TECHNICAL MEMO

Prepared by:
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Date: August 25, 2021

Re: City of Vaughan Groundwater "Areas of Concern" Mapping – v1

Table of Contents

1. Background – Information & Analysis System

The Oak Ridges Moraine Groundwater Program (ORMGP; Appendix A) has developed and maintains a Groundwater Information and Analysis System. The ORMGP information system contains data and mapping related to, but not limited to, geology, groundwater levels and quality, streamflow and climate. The information system also contains a digital library of documents related to the ORMGP study area (Figure A1) that includes consultant and agency reports, journal articles, etc. Interpretive products are also available such as the three-dimensional arrangement of geologic units as depicted on the cross-sections shown on Figure 1 and Figure 5.

All information managed by the ORMGP is available to all partner agencies (Regions of York, Peel, Durham, City of Toronto, and the nine Conservation Authorities on the Oak Ridges Moraine) and their designates (e.g., consultants). Information related to borehole locations, climate stations and permit to take water locations are available to the public and some information is password protected on the Program website (www.oakridgeswater.ca). Since

late 2015, technical staff at other government agencies (e.g., Ontario Geological Survey, Geological Survey of Canada, and Ontario Ministry of the Environment, Conservation and Parks (MECP; Central Region) have also been provided with full access to the Program’s password protected website, and more recently the Program has started a subscription access to the consulting community. The goal is to increase the user-base which is seen as a key aspect of the continual improvement philosophy of the information and analysis system.

To facilitate increased utilization of water-related information into the decision-making process, work is being conducted to prepare mapping of known/expected areas where groundwater issues (i.e., shallow groundwater and/or artesian (flowing) conditions) may be encountered. The goal is to avoid groundwater ‘surprises’ when undertaking infrastructure/development construction and/or maintenance projects. The main objective, from a groundwater perspective, is to proactively assess, understand and map areas that might pose a concern related to infrastructure prior to any on-site construction activity. A key aspect of this mapping is that the interpretations can be refined as new information is incorporated. It should be noted that a groundwater issue (e.g., too much groundwater, or groundwater under pressure) from an infrastructure/development perspective may also be viewed as an opportunity from another perspective (e.g., heat exchange, water supply).

2. Regional Groundwater Issues – ORMGP Study Area

The ORMGP study area covers much of south-central Ontario (Figure A1). A working hypothesis is that groundwater issues or potential areas of concern for south-central Ontario generally relate to four types of hydrogeologic settings (Figure 1) as follows:

1) Confined Oak Ridges Aquifer Complex (ORAC; or other regional/local aquifers). Example areas include Richmond Hill and Stouffville;
2) Areas of aquifer outcrop/subcrop along steep topographic slopes. Examples include along deep river valleys, along the Lake Iroquois shoreline, and on the north slope of the Oak Ridges Moraine (e.g., Uxbridge) where discharge from aquifers to the surface occurs or is restricted by confining units on the slopes;
3) Coarse-grained sand and gravel deposits (channels) within sediments beneath the Lower Newmarket Till, or more generally in the shallow subsurface. Examples include the ‘Yonge Street Aquifer’ in the communities of Aurora, Newmarket, Holland Landing and Queensville and in the Markham-Stouffville area such as at 16th Avenue and Highway 48; and
4) Gravel zones within bedrock valleys (e.g., western part of the City of Toronto).

It is acknowledged that there may be miscellaneous local areas with thin aquifers of limited lateral extent that may be under confined conditions. It is also acknowledged that much of the study area may contain shallow water table conditions that will need to be controlled during excavation and construction. Also, locations situated near large lakes (e.g., Lake Ontario) may need groundwater control in perpetuity. The groundwater “Areas of Concern” presented herein are considered areas where groundwater control may pose problems (and likely financial costs) beyond the typical situations of water table control during and/or post construction.

3. Local Groundwater "Areas of Concern" – City of Vaughan

3.1 Physical Setting

The City of Vaughan is situated on the south flank of the Oak Ridges Moraine, bounded by Highway 50 on the west, Steeles Avenue on the south, Yonge Street and Bathurst Streets on the east, and just north of the King Vaughan Road in the north (herein referred to as the study area; Figure 2). The ground elevation ranges from a high of 330 metres above sea level (masl) in the northeast part of the study area to a low of 135 masl in the southwest part of the study area. The study area occurs along the south flank of the Oak Ridges Moraine with surface water drainage towards the south to the Humber River (west half of study area) and the Don River (east half of study area). The Greenbelt (OMMAH, 2005) occurs over much of the northern part of the study area as shown on Figure 2, and incorporates lands included in the Oak Ridges Moraine Conservation Plan (OMMAH, 2002).

The surficial geology for the study area is mapped as being covered with till deposits, with a glaciolacustrine silt and clay veneer over much of the southwestern part of the City (Figure 3). The northeast part of the study area has sand mapped at surface which is associated with the Oak Ridges Moraine (ORM). River valleys contain surficial deposits of sand, gravel, silt and clay (Ontario Geological Survey, 2010). Quaternary sediment thickness within the study area ranges from zero metres within the valley of the Humber River where bedrock outcrops to 240 m over the east half of the study area beneath the ORM and above the Laurentian bedrock valley (Figure 4; Figure 5). The interpreted thalwegs of the study area bedrock valleys are shown on Figure 4. Bedrock within the study area is shale of the Georgian Bay and Blue Mountain Formations with a sliver of limestone of the Lindsay Formation present in the northeast corner of the study area (Ontario Geological Survey, 2006).

Shallow groundwater flow (i.e., water table) within the study area is generally south to southwest with strong local deflections towards the Humber and Don Rivers (Figure 6). Water table elevation ranges from a high of 300 masl in the northeast Vaughan area beneath the ORM to a low of 130 masl in the southwest Vaughan area along the valley of the Humber River. This corresponds to a water table depth of 30 to 40 metres below ground surface (mbgs) in the northeast to near ground surface in the southwest (Figure 7). Aquifers situated beneath Vaughan can be considered as either upper or deep aquifers, separated by the Lower Newmarket till (LNt; Figure 5). The upper aquifer system beneath Vaughan occurs within deposits of the Oak Ridges Moraine and is termed the Oak Ridges Aquifer Complex (ORAC). This aquifer system is interpreted to be greater than 80 m thick in the north and northeast and thins southwards towards Steeles Avenue. The ORAC is largely unconfined over upland areas (i.e., beneath the ORM) with local confining conditions occurring along the south slope of the ORM where overlain by the Halton Till, sometimes leading to flowing well conditions (Figure 7). It is acknowledged that both unconfined (water table) and confined (potentiometric surface) conditions exist within the upper aquifer system. For simplicity, this document will herein refer to interpreted groundwater levels within the upper aquifer system as the water table.

Two deep confined aquifers (beneath the Lower Newmarket till) occur within deposits of the Thorncliffe and Scarborough Formations. Groundwater flow within the deep aquifer system is generally from north to south beneath the study area. The deep aquifer system is replenished by vertical downward groundwater flow through the overlying aquitard (Lower Newmarket Till and Channel-silt). Groundwater discharge from the deep aquifer system occurs over the western half of the study area along the Humber River. Flowing well conditions within the

deep aquifers can also occur along the Humber River valley (Figure 7). Figure 8 shows observed river flows during low flow streamflow surveys where flow is measured at many points along stream reaches remote from precipitation and snowmelt events. Low flow surveys are useful tools for outlining gaining and losing stream reaches. Stream reaches gaining in flow are considered to represent receipt of groundwater discharge (Hinton, 1997; Hinton *et al.,* 1998). The data illustrate the increase in baseflow to streams for stream reaches situated south of the ORM.

The City of Vaughan obtains much of its municipal water supply from a distribution system sourced by Lake Ontario (Figure 9). Rural areas in the northern part of the study area are on private wells and septic systems. Kleinburg was the last urban area within the City of Vaughan to obtain a water supply from groundwater. Starting in 2012, this municipal groundwater supply was augmented with water from Lake Ontario. As of November 2013, Kleinburg is mainly serviced by Lake Ontario water, with wells providing a backup emergency supply (York Region, 2014). Nobleton, situated north of the City of Vaughan boundary, still obtains a municipal water supply from groundwater.

For further information related to the hydrogeology of the study area, detailed investigations have been conducted as part of landfill siting investigations in the northeast part of the study area south of King City (Interim Waste Authority Limited, 1994) and for major infrastructure (e.g., sewer construction, railroad cut) work in the southwestern part of the study area (Golder Associates, 2018; Karrow *et al*., 2001). These investigations (Figure 10) cover the range of hydrogeologic conditions that occur within the study area where thick Quaternary sediments over bedrock occur to the north and east, and thinner drift over bedrock occurs to the southwest. A historical perspective of groundwater resources in Vaughan (Township) is provided in Hainstock *et al*., 1948.

3.2 Factors/Considerations

Groundwater “Areas of Concern” within the City of Vaughan generally relate to the presence of shallow groundwater level conditions within deposits of the Oak Ridges Aquifer Complex (ORAC). The ORAC generally thins and pinches out near the south and southwest boundaries of Vaughan. Localized confined conditions where groundwater levels in wells are at or above ground surface can exist in areas where higher topographic change or gradients occur, such as along the southern edge of the Oak Ridges Moraine and along the edge of the Humber River valley. Locally confined conditions are created where the upper aquifer sediments (ORAC) are overlain by finer-grained aquitard (Halton Till) materials with the driving energy created by elevated groundwater levels upgradient beneath the Oak Ridges Moraine (groundwater flow is generally north to south). These areas of elevated groundwater levels can lead to excavation instability and/or groundwater control concerns during and post-construction. “Areas of Concern” then relate to interaction with the ORAC which is a regional aquifer system. In some areas the water table can be up to 40 mbgs (Figure 7) such as beneath the Oak Ridges Moraine, and local topographic highs between river valleys in the western part of the study area. In these areas of deep water table there is minimal potential for “Areas of Concern”, depending on depth of excavation. Shallow perched water table conditions may also exist in some areas, particularly beneath the Oak Ridges Moraine, which may require groundwater control.

The driving factor to delineating groundwater “Areas of Concern” within Vaughan is the presence of groundwater levels near or above ground surface within the upper aquifer (ORAC). The ORAC is interpreted to occur throughout most of the study area based on

currently available information. The factors incorporated into the “Areas of Concern” mapping presented below are as follows:

a) The upper aquifer (ORAC) occurs within sediments associated with the Oak Ridges Moraine that occurs throughout much of Vaughan (Figure 11). Depending on depth of any excavation, “Areas of Concern” can be anticipated where the ORAC is interpreted to exist. The interpreted depth to the ORAC for the study area is shown on Figure 12. It should be noted that the Humber River valley has eroded down to the Lower Newmarket till south of Nashville Road and Major Mackenzie Drive. The Lower Newmarket till is the separating aquitard between the upper and deep aquifer system. Therefore, in the southwest part of the study area the upper aquifer system is anticipated to not be hydraulically connected to the regional ORAC situated further to the north and east, due to local drainage;
b) Areas where groundwater levels within the upper aquifer occur either above ground or within 4 m of ground surface (Figure 7). The depth of 4 m was chosen here to reflect the approximate depth of typical infrastructure excavations (e.g., sanitary sewer depths) or basement structures with one or two levels of underground parking. Obviously site-specific subsurface details need to be considered depending on the final construction depth and type of construction proposed. The methodology used to interpret the water table is included in Appendix C;
c) Known well locations screened in the upper aquifer where groundwater levels are at or above ground surface (i.e., ‘flowing wells’; Figure 7);
d) Groundwater Knowledge locations. These are known locations where previous activities (e.g., drilling, construction) have encountered groundwater-related issues. Many of these locations required groundwater control, either during construction or in perpetuity. These locations are being compiled through discussions between senior practitioners and ORMGP staff with currently known locations shown on Figure 13. Within the study area, known locations of flowing wells and/or groundwater issues could be enhanced with the assistance of York Region, City of Vaughan and TRCA staff; and
e) Long-term groundwater level trends. Long-term is defined here as being time frames longer than seasonal changes in upper aquifer groundwater levels, where highs occur in spring and lows occur in the fall.

Factor ‘e’ is viewed as an important consideration as the interpreted water table described above (Factor ‘b’) is considered an average water table condition based on data collated from multiple locations over different years and seasons. Any transient change in groundwater levels may affect “Areas of Concern” mapping. Observed long-term groundwater levels for the shallow subsurface (water table in surficial till; ORAC) within or near the study area are available for the locations listed in Table 1 and shown on Figure 14. Observed groundwater levels are provided for both upper and deep flow system piezometers to allow comparison of groundwater level variation within both the shallow and deeper subsurface. Hydrographs of groundwater levels within or near the study area are shown on Figures 15 to 24. Observed seasonal groundwater level fluctuations for the shallow subsurface (Halton Till, ORAC) exhibit a 0.5 to 2.5 m annual fluctuation range. Observed seasonal groundwater fluctuations for the deep aquifer system are more subdued at less than a 1 m annual range.

