	☐	☐

Feature ~~Bankfull~~ Width (m)	0.35	/	/	Wetted Width (m)	NA	/	/
Feature ~~Bankfull~~ Depth (m)	0.10	/	/	Wetted Depth (m)	/	/	/

- **Riffle/Pool Spacing (m)** NA — **% Riffles:** NA — **% Pools:** NA — **Meander Amplitude:** NA
- **Pool Depth (m)** NA — **Riffle Length (m)** NA — **Undercuts (m)** NA
- **Velocity (m/s)** NA / / — Wiffle ball / ADV / Estimated

Bank Angle: ☑ 0 – 30 ☐ 30 – 60 ☐ 60 – 90 ☐ Undercut

Bank Erosion: ☑ < 5% ☐ 5 – 30% ☐ 30 – 60% ☐ 60 – 100%

Comments: ▷ CSP 2m
▷ Swale U/S

Notes:

* Feature appears entrenched U/S of property line but not entrenched @ ROW

Completed by: CH   Checked by: ________

GEO | MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code: PN19109

Date:	Nov 28, 2019	**Stream/Reach:**	WDT1-1 (DS or S of Kirby Rd).
Weather:	Sun + 2°c	**Location:**	Kirby Rd, Vaughan
Field Staff:	CH	**Watershed/Subwatershed:**	West Don River
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 3 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 11 | **Channel Zone** (Table 4): 1 | **Flow Type** (Table 5): 3 | ☐ Groundwater | Evidence: None

Riparian Vegetation
None - Active Ag. field

Dominant Type: (Table 6) NA
Species: ________

Coverage: ☑ None ☐ Fragmented ☐ Continuous
Channel widths: ☐ 1-4 ☐ 4-10 ☐ >10
Age Class (yrs): ☐ Immature (<5) ☐ Established (5-30) ☐ Mature (>30)
Encroachment: (Table 7) [ ]

Aquatic/Instream Vegetation
Type (Table8) None | Coverage of Reach (%) [ ]
Woody Debris: ☐ Present in Cutbank ☐ Present in Channel ☑ Not Present
Density of WD: ☐ Low ☐ Moderate ☐ High
WDJ/50m: [ ]

Water Quality
Dry
Odour (Table 16): /
Turbidity (Table 17): /

Channel Characteristics

Sinuosity (Type) (Table 9): 1
Sinuosity (Degree) (Table 10): 1
Gradient (Table 11): 1
Number of Channels (Table 12): 1
Entrenchment (Table 13): 1
Type of Bank Failure (Table 14): None
Downs's Classification (Table 15): 5

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
~~Riffle Substrate~~	☐	☐	☐	☐	☐	☐	☐
~~Pool~~ Substrate	☑	☐	☐	☐	☐	☐	☐
~~Bank Material~~	☐	☐	☐	☐	☐	☐	☐

Bankfull Width (m): No definition / /
Wetted Width (m): Dry / /
Bankfull Depth (m): / / /
Wetted Depth (m): / / /
Riffle/Pool Spacing (m): NA | **% Riffles:** NA | **% Pools:** NA | **Meander Amplitude:** NA
Pool Depth (m): NA | **Riffle Length (m)**: NA | **Undercuts (m)**: NA
Velocity (m/s): Dry / / | **Wiffle ball / ADV / Estimated**

Bank Angle: ☐ 0 – 30 ☐ 30 – 60 ☐ 60 – 90 ☐ Undercut
Bank Erosion: ☐ <5% ☐ 5 – 30% ☐ 30 – 60% ☐ 60 – 100%

Comments: ▷Double CSPs @ 0.6m
▷3RD CSP @ 0.4m ~3m W of Double.

Notes: No feature D/S of CSPs. No swale or flow path.

Completed by: CH Checked by: ________

GEO | MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code: PN19109

Date:	Nov 28, 2019	**Stream/Reach:**	WDT1-2 (U/S of N of Kirby Rd)
Weather:	Sun + 2°C	**Location:**	Kirby Rd, Vaughan
Field Staff:	CH	**Watershed/Subwatershed:**	West Don River
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 3 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 12 | **Channel Zone** (Table 4): 1 | **Flow Type** (Table 5): 3 | ☐ Groundwater | Evidence: None

Riparian Vegetation — None - Ag Field

Dominant Type: (Table 6) NA
Species: ____

Coverage: ☒ None ☐ Fragmented ☐ Continuous

Channel widths: ☐ 1-4 ☐ 4-10 ☐ > 10

Age Class (yrs): ☐ Immature (<5) ☐ Established (5-30) ☐ Mature (>30)

Encroachment: (Table 7) [ ]

Aquatic/Instream Vegetation

Type (Table8): None Coverage of Reach (%): 0

Woody Debris: ☐ Present in Cutbank ☐ Present in Channel ☑ Not Present

Density of WD: ☐ Low ☐ Moderate ☐ High WDJ/50m: [ ]

Water Quality

Dry

Odour (Table 16): /

Turbidity (Table 17): /

Channel Characteristics

Sinuosity (Type) (Table 9): 1 | **Sinuosity (Degree)** (Table 10): 1 | **Gradient** (Table 11): 1 | **Number of Channels** (Table 12): 1

Entrenchment (Table 13): 1 | **Type of Bank Failure** (Table 14)*: 1 | **Downs's Classification** (Table 15): S

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
~~Riffle~~ Substrate	☑	☐	☐	☐	☐	☐	☐
~~Pool Substrate~~	☐	☐	☐	☐	☐	☐	☐
Bank Material *	☑	☐	☐	☐	☐	☐	☐

Feature ~~Bankfull~~ Width (m)	* 0.8	/	/	Wetted Width (m)	Dry	/	/
Feature ~~Bankfull~~ Depth (m)	0.25	/	/	Wetted Depth (m)	/	/	/

Riffle/Pool Spacing (m): NA | **% Riffles:** NA | **% Pools:** NA | **Meander Amplitude:** NA

Pool Depth (m): NA | **Riffle Length (m):** NA | **Undercuts (m):** NA

Velocity (m/s): Dry | / | / | Wiffle ball / ADV / Estimated

Comments: ▷ Double CSP both @ 0.6m

Bank Angle: ☐ 0 – 30 ☑ 30 – 60 ☐ 60 – 90 ☐ Undercut

Bank Erosion: * ☑ < 5% ☐ 5 – 30% ☐ 30 – 60% ☐ 60 – 100%

Notes: ▷ No defined feature through field. Ag. activities through slight depression further U/S.
▷ No banks or bed U/S.

* Defined swale w/i ROW for ~5m btwn CSPs + edge of agricultural field.

Completed by: CH Checked by: ____

THURBER ENGINEERING LTD.

To:	Michelle Mascarenhas, P.Eng. HDR Inc. 1000 York Blvd., Suite 300 Richmond Hill, ON L4B 1J8	June 19, 2021
From:	Alireza Hejazi, P.Eng. David Hill, P.Eng., P.Geo.	

Thurber File No.: 26130

TECHNICAL MEMORANDUM
GROUNDWATER MONITORING PROGRAM
MUNICIPAL CLASS EA STUDY FOR KIRBY ROAD WIDENING
FROM JANE STREET TO DUFFERIN STREET
CITY OF VAUGHAN, ONTARIO

1 INTRODUCTION

Thurber Engineering Ltd. (Thurber) was retained by HDR Inc. (HDR) to conduct a Hydrogeological Investigation in support of the Municipal Class Environmental Assessment (EA) study for the proposed widening of Kirby Road between Jane Street and Dufferin Street in the City of Vaughan, Ontario. The investigation includes groundwater level measurements over a duration of two years. This memorandum summarizes the groundwater levels observed over the first year, from July 2020 to June 2021.

Groundwater monitoring was conducted by Thurber staff on a bi-monthly basis from July 2020 to June 2021 (Table 1 and Table 2 in Appendix A). In addition, eight (8) level loggers were instrumented in selected monitoring wells to record groundwater levels on an hourly basis, to measure seasonal groundwater fluctuations. A barologger was also installed to record barometric pressure to correct level logger readings for atmospheric pressure. A map illustrating the location of the monitoring wells is provided on Figure 1. Table 1 and Table 2 summarize the recorded groundwater levels from all on-site monitoring wells. Hydrographs of these groundwater data are provided in Appendix A.

Between the period of July 21, 2020 and June 23, 2021, seven (7) rounds of water level measurements were collected by Thurber staff from twelve on-site monitoring wells. In general, the groundwater table reflects local topography. The water level elevations in the monitoring wells ranged from 264.3 m to 309.3 m. The highest groundwater level (Elev.309.3 m, depth 1.3 m) was measured in Monitoring Well 20-09S and the lowest water level (Elev. 264.3 m, depth 27.27 m) was measured in Monitoring Well 20-05.

The hydraulic gradient across the site is generally neutral to downward (Table 3 in Appendix A). The magnitude of vertical hydraulic gradients observed at Monitoring Wells 20-09S/D was estimated to be relatively small (<-0.05 m/m) and can be considered as near neutral gradient.

The hydrographs in Appendix A illustrate the seasonal fluctuation in the groundwater levels. Higher groundwater levels were observed during the winter and spring months (December to May), and lower levels were observed during the summer and autumn months (July to November). The range in seasonal fluctuation in each well was from 0.3 m (in Monitoring Well 20-12D) to 2.5 m (in Monitoring Well 20-01) over the course of the monitoring period.

2 CLOSURE

We trust this memo meets your requirements. If you have any questions or require further information, please contact the undersigned at your convenience.