The interpreted regional water table configuration for the upper aquifer system (Factor ‘b’) is based on data from all locations within the database and incorporates water level measurements from multiple years at various times throughout the year. A test of this interpreted water table surface can be conducted by comparison to observations at the limited upper flow system monitoring wells present within the study area. A comparison of

the interpreted water table elevation (Figure 6) to observed average groundwater levels within the ORAC and overlying Halton Till at the monitoring locations listed in Table 1 is included on Figure 25. The interpreted versus observed water table elevations compare favorably except at a couple of locations (Nobleton, Bathurst Glen GC) where local groundwater takings may be affecting shallow groundwater levels. Observed groundwater levels for the last decade at all locations, except Nobleton and Bathurst Glen GC, appear to lack any significant long-term trends in groundwater level fluctuations other than seasonal. This provides confidence in use of the average water table interpretation as a regional screening tool. The lack of apparent regional long-term trends (beyond seasonal) in upper and deep system groundwater levels is also confirmed by observed streamflow hydrographs for Environment Canada streamflow gauges within and near Vaughan shown on Figure 14. Cumulative discharge trends are shown for three active Environment Canada streamflow gauges situated within Vaughan on Figure 26. Significant changes in groundwater levels, and by extension total streamflow and groundwater discharge (aka baseflow), would be illustrated with a change in slope on a cumulative discharge plot. For example, the change in slope during the 1970s at the East Humber River near Pine Grove (02HC009) gauge could be caused by cessation of municipal groundwater pumping at Woodbridge (Figure 26). There are no apparent recent trends (last four decades) seen on the cumulative discharge curves for total streamflow and interpreted groundwater discharge ('baseflow').

Another data set that could be considered in future versions of the City of Vaughan's groundwater "Areas of Concern" mapping is the MECP Permit to Take Water (PTTW) locations (Figure 27), particularly those permits related to construction dewatering activities that might be indicative of groundwater problem areas. These locations have not been considered in this 2021 mapping exercise (version 1) owing to uncertainty regarding the actual source (well location and depth) and quantity of takings (surface water versus groundwater) in the currently available MECP PTTW database.

In summary, the proposed methodology to delineate groundwater "Areas of Concern" within the City of Vaughan includes:

1) Factors a) and b): The upper aquifer system is present throughout much of Vaughan at thicknesses ranging from over 50 m in the northeast beneath the Oak Ridges Moraine, to thin to pinching out (0 m) in the southwest. Coarser-grained aquifer sediments are associated with Oak Ridges Moraine sediment which are often overlain by finer-grained sediments mapped as Glaciolacustrine silt and clay and Halton Till, which can locally create confined aquifer conditions. Groundwater "Areas of Concern" for Vaughan are expected to occur where the ORAC is present and the water table within the upper aquifer system (ORAC) is either above, or within 4 m of ground surface; and
2) Factors c), d) and e): The locations considered in Factors 'c' and 'd' are seen as checks on the interpreted water table for the upper aquifer system (Factor 'b'). If the area delineated by Factor 'b' does not include the locations listed in Factors 'c' ('flowing' wells in upper aquifer) and 'd' (groundwater knowledge), then the mapping is adjusted to incorporate these locations. The mapping area is also informed by considering Factor 'e', which in this case has been used to test the level of confidence in using the interpreted water table surface.

3.3 Mapping & Summary

Having considered all the known details of the groundwater flow system for the study area discussed above, Figure 28 generally illustrates where the current interpretation of the water table is within 4 m of ground surface or above ground surface (green shading). It should be noted that the ORAC is interpreted to occur throughout much of the study area at thicknesses

greater than 2 m as shown on Figure 11. On Figure 28, the shaded areas (green) outline groundwater "Areas of Concern" for the study area. Two point sources of data are also shown on Figure 28 as a check of the shaded areas. These locations include wells where an observed groundwater level is at or above ground surface ('flowing' wells), and 'Groundwater Knowledge' locations, in this case three locations where high yielding wells and/or flowing well conditions were encountered within the upper flow system. All flowing well and 'Knowledge – Groundwater' locations are included within the delineated "Areas of Concern".

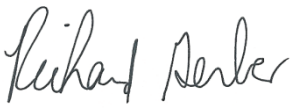
The groundwater "Areas of Concern" map (Figure 28) should be regularly updated and refined as more information is obtained (e.g., if site specific construction details are different than the assumptions listed here). The groundwater "Areas of Concern" mapping presented here represents a snapshot summary that synthesizes existing subsurface groundwater level data and understanding within the City of Vaughan at the time of preparation. A qualifying statement accompanying the mapping is included in Appendix B. Given the reliance of this mapping on the interpreted water table surface, Appendix C includes the metadata summary for the preparation of the water table mapping.

This memo has outlined the various factors that have been considered to prepare groundwater "Areas of Concern" mapping for the City of Vaughan. The map can be used by the City of Vaughan, the TRCA and York Region to inform the development approval process and applicable requirements for pre- and post-development necessary regarding groundwater investigation and control.

Should you have any questions or wish to discuss further please do not hesitate to contact any of the undersigned.

Sincerely,

Oak Ridges Moraine Groundwater Program



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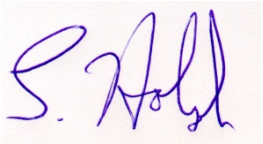

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4. References

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Version History

Version	Changes
v1: 25-Aug-2021	- First version.

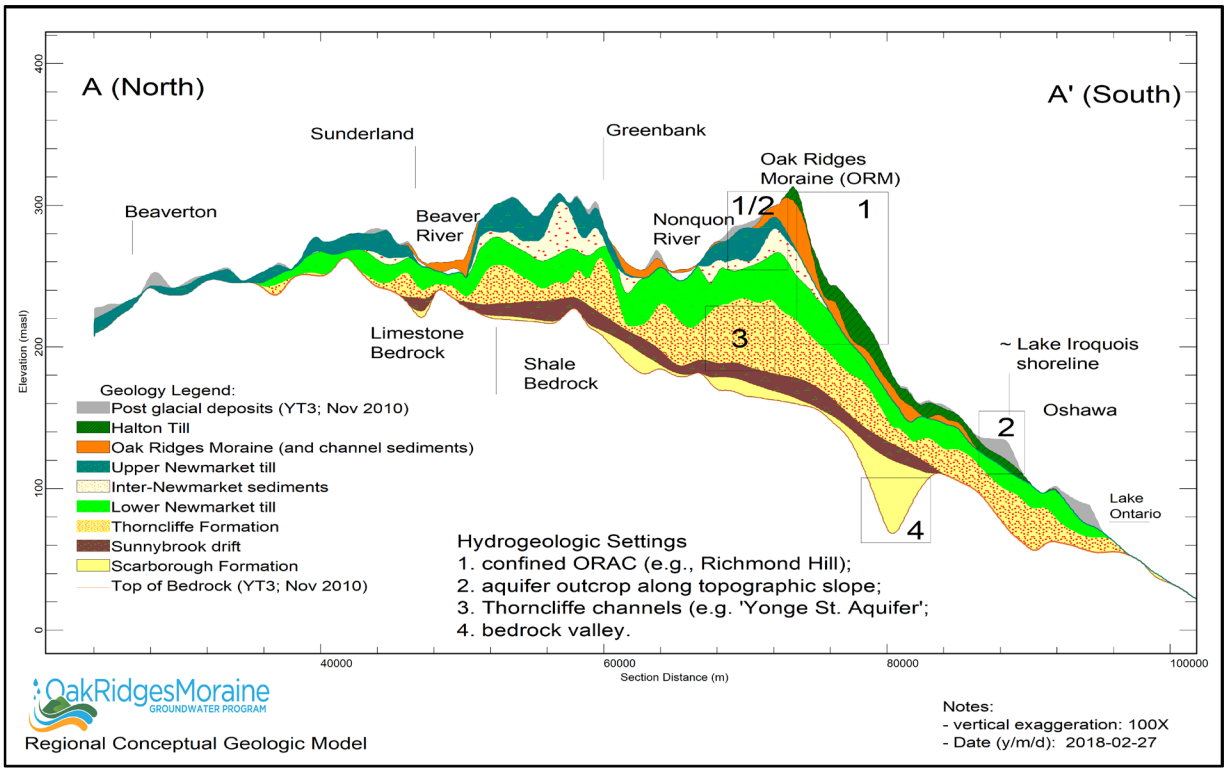


Figure 1: North-south cross-section through the ORMGP study area from Lake Simcoe (north) to Lake Ontario (south). The numbered areas depict example locations of where hydrogeologic settings may relate to areas of potential groundwater concern. Refer to Section 2 for further description.

Table 1: Long-term groundwater monitoring locations within or near Vaughan. Monitoring locations shown on Figure 14.

Monitoring Well Name	Install Date	Hydrostratigraphic [1]Unit	Ground Elevation (masl)	Borehole Bottom Elevation (masl)	Borehole Depth (mbgs)	Depth to Screen Top (mbgs)	Depth to Screen Bottom (mbgs)	Datalogger Start Date	Hydrograph Figure	[2]Interpreted Regional Water Table (masl)	[3]Observed Avg GW Level at Monitor (masl)
PGMN-059 Summit GC		ORAC	270.8	256.8	14.0	13.7	14.0	31-Jul-2001	Figure 15	271	269.8
Bathurst Glen PW1-91	26-Jul-1991	ORAC	315.0	256.5	58.5	53.3	54.3	01-Jan-2010	Figure 16	290	277.8
King City MW01s	06-Apr-2004	ORAC	279.7	221.6	58.1	6.1	9.1	20-May-2004	Figure 17	276	278.4
King City MW01d	06-Apr-2004	ORAC	279.7	221.6	58.1	36.6	42.7	20-May-2004			
King City MW03s	20-Apr-2004	ORAC	278.0	163.7	114.3	5.8	8.8	20-May-2004	Figure 17	278	276.3
King City MW03d	20-Apr-2004	Thorncliffe	278.0	163.7	114.3	104.6	110.6	20-May-2004			
King City MW04	21-Feb-1980	Thorncliffe	278.6	177.1	101.5	97.5	100.0	28-May-2003			
Nobleton MW01s	30-Jun-2006	ORAC	269.0	232.4	36.6	33.5	36.6	29-May-2007	Figure 18	268	252.4
Nobleton MW01d	28-Jun-2006	Scarborough	269.0	158.6	110.3	103.6	106.7	19-Sep-2006			
Nobleton MW02s	13-Jul-2006	ORAC	265.4	225.2	40.2	37.2	40.2	20-Oct-2006	Figure 18	265	253.0
Nobleton MW02d	29-Jun-2006	Scarborough	265.0	152.7	112.3	107.0	108.2	19-Sep-2006			
Nobleton MW03s	05-Jul-2006	ORAC	263.0	220.0	43.0	27.7	30.8	29-May-2007	Figure 18	262	254.0
Nobleton MW03d	29-Jun-2006	Thorncliffe	262.1	159.7	102.4	86.4	89.5	19-Sep-2006			
Nobleton MW04s	22-Aug-2006	ORAC	260.5	236.2	24.4	18.6	21.0	07-Jun-2012	Figure 18	260	254.8
Nobleton MW04i	07-Sep-2006	ORAC	260.4	219.3	41.1	37.8	40.8	29-May-2007			
Nobleton MW04d	22-Aug-2006	Scarborough	260.5	158.4	102.1	99.1	102.1	19-Sep-2006			
Nobleton MW05	05-Sep-2006	Scarborough	260.3	157.9	102.4	94.8	96.7	19-Sep-2006			
Nobleton MW06	14-Aug-2006	Scarborough	260.8	152.6	108.2	96.6	103.0	19-Sep-2006			
Nobleton MW08s	18-Feb-2013	ORAC	264.3	168.3	96.0	27.7	30.8	05-Mar-2013	Figure 18	264	251.5
Nobleton MW08d	17-Feb-2013	Scarborough	264.3	168.3	96.0	93.0	96.0	05-Mar-2013			
PGMN-327 Bolton-s	27-Apr-1994	Halton Till	260.8	163.9	96.9	13.1	15.8	24-Aug-2016	Figure 19	250	251.4
PGMN-327 Bolton-d	27-Apr-1994	Scarborough	260.8	163.9	96.9	79.9	87.2	05-Sep-2003			
Bolton TW3/80d	1980	Scarborough	214.8	85.2	129.5	106.7	109.7	07-Oct-2002			
Kleinburg MW01	15-Nov-1990	Glaciolacustrine	218.3	213.1	5.2	3.6	5.2	29-May-2007	Figure 20	216	215.7
Kleinburg MW02	21-Aug-1975	Scarborough	217.0	130.4	86.6	69.8	73.2	25-Jan-1994			
Kleinburg MW03	18-Jul-2003	Channel-silt	188.0	186.2	1.8	1.6	1.8	06-Aug-2003			
Kleinburg MW04	18-Jul-2003	Channel-silt	188.4	184.8	3.6	2.2	3.6	06-Aug-2003			
Kleinburg MW05	18-Jul-2003	Channel-silt	188.5	186.5	2.0	1.4	2.0	06-Aug-2003			
Kleinburg PW01	24-Jul-1959	Channel-silt	197.4	175.7	21.6	19.8	21.3	06-Feb-2003			
PGMN-075 Kortright	16-Oct-1991	ORAC	206.0	170.0	36.0	33.8	35.4	09-Oct-2001	Figure 21		
PGMN-497 Kortright	12-Dec-2011	ORAC	206.8	171.4	35.4	29.3	35.4	10-Feb-2012	Figure 21	181	176.2
PGMN-367 Claireville		Shale - Bedrock	192.6	162.0	30.6	26.0	27.4	05-Sep-2003	Figure 22		
Vaughan MW01s	24-Oct-2003	Halton Till	188.0	178.8	9.1	3.1	9.1	03-Aug-2010	Figure 23	179	178.8
Vaughan MW01i	24-Oct-2003	ORAC	187.8	167.2	20.6	16.1	20.7	03-Aug-2010			
Vaughan MW01d	24-Oct-2003	Thorncliffe	187.8	150.5	37.3	34.4	37.5	03-Aug-2010			
Earl Bales Park-s	29-Sep-2004	Halton Till	184.0	88.0	96.0	7.3	10.4	15-Aug-2008	Figure 24	175	174.7
Earl Bales Park-d	29-Sep-2004	Scarborough	184.0	88.0	96.0	81.4	82.9	09-Sep-2006			

Notes

[1]Upper aquifer system (including water table) locations are shaded.