Yours truly,

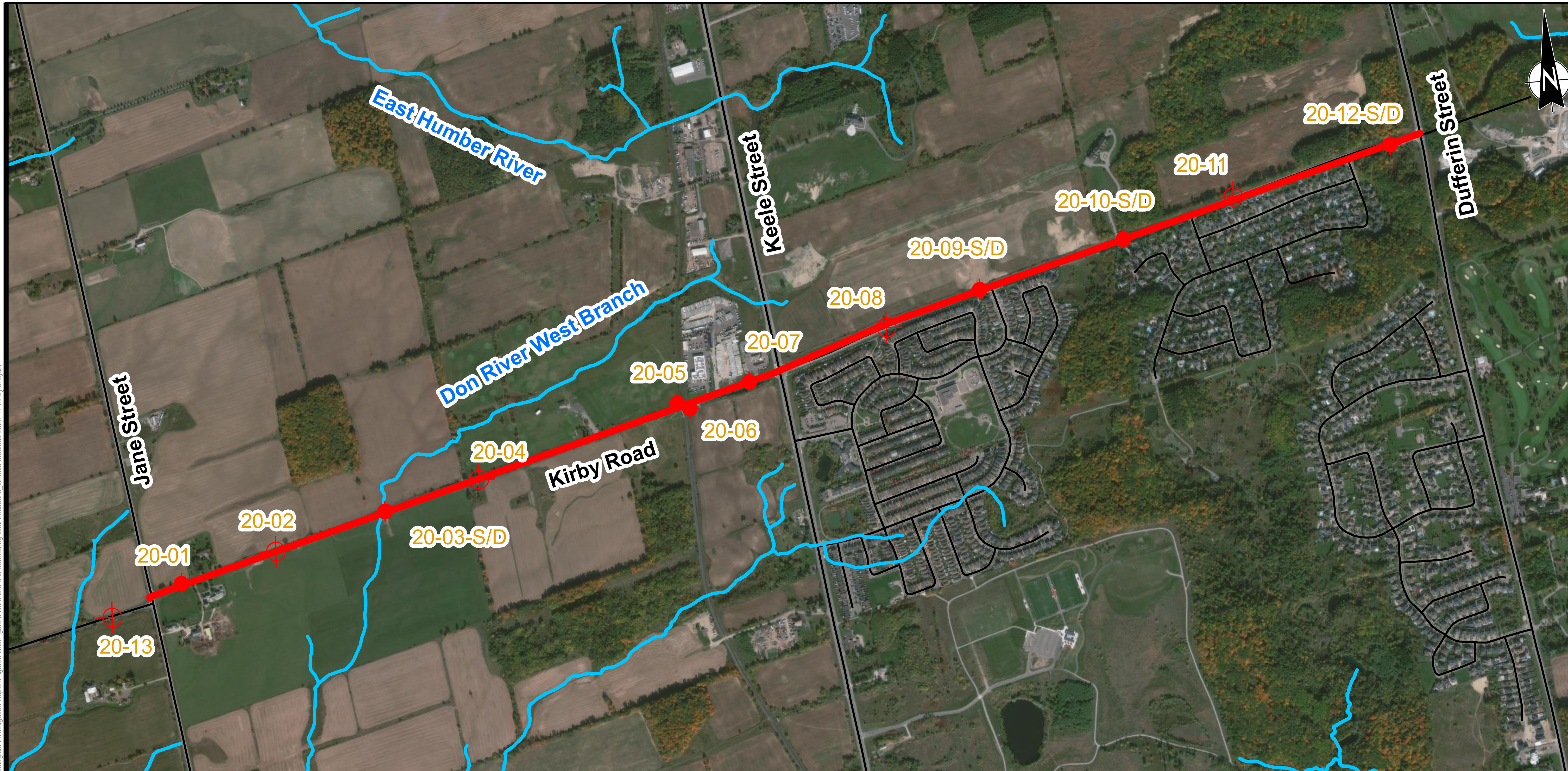
Thurber Engineering Limited

Alireza Hejazi, Ph.D., P.Eng.
Senior Hydrogeologist and Environmental Engineer

David Hill, M.A.Sc., MBA, P.Eng., P.Geo.
Senior Hydrogeologist / Review Engineer

Attachments:

Figure 1 - Monitoring Well Location Map
Appendix A - Measured Groundwater Levels and Hydrographs



LEGEND:

- Borehole
- Monitoring Well
- Site Boundary
- Watercourse
- Road

200 100 0 200 m

UTM 17 NAD 83

KIRBY ROAD CLASS EA STUDY
VAUGHAN, ONTARIO
HDR INC.

BOREHOLE AND MONITORING WELL LOCATIONS

FIGURE 1

DRAWN BY	AH
DESIGNED BY	AH
APPROVED BY	DH
SCALE	1:12,000
DATE	JULY 22, 2020
PROJECT No.	26130

THURBER ENGINEERING LTD.

H:\20000-29999\26000-26999\26130 Kirby Road EA\Reports & Memos\Hydrogeological Investigation Report\Figures\GIS\Figure 9 Borehole and Monitoring Well Locations_v2.mxd modified 2020-11-20 by ahejazi

THURBER

Appendix A
Measured Water Levels and Hydrographs

Table 1 - Measured Groundwater Levels at Monitoring Wells (Elevation: metres above sea level)

Monitoring Well ID	Ground Elevation (m)	21-Jul-2020	28-Jul-2020	25-Sep-2020	20-Nov-2020	14-Jan-2021	17-Mar-2021	23-Jun-2021
BH20-01	271.4	268.71	268.64	268.21	268.49	269.68	270.32	269.03
BH20-03-S	272.7	dry	dry	dry	dry	270.32	270.89	269.91
BH20-03-D	272.7	268.33	268.25	267.58	267.28	267.51	268.74	268.14
BH20-05	291.0	264.95	264.99	264.83	264.72	265.45	264.53	264.31
BH20-06	291.5	288.37	288.33	288.13	288.10	288.98	288.94	288.48
BH20-07	298.2	295.95	295.92	295.58	295.74	296.50	296.16	296.08
BH20-09-S	310.7	308.81	308.91	308.70	308.95	309.28	309.34	308.75
BH20-09-D	310.7	308.11	308.93	308.70	308.93	309.30	309.19	308.88
BH20-10-S	291.7	dry	dry	dry	dry	290.49	290.67	dry
BH20-10-D	291.7	dry	dry	dry	dry	dry	285.93	dry
BH20-12-S	295.6	dry	dry	dry	292.78	292.79	292.71	dry
BH20-12-D	295.6	285.47	285.40	285.09	285.13	285.13	285.13	285.11

Table 2 - Measured Groundwater Levels at Monitoring Wells (Depth: metres below ground surface)