[2]Interpreted regional water table elevation shown on Figure 6. Metadata included in Appendix C. Includes data from all locations in database measured over many years during various seasons.

[3]Observed average groundwater level elevation at upper flow system monitoring location calculated for period of record using sHydrograph v7.0 at www.oakridgeswater.ca.

Interpreted water table comparison to observed groundwater level elevation shown on Figure 25.

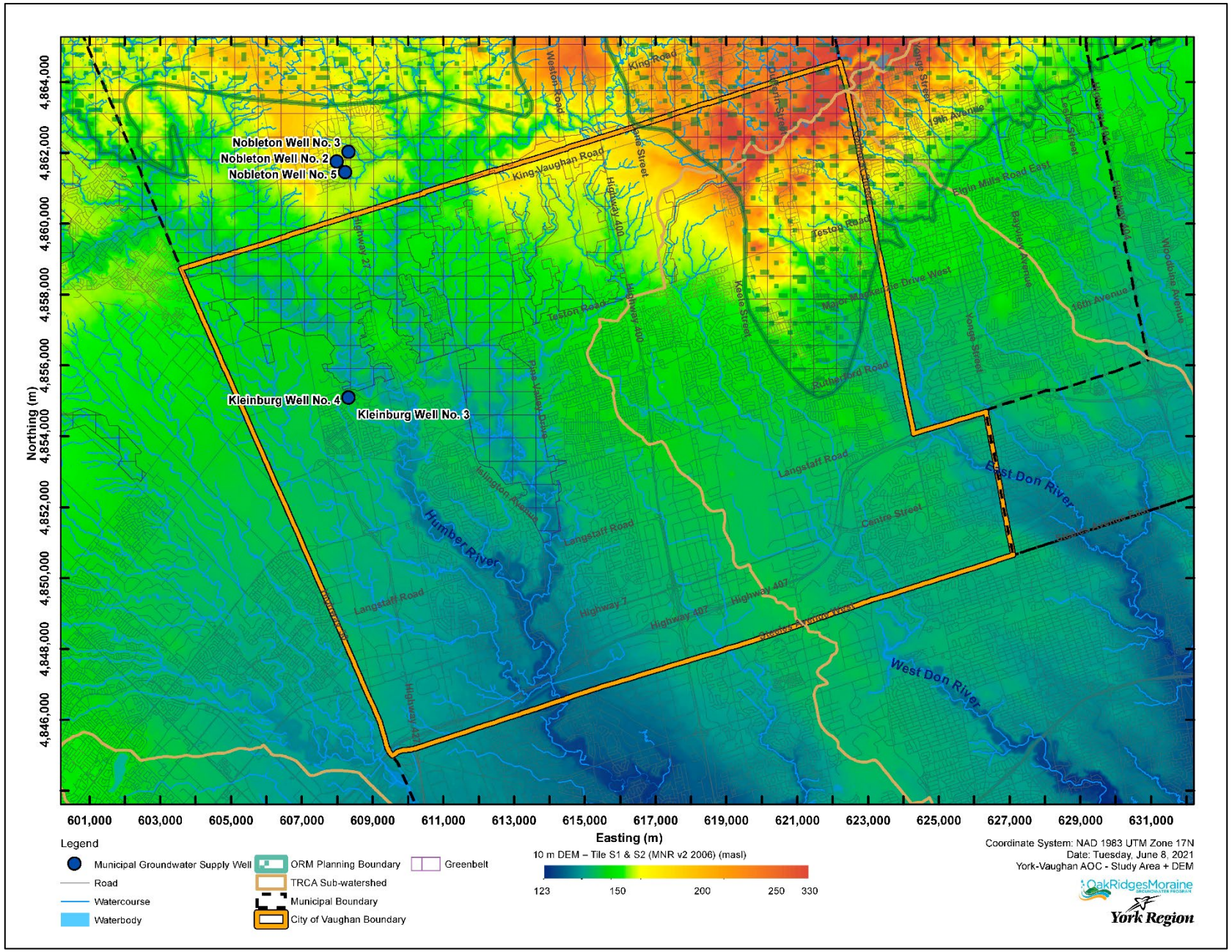


Figure 2: City of Vaughan study area and ground surface topography. Greenbelt shown as hatched area.

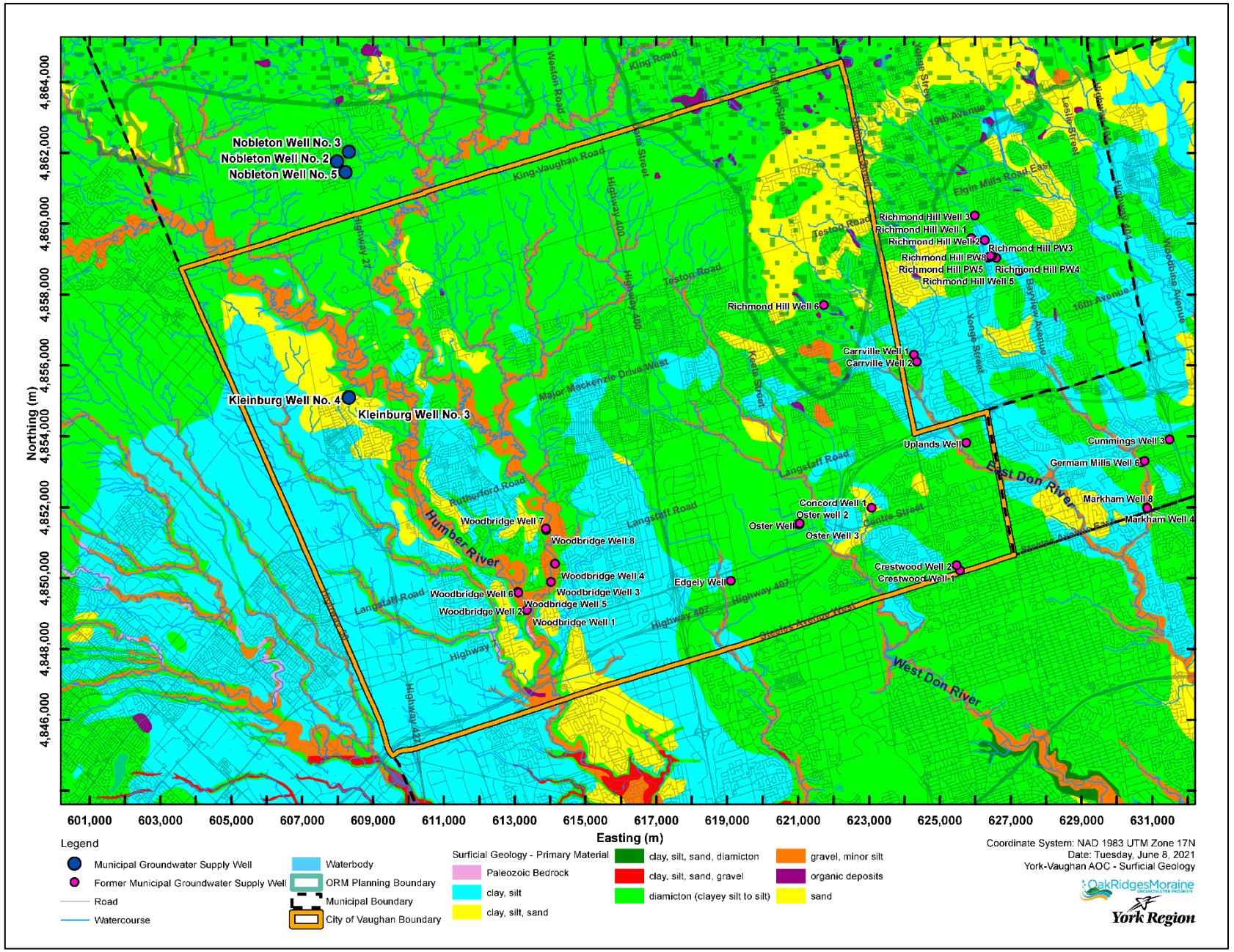


Figure 3: Surficial geology (OGS, 2010).

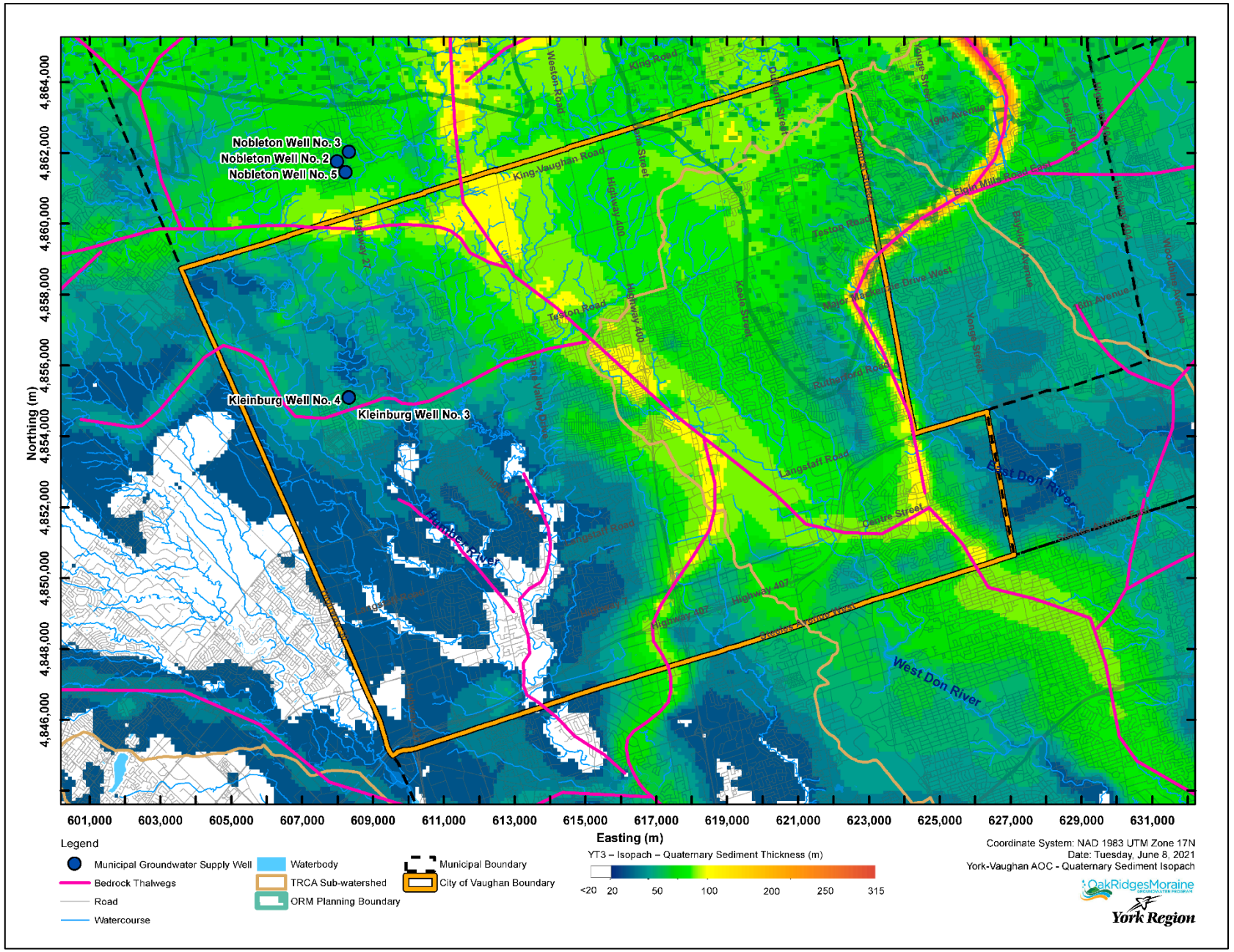


Figure 4: Quaternary sediment thickness in metres. Interpretation from Earthfx Inc., 2014.