Monitoring Well ID	Well Depth (m)	21-Jul-2020	28-Jul-2020	25-Sep-2020	20-Nov-2020	14-Jan-2021	17-Mar-2021	23-Jun-2021
BH20-01	4.6	2.73	2.80	3.23	2.95	1.76	1.12	2.41
BH20-03-S	3.0	dry	dry	dry	dry	2.41	1.84	2.82
BH20-03-D	7.6	4.39	4.47	5.14	5.44	5.21	3.98	4.58
BH20-05	29.1	26.02	25.98	26.14	26.25	25.52	26.44	26.66
BH20-06	6.6	3.12	3.16	3.36	3.39	2.51	2.55	3.01
BH20-07	4.4	2.26	2.29	2.63	2.47	1.71	2.05	2.13
BH20-09-S	3.0	1.89	1.79	2.00	1.75	1.42	1.36	1.95
BH20-09-D	6.0	2.57	1.75	1.98	1.75	1.38	1.49	1.80
BH20-10-S	2.8	dry	dry	dry	dry	1.18	1.00	dry
BH20-10-D	5.9	dry	dry	dry	dry	dry	5.80	dry
BH20-12-S	2.9	dry	dry	dry	2.81	2.80	2.88	dry
BH20-12-D	10.7	10.18	10.25	10.56	10.52	10.52	10.52	10.54

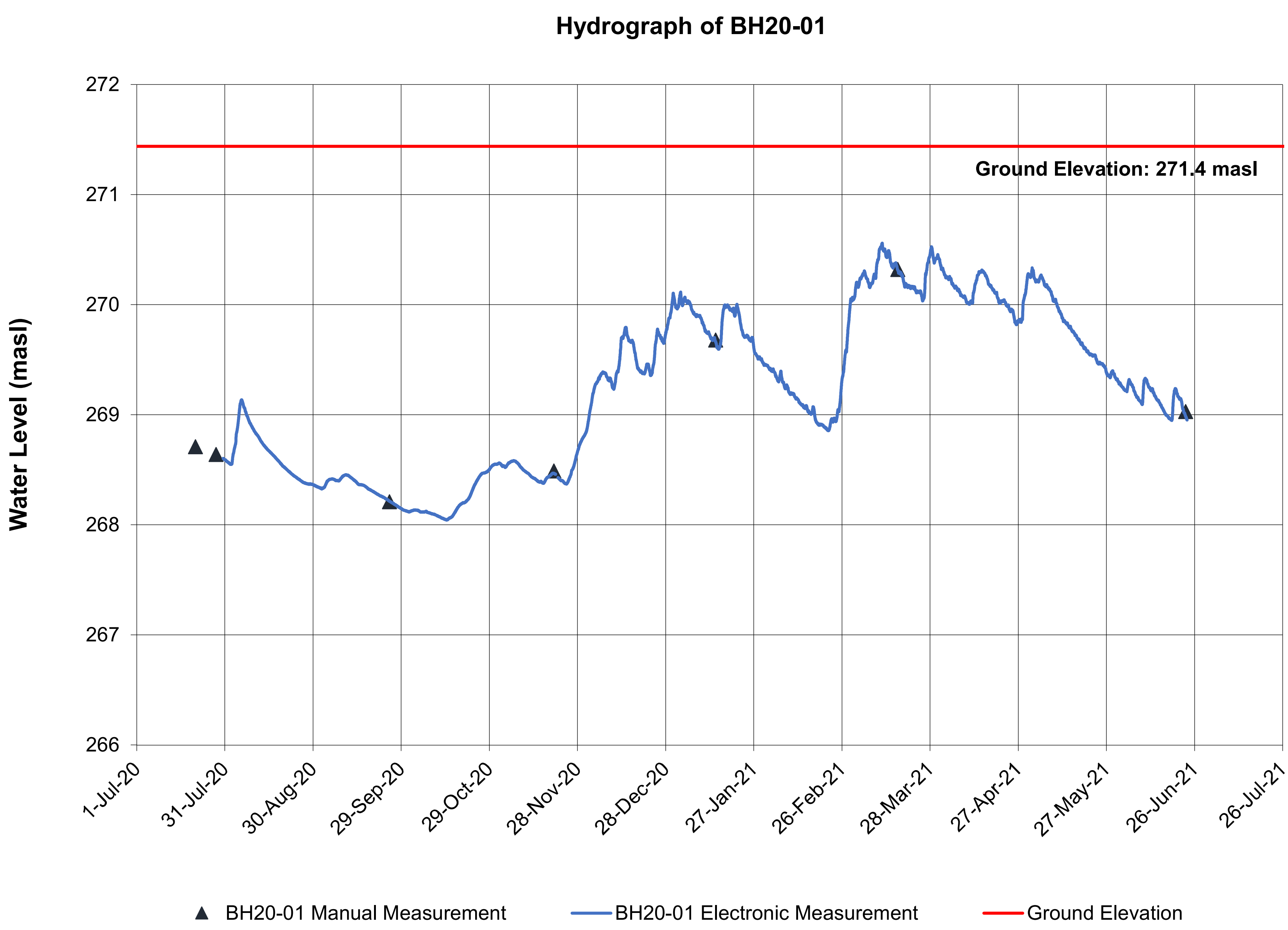
Table 3 - Calculated Vertical Hydraulic Gradient

Monitoring Well ID	21-Jul-2020	28-Jul-2020	25-Sep-2020	20-Nov-2020	14-Jan-2021	17-Mar-2021	23-Jun-2021
BH20-03-S/D	-	-	-	-	0.61	0.47	0.39
BH20-09-S/D	0.23	-0.01	0.00	0.01	-0.01	0.05	-0.04
BH20-10-S/D	-	-	-	-	-	1.57	-
BH20-12-S/D	-	-	-	1.01	1.01	1.00	-

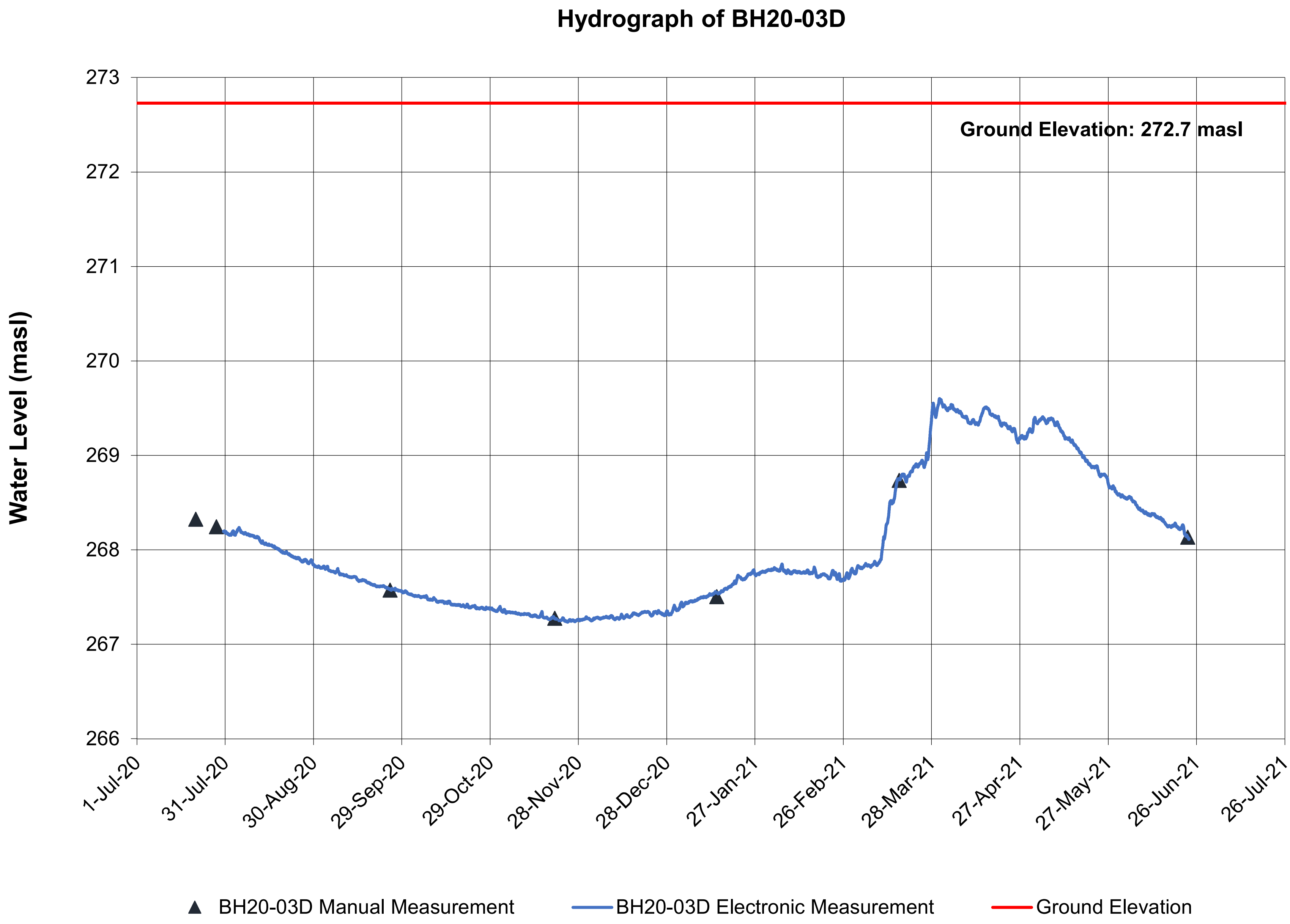
Notes:

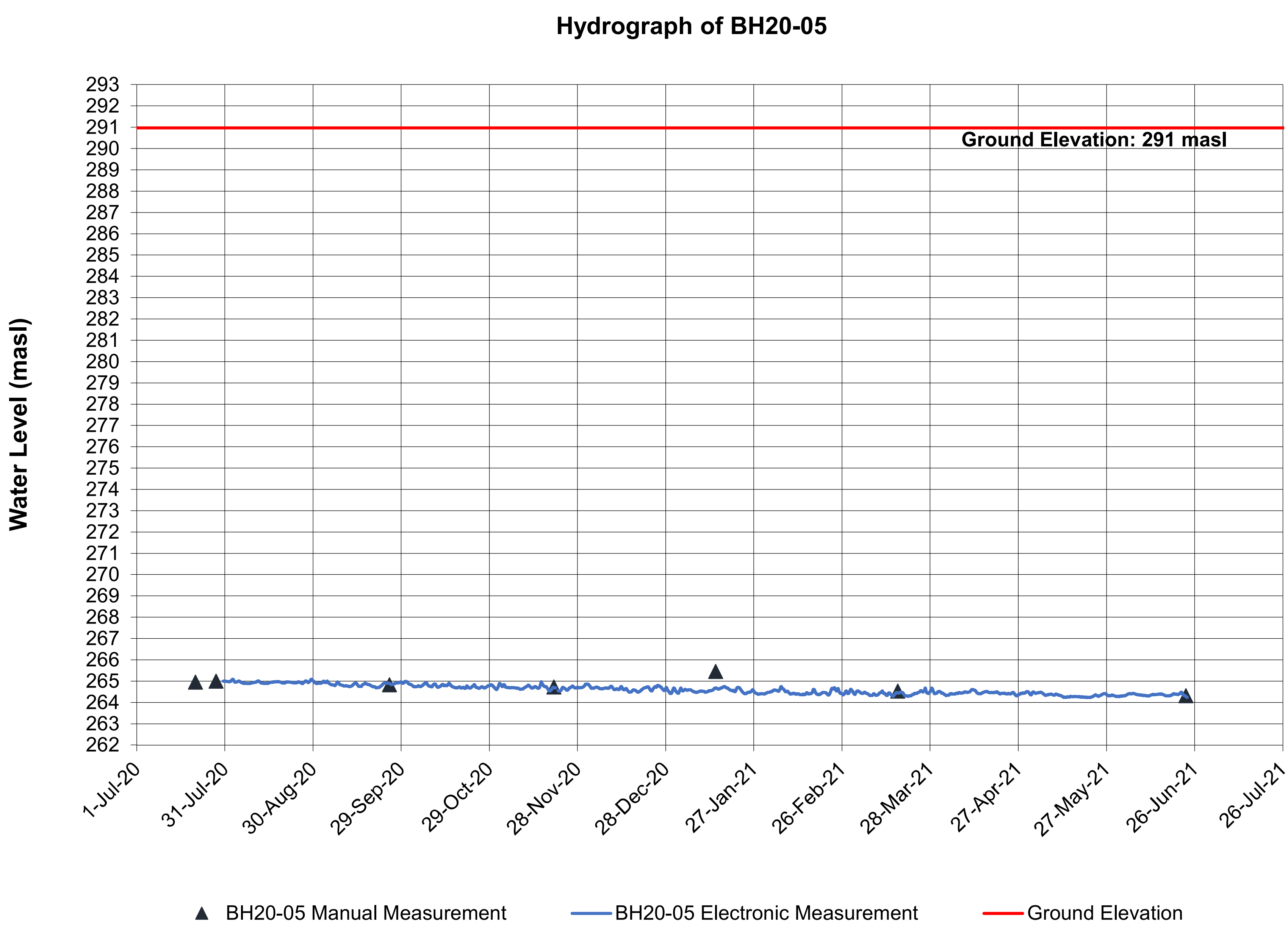
Negative values indicate an upward gradient; positive values indicate a downward gradient.