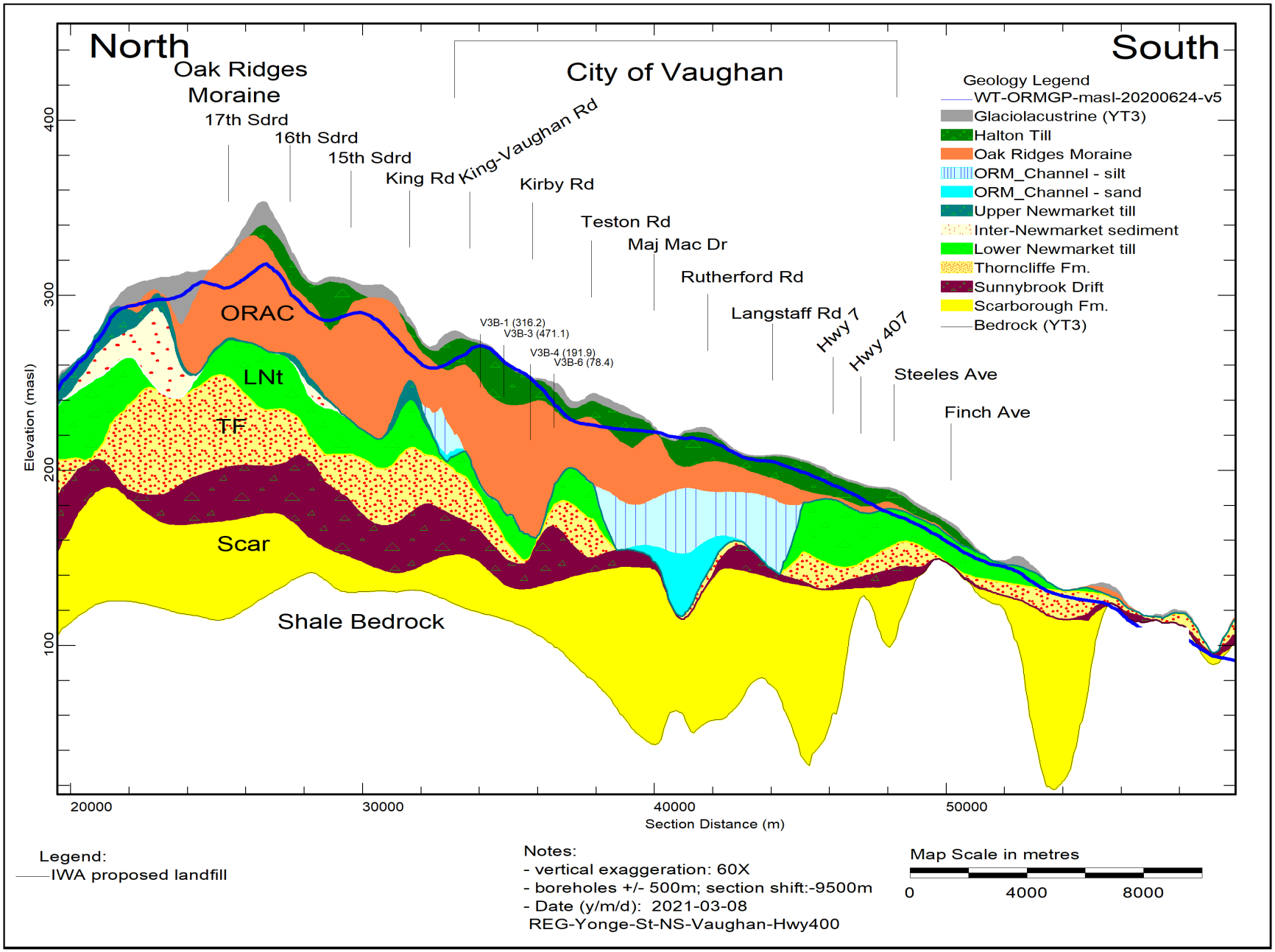


Figure 5: North-south cross along Hwy 400. Geologic layer interpretation from Earthfx Inc., 2014.

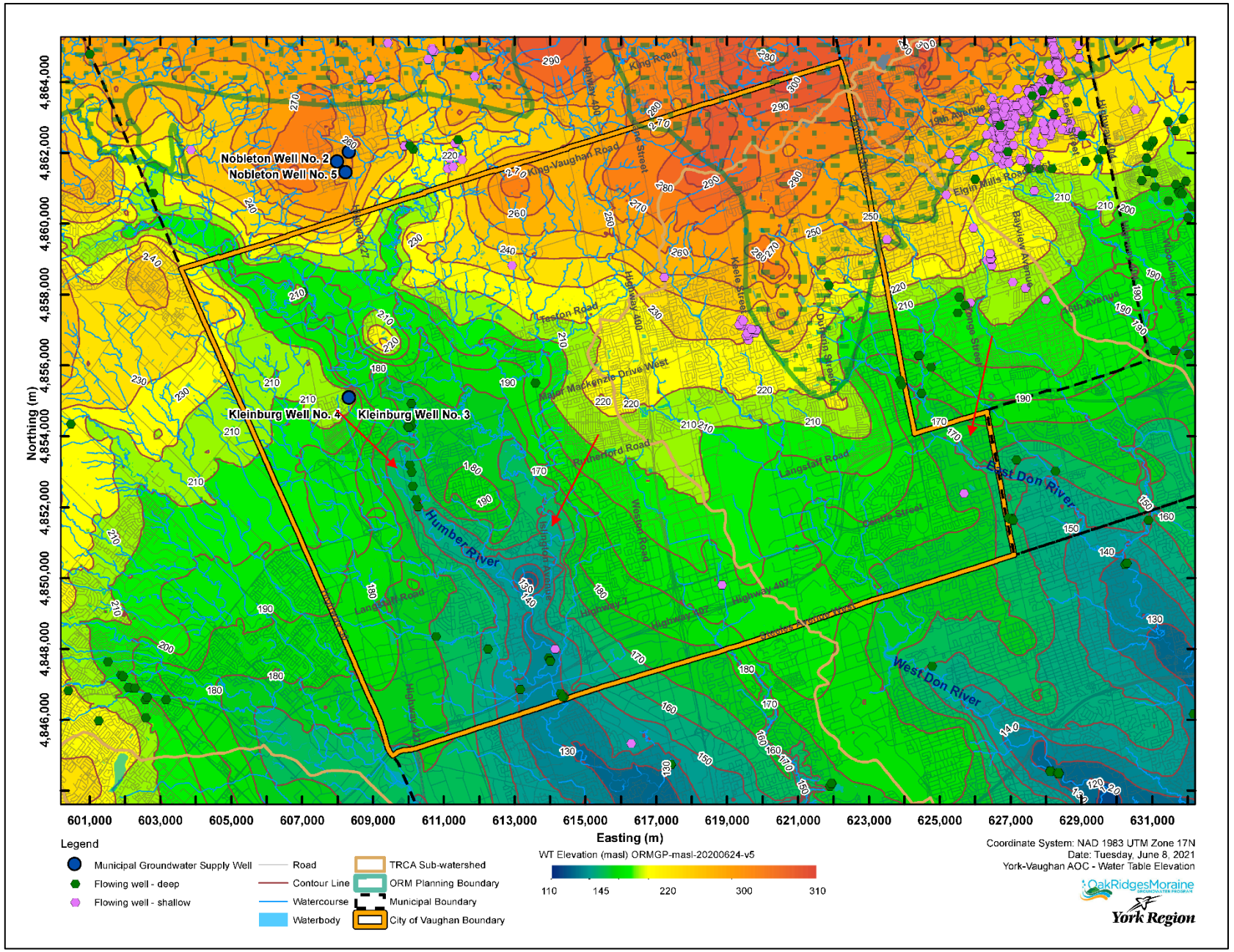


Figure 6: Interpreted water table elevation and direction of shallow groundwater flow. Metadata are included as Appendix C.

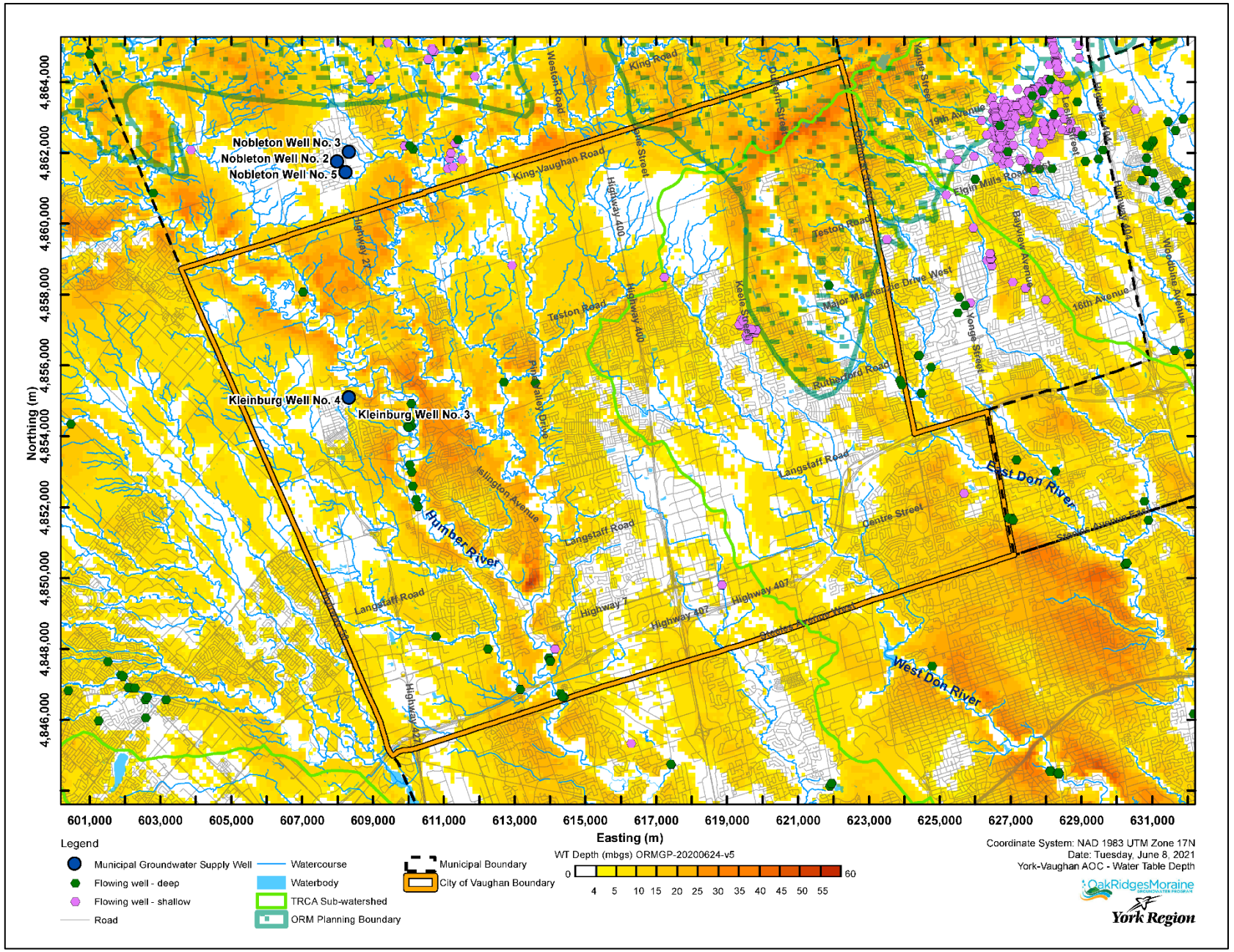


Figure 7: Interpreted water table depth in metres below ground surface.

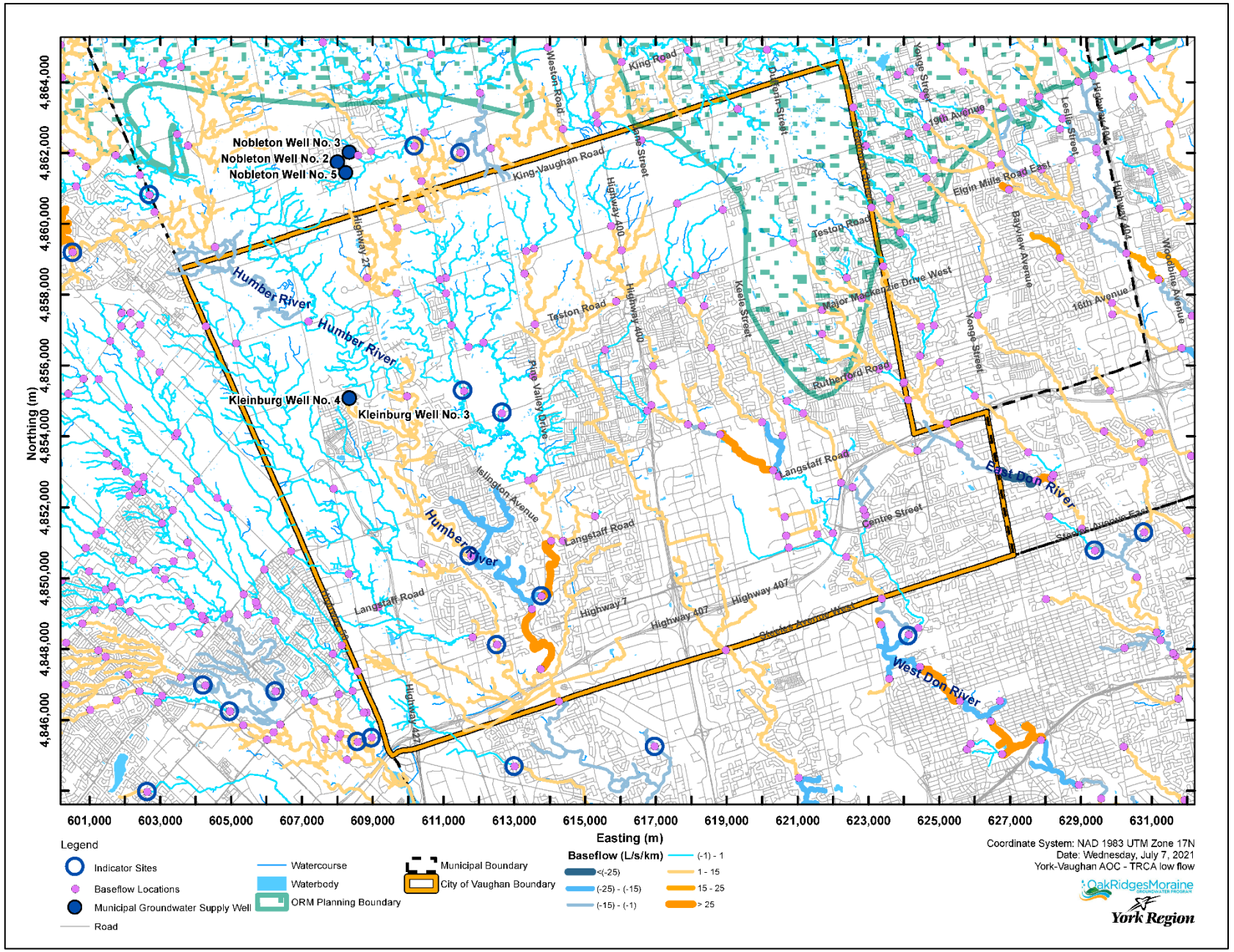


Figure 8: Summary of TRCA low flow streamflow surveys. Figure adapted from TRCA, 2007.