'-' indicates that the vertical hydraulic gradient could not be estimated due to water level measurement(s) for one or both wells being unavailable.

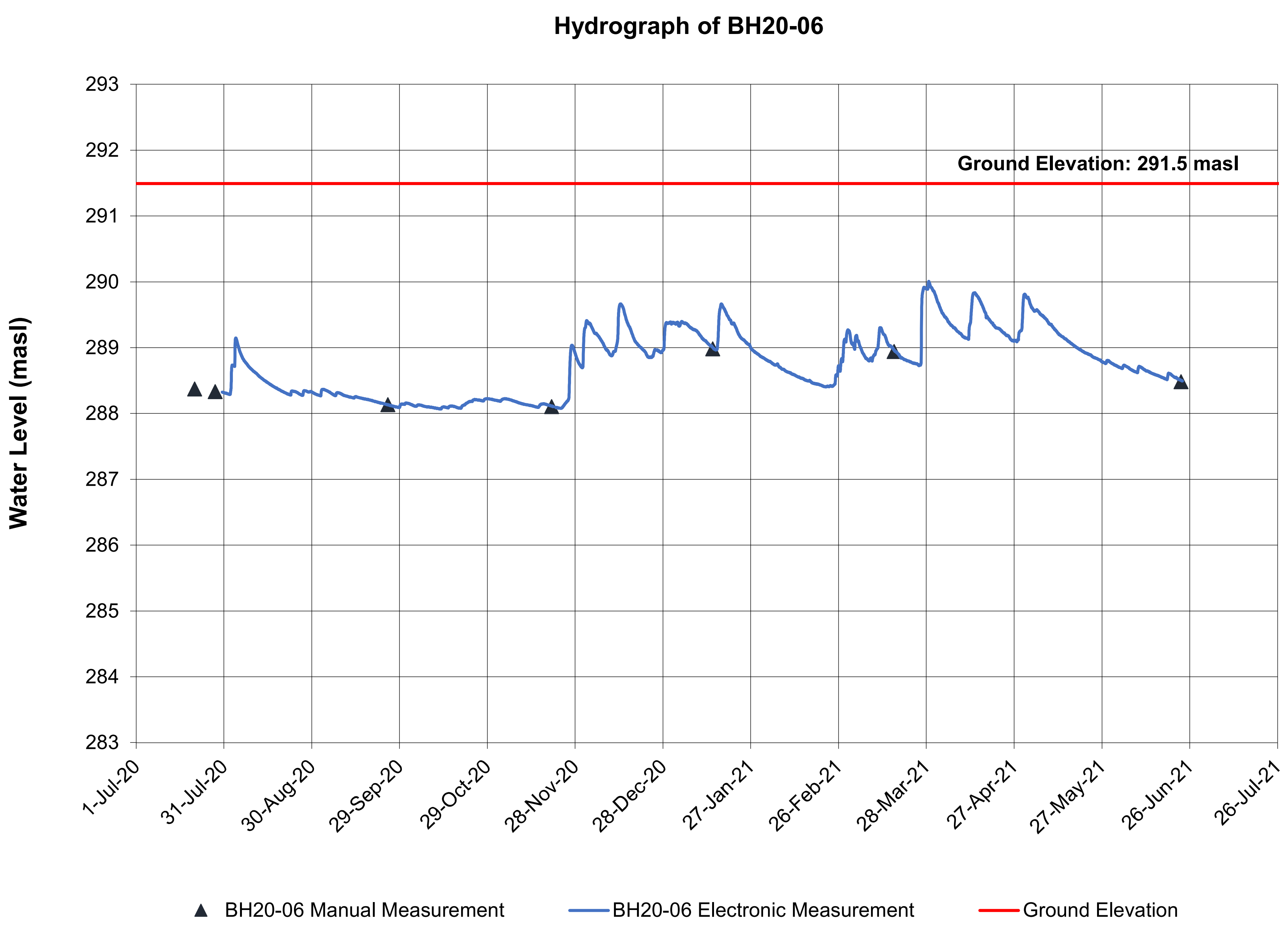


Hydrograph of BH20-01
272
271
270
269
268
267
266
Water Level (masl)
Ground Elevation: 271.4 masl
1-Jul-20
31-Jul-20
30-Aug-20
29-Sep-20
29-Oct-20
28-Nov-20
28-Dec-20
27-Jan-21
26-Feb-21
28-Mar-21
27-Apr-21
27-May-21
26-Jun-21
26-Jul-21
BH20-01 Manual Measurement
BH20-01 Electronic Measurement
Ground Elevation

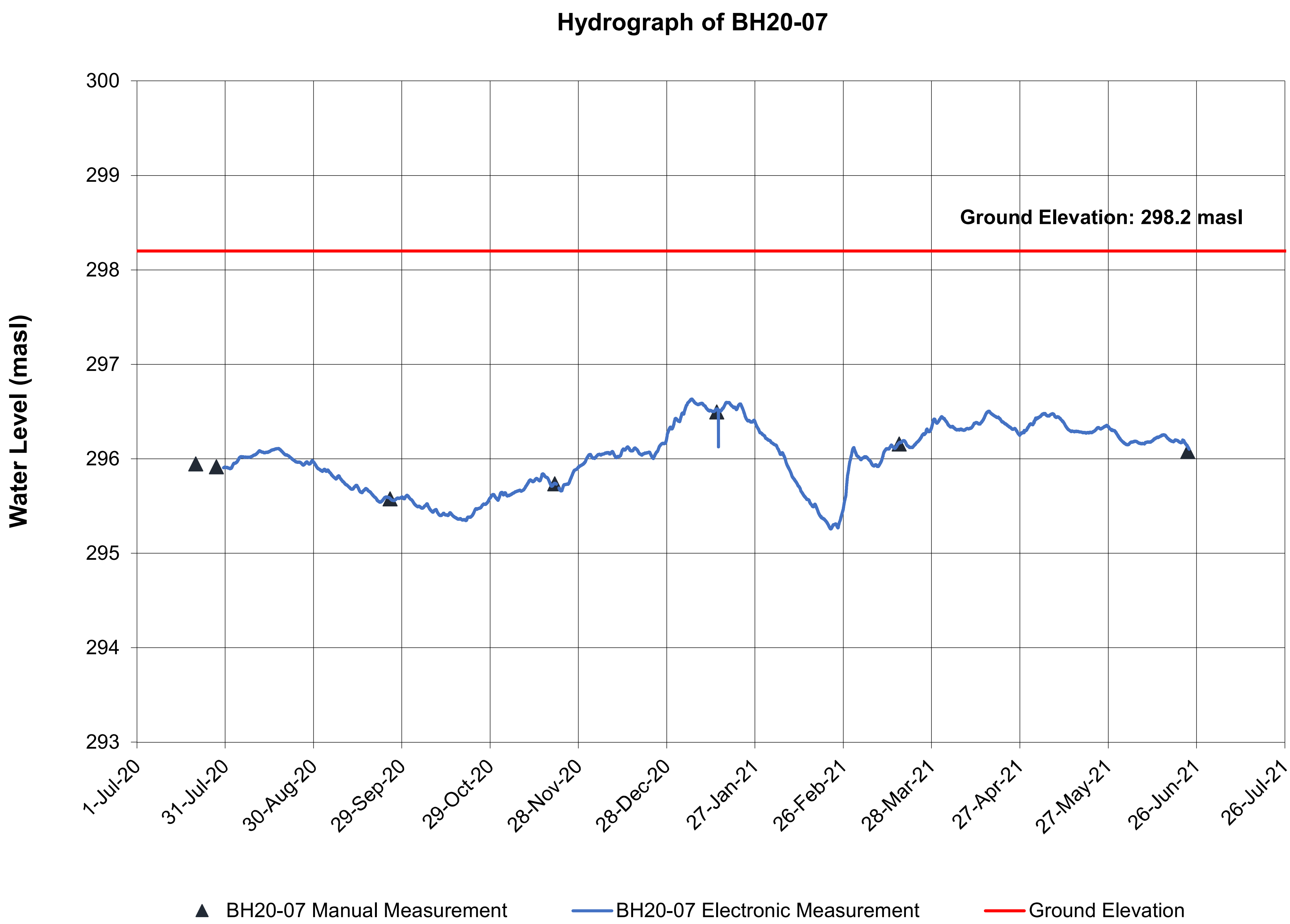

Hydrograph of BH20-03D
273
272
271
270
269
268
267
266
Water Level (masl)
Ground Elevation: 272.7 masl
1-Jul-20
31-Jul-20
30-Aug-20
29-Sep-20
29-Oct-20
28-Nov-20
28-Dec-20
27-Jan-21
26-Feb-21
28-Mar-21
27-Apr-21
27-May-21
26-Jun-21
26-Jul-21
BH20-03D Manual Measurement
BH20-03D Electronic Measurement
Ground Elevation