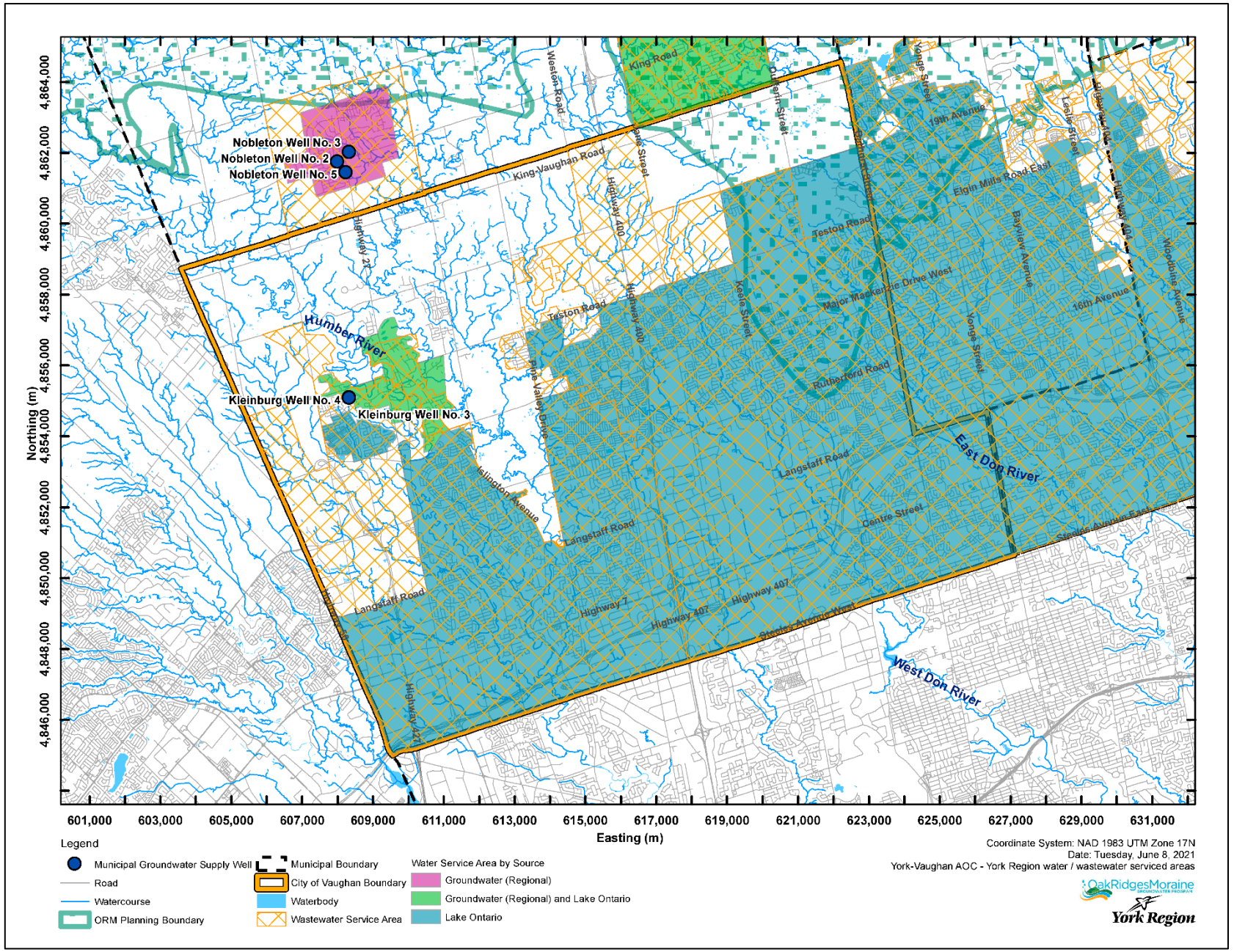


Figure 9: York Region municipally serviced areas - water systems and wastewater systems (York Region, 2016).

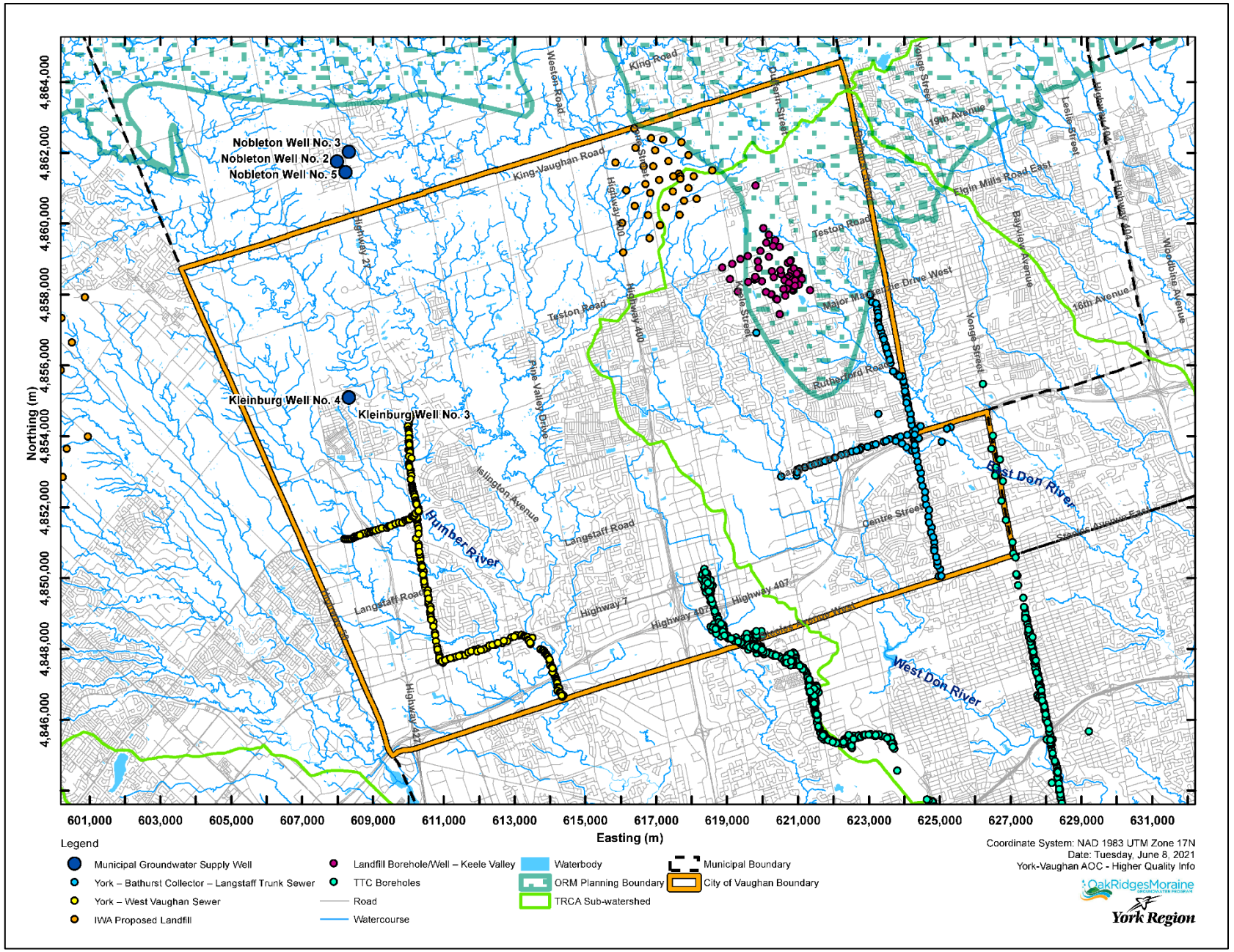


Figure 10: Locations of 'higher' quality information used to interpret subsurface conditions within the study area.

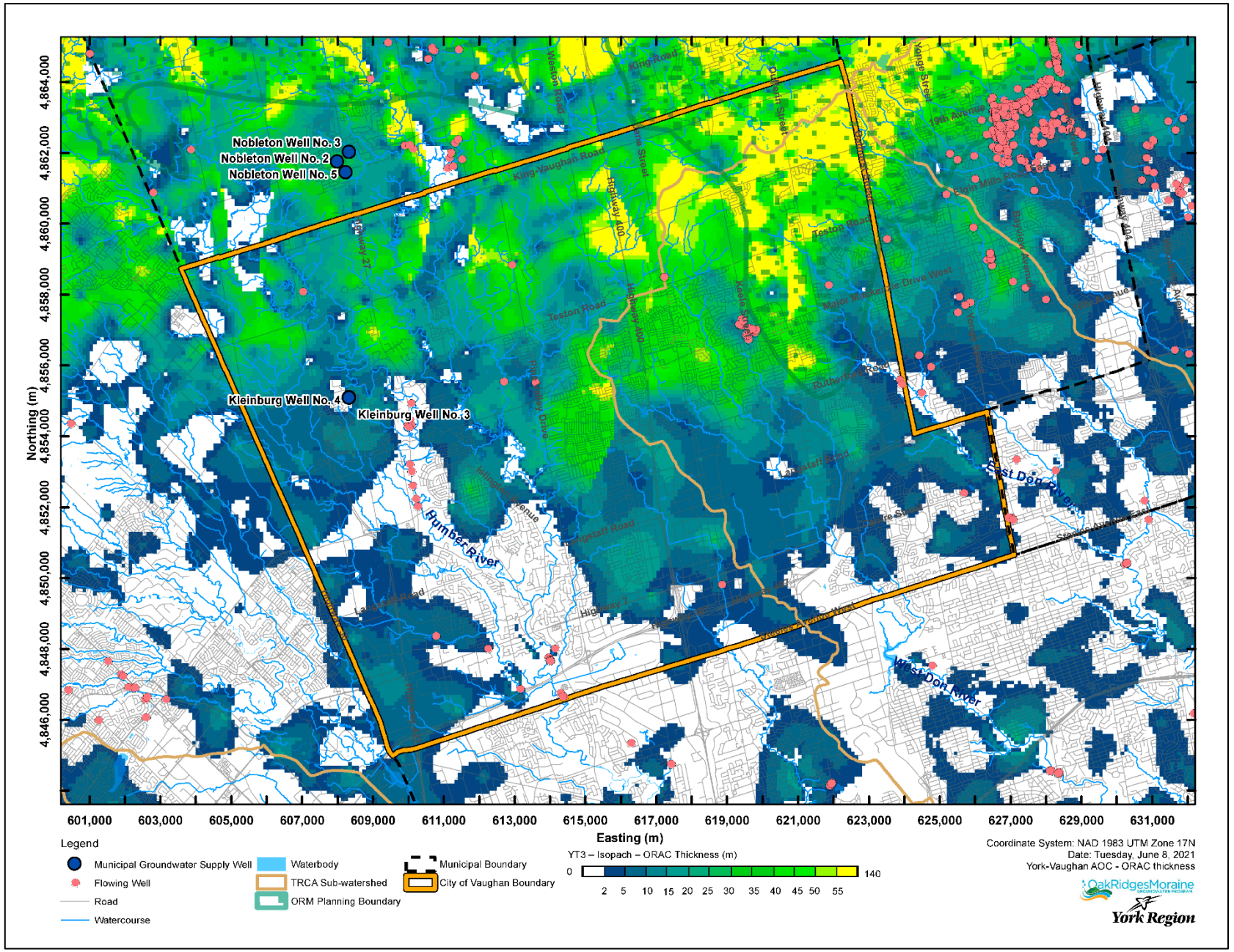


Figure 11: Areas where interpreted ORAC thickness is greater than 2m. Interpretation from Earthfx Inc., 2014.

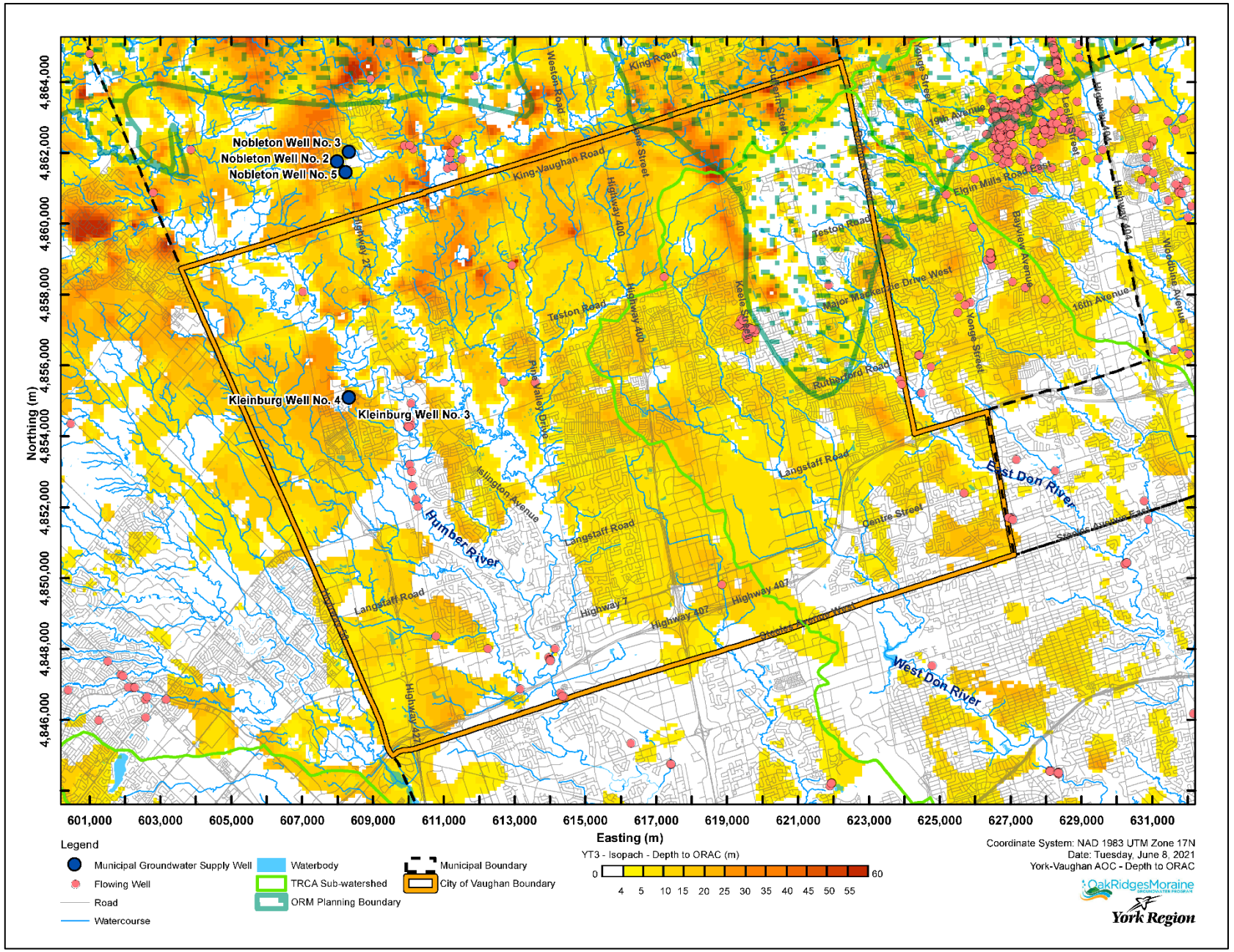


Figure 12: Interpreted depth to ORAC (m). Interpretation from Earthfx Inc., 2014.

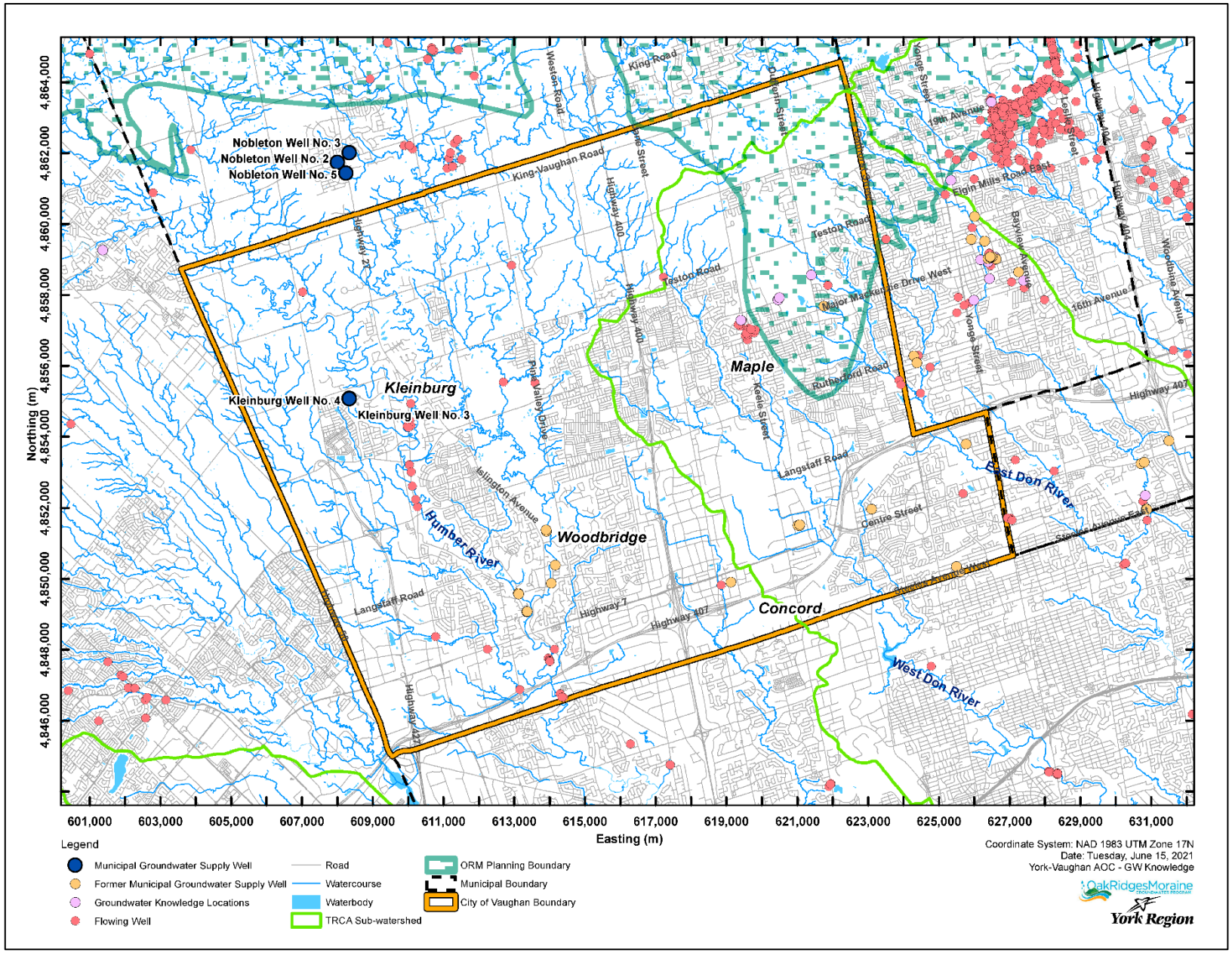


Figure 13: Groundwater Knowledge locations. Three currently occur near Maple and represent areas where historical higher yielding wells were located (Maple Community Centre, Keele Valley landfill, MNR fish hatchery).

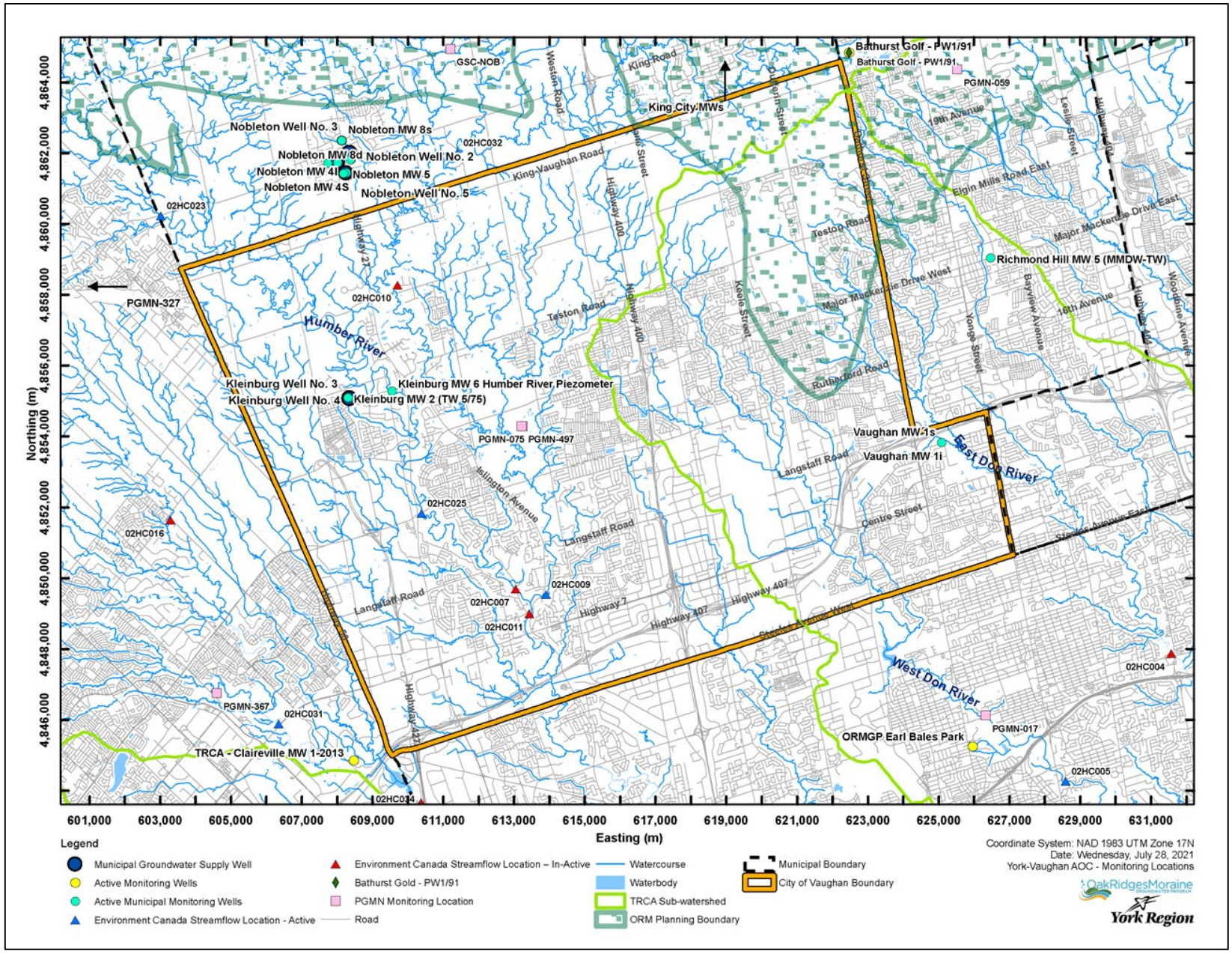


Figure 14: Streamflow and groundwater monitoring locations. King City and PGMN327/Bolton monitoring wells are slightly outside of the figure extents as illustrated by arrows.

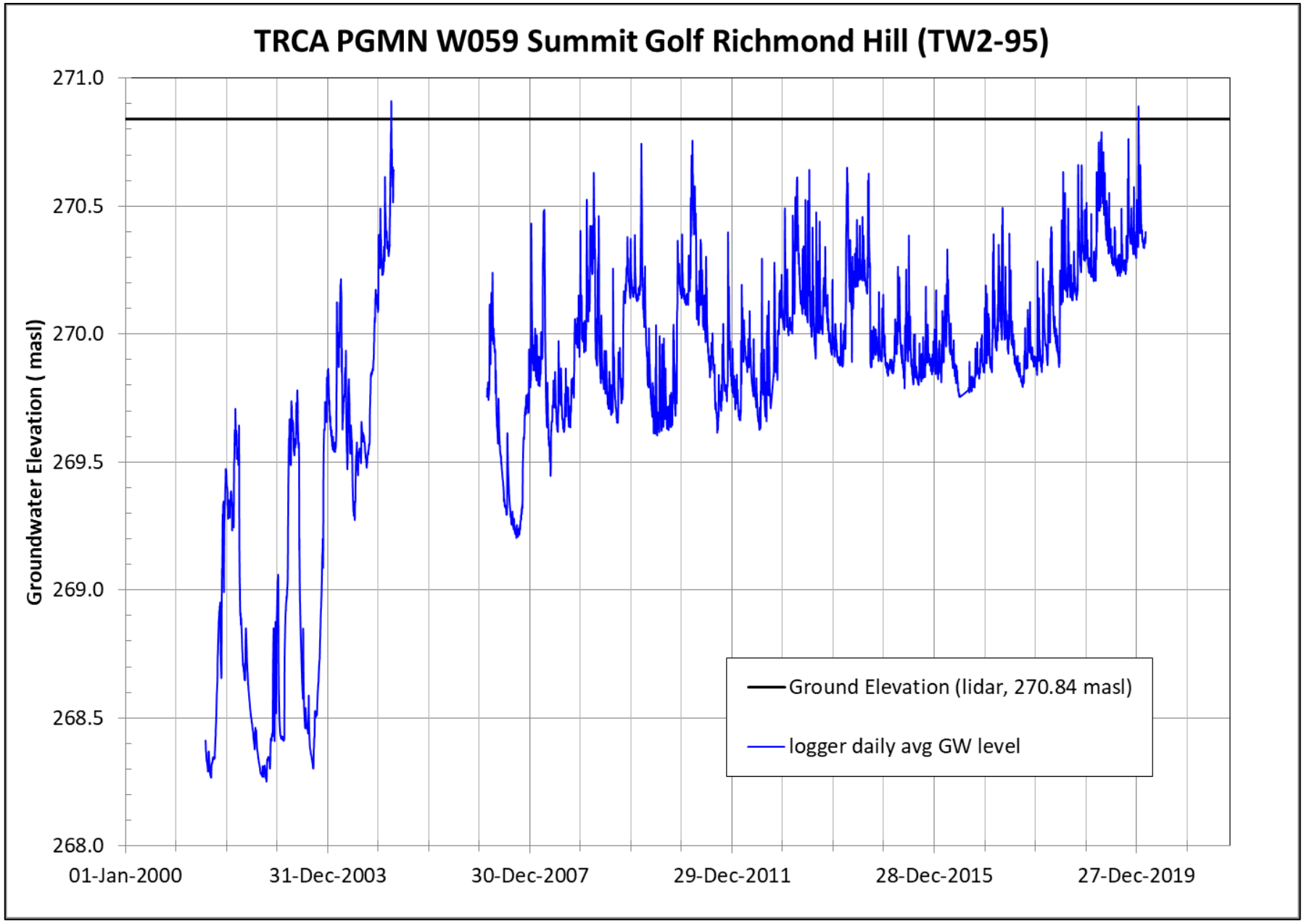


Figure 15: Daily average groundwater levels for TRCA PGMN W059 Summit Golf Course. Data from TRCA. See Figure 14 for location.