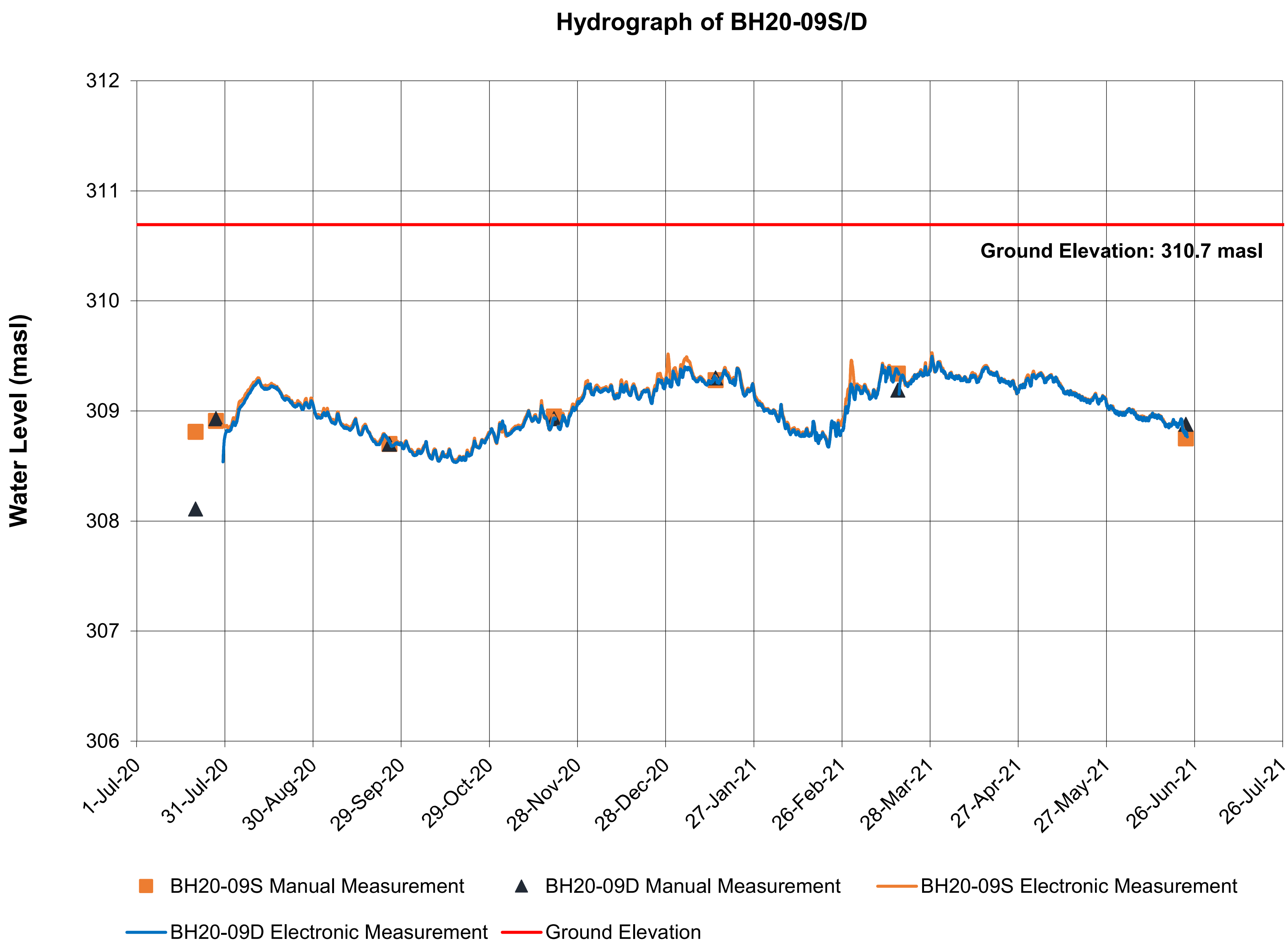


Hydrograph of BH20-05
Water Level (masl)
293
292
291
290
289
288
287
286
285
284
283
282
281
280
279
278
277
276
275
274
273
272
271
270
269
268
267
266
265
264
263
262
Ground Elevation: 291 masl
1-Jul-20
31-Jul-20
30-Aug-20
29-Sep-20
29-Oct-20
28-Nov-20
28-Dec-20
27-Jan-21
26-Feb-21
28-Mar-21
27-Apr-21
27-May-21
26-Jun-21
26-Jul-21
BH20-05 Manual Measurement
BH20-05 Electronic Measurement
Ground Elevation



Hydrograph of BH20-06
Ground Elevation: 291.5 masl
Water Level (masl)
293
292
291
290
289
288
287
286
285
284
283
1-Jul-20
31-Jul-20
30-Aug-20
29-Sep-20
29-Oct-20
28-Nov-20
28-Dec-20
27-Jan-21
26-Feb-21
28-Mar-21
27-Apr-21
27-May-21
26-Jun-21
26-Jul-21
BH20-06 Manual Measurement
BH20-06 Electronic Measurement
Ground Elevation


Hydrograph of BH20-07
Water Level (masl)
300
299
298
297
296
295
294
293
Ground Elevation: 298.2 masl
1-Jul-20
31-Jul-20
30-Aug-20
29-Sep-20
29-Oct-20
28-Nov-20
28-Dec-20
27-Jan-21
26-Feb-21
28-Mar-21
27-Apr-21
27-May-21
26-Jun-21
26-Jul-21
BH20-07 Manual Measurement
BH20-07 Electronic Measurement
Ground Elevation



Hydrograph of BH20-09S/D
Water Level (masl)
312
311
310
309
308
307
306
Ground Elevation: 310.7 masl
1-Jul-20
31-Jul-20
30-Aug-20
29-Sep-20
29-Oct-20
28-Nov-20
28-Dec-20
27-Jan-21
26-Feb-21
28-Mar-21
27-Apr-21
27-May-21
26-Jun-21
26-Jul-21
BH20-09S Manual Measurement
BH20-09D Manual Measurement
BH20-09S Electronic Measurement
BH20-09D Electronic Measurement
Ground Elevation

Hydrograph of BH20-12D