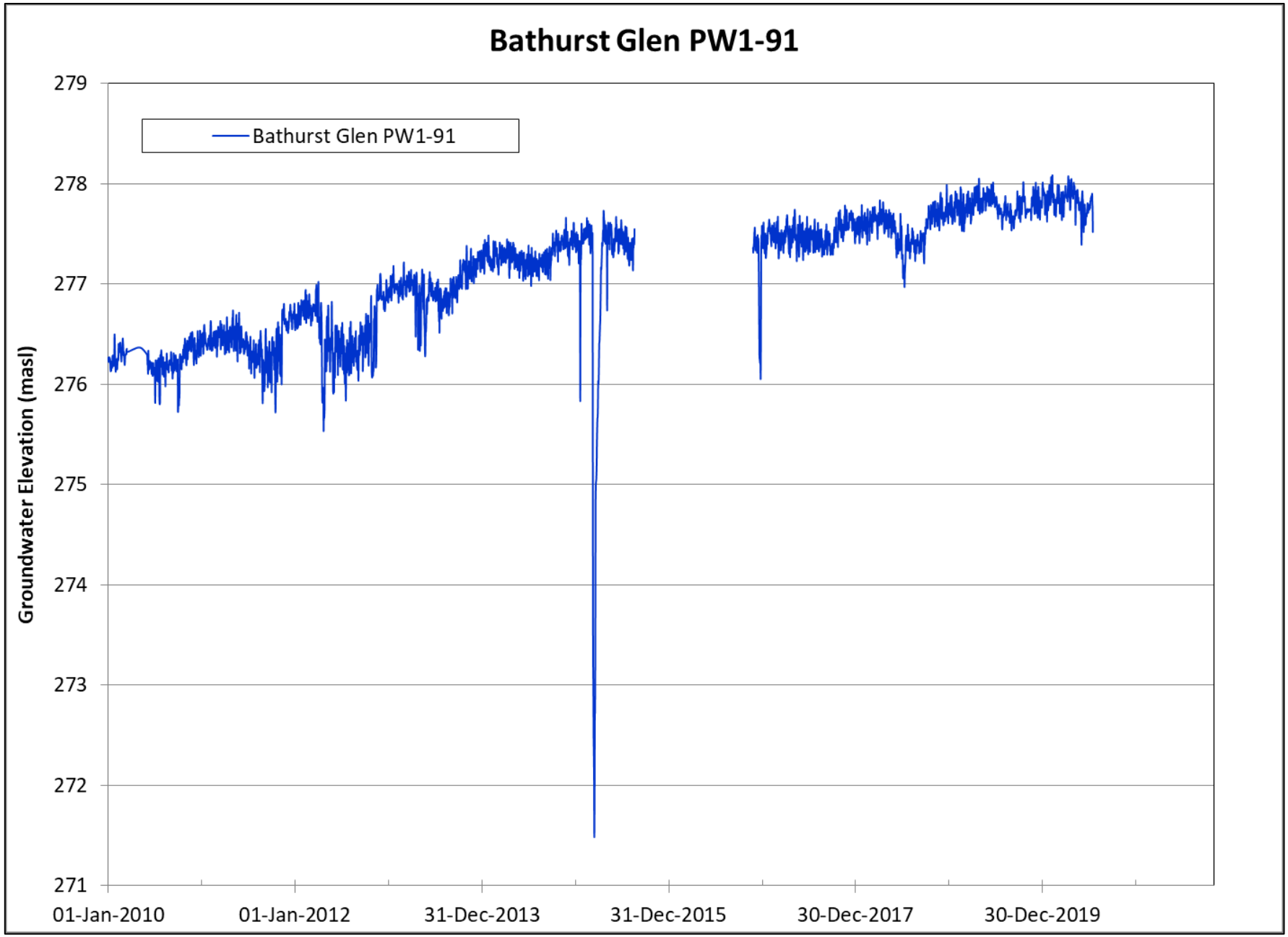


Figure 16: Observed groundwater levels at Bathurst Glen Golf Course PW1-91. Data from TRCA.

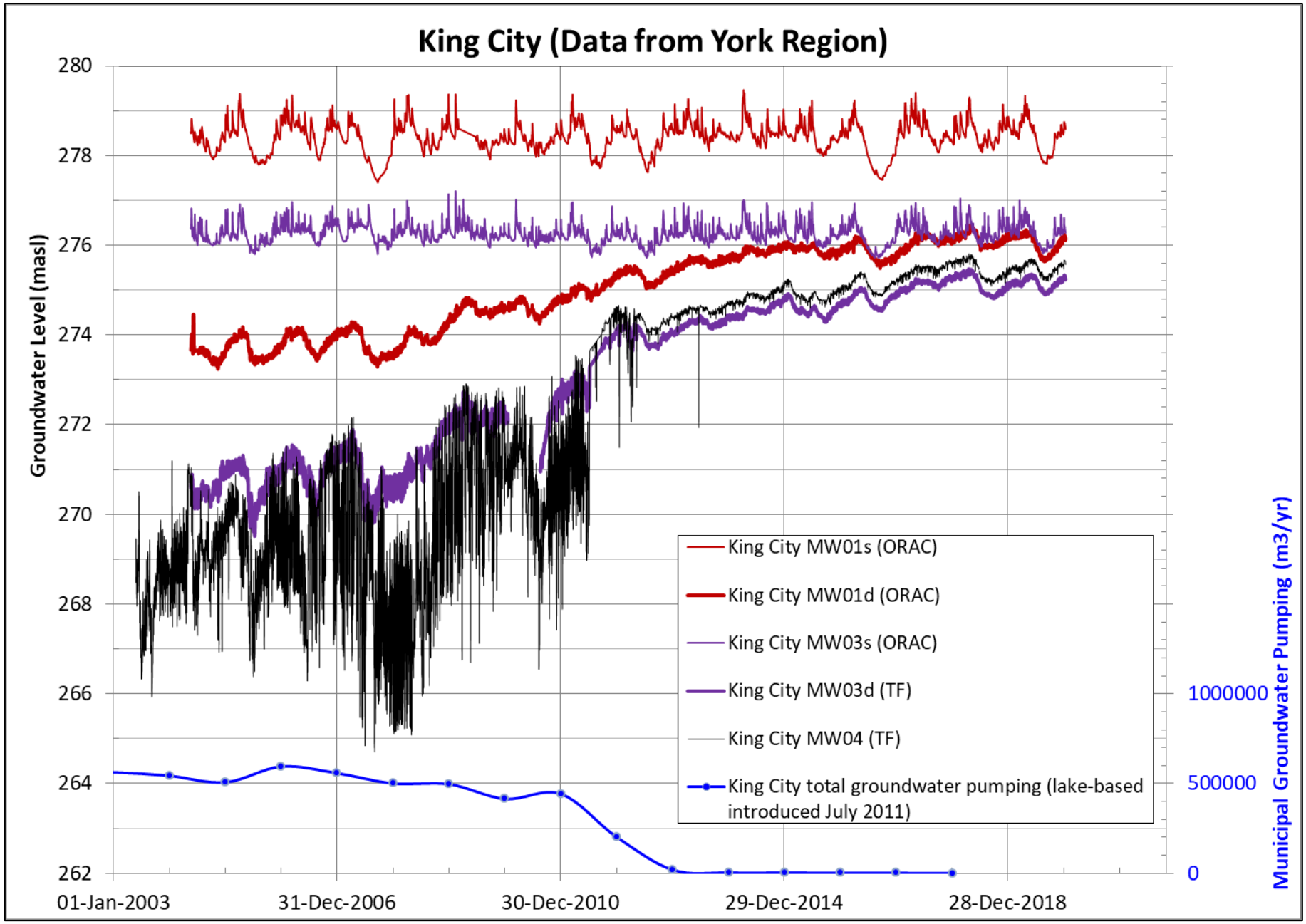


Figure 17: Observed groundwater levels at King City. Data from York Region.

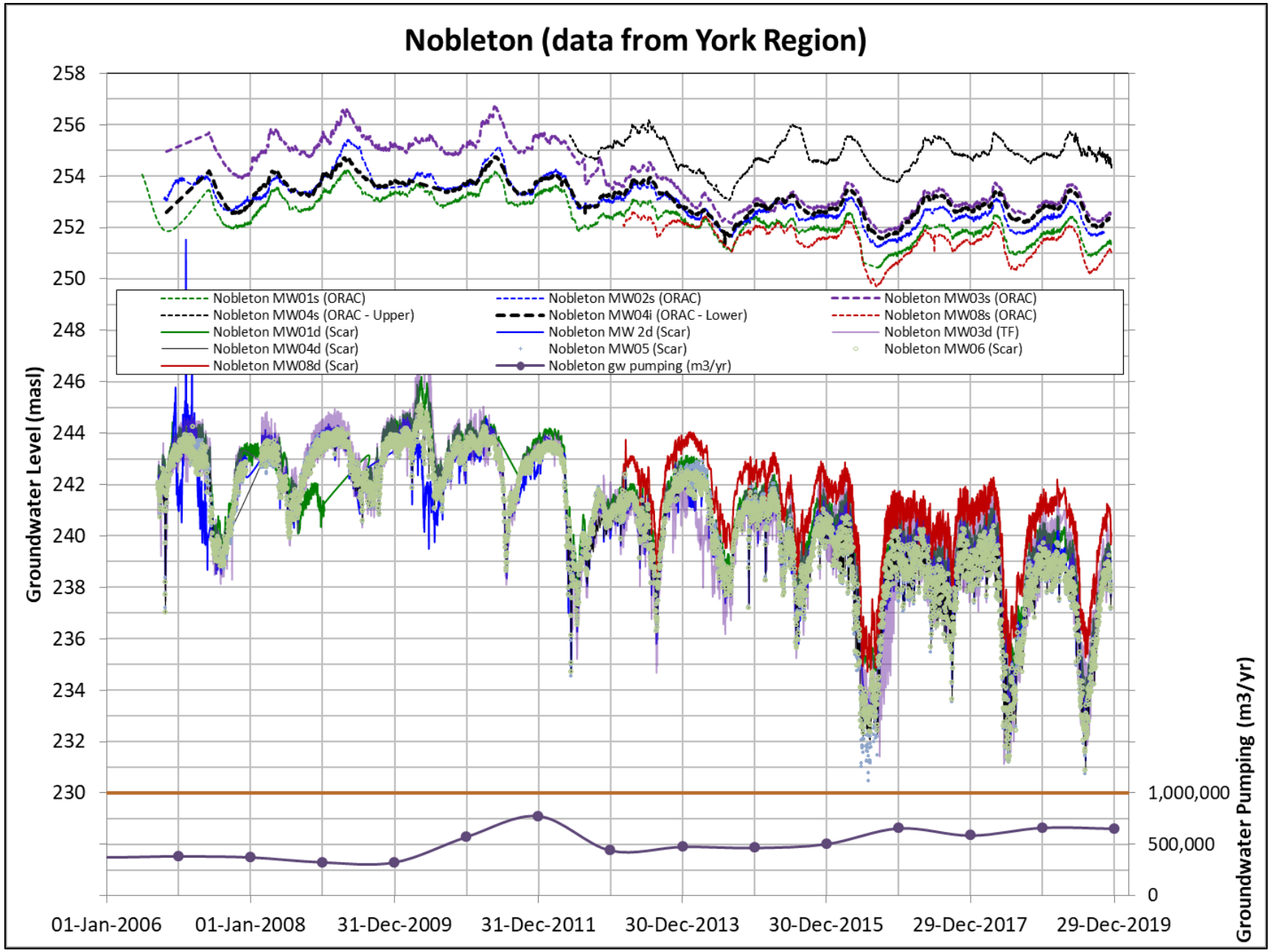


Figure 18: Observed groundwater levels at Nobleton. Data from York Region.

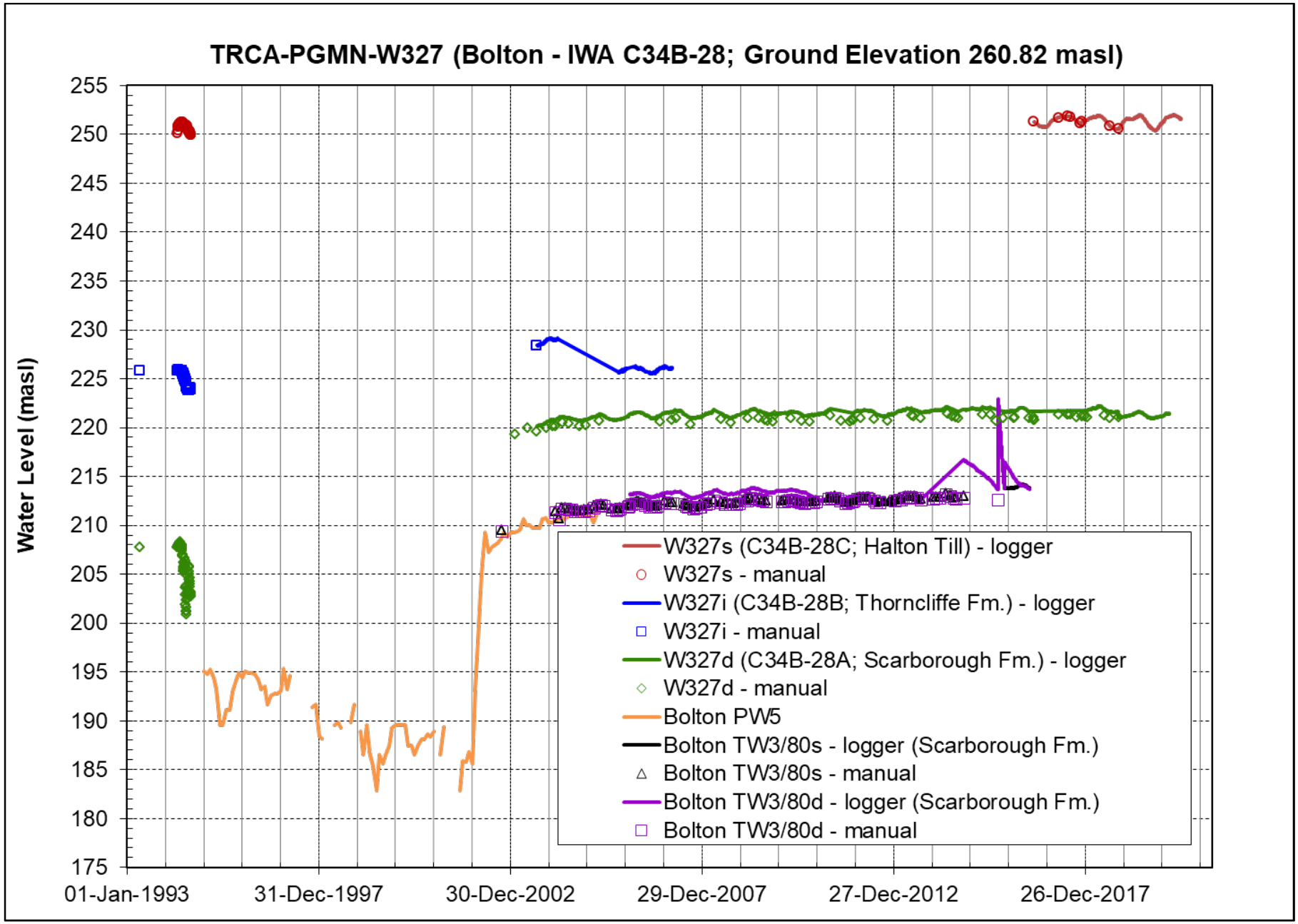


Figure 19: Observed groundwater levels at Bolton. Data from Peel Region and TRCA.

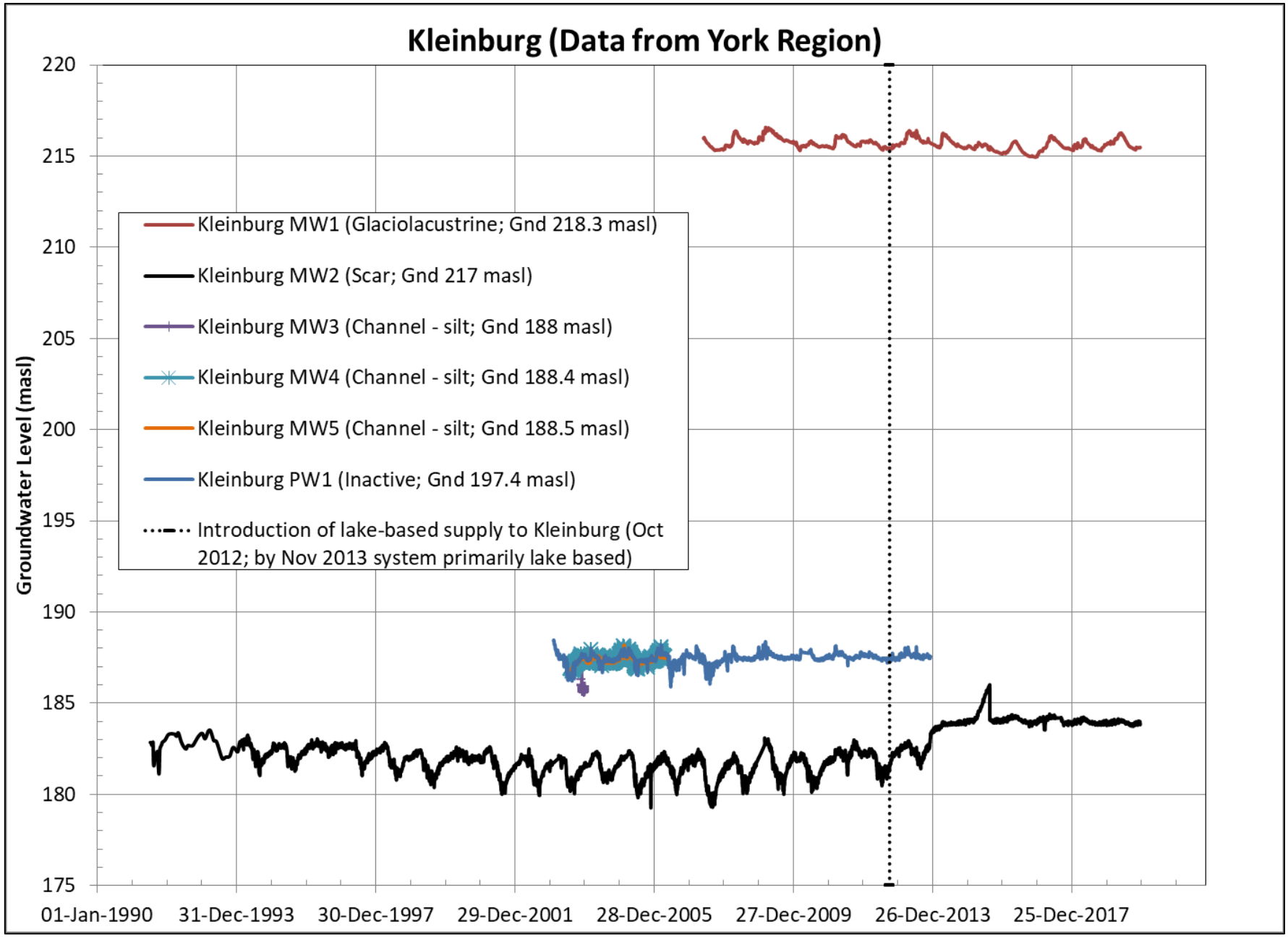


Figure 20: Observed groundwater levels in Kleinburg. Data from York Region.

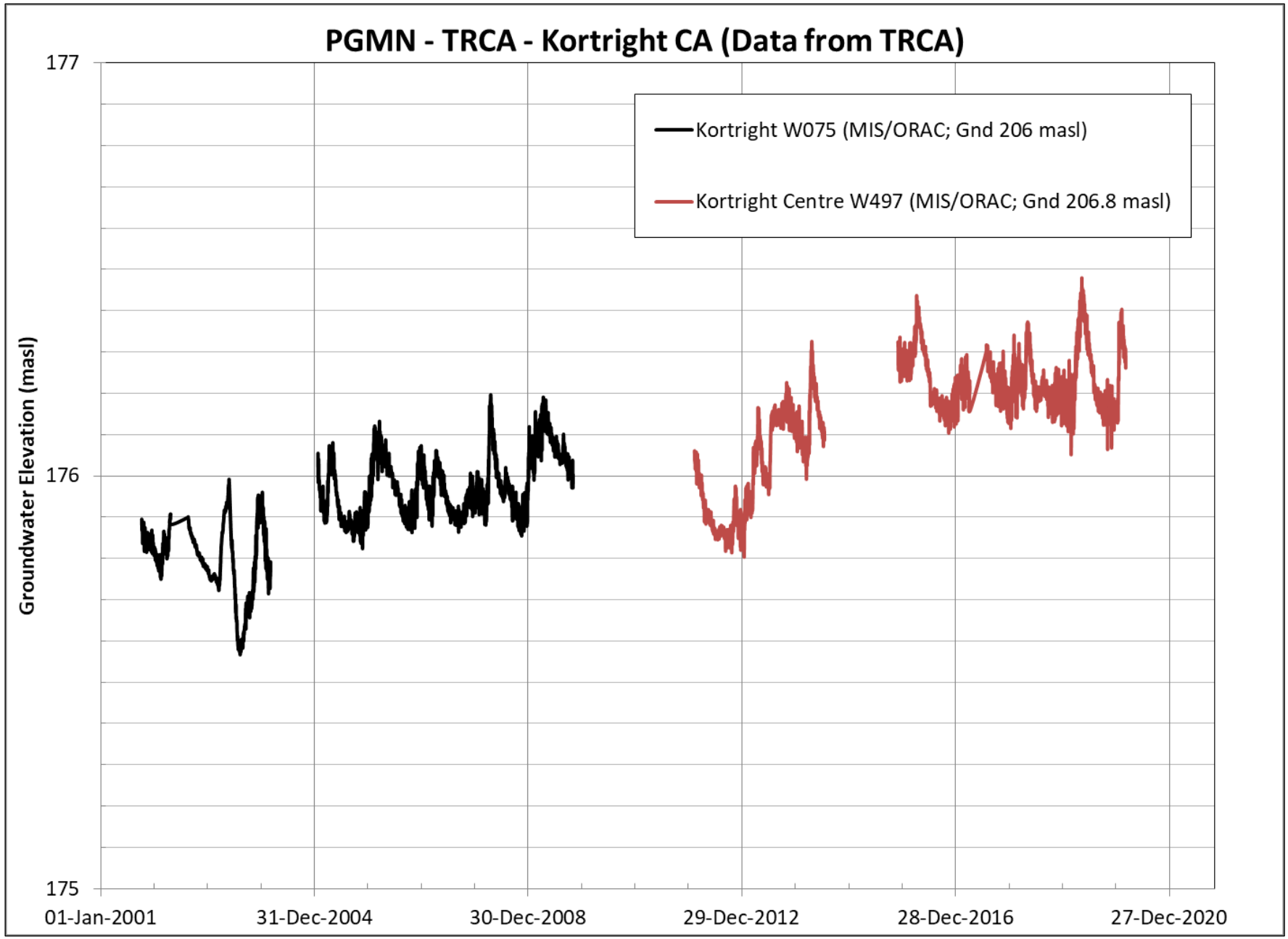


Figure 21: Observed groundwater levels at Kortright Conservation Area. Data from TRCA.

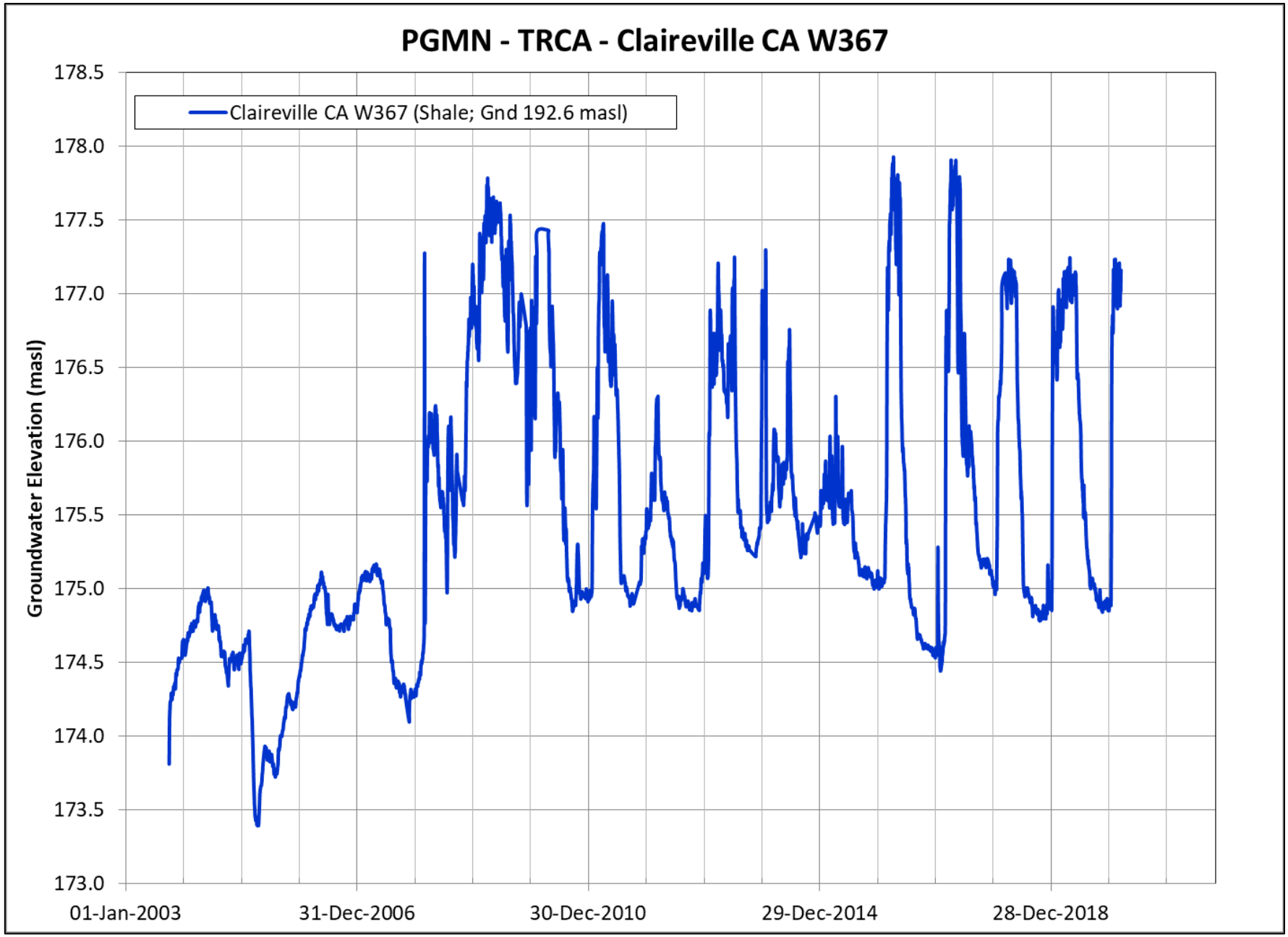


Figure 22: Observed groundwater levels at Claireville Conservation Area (PGMN-367). Data from TRCA.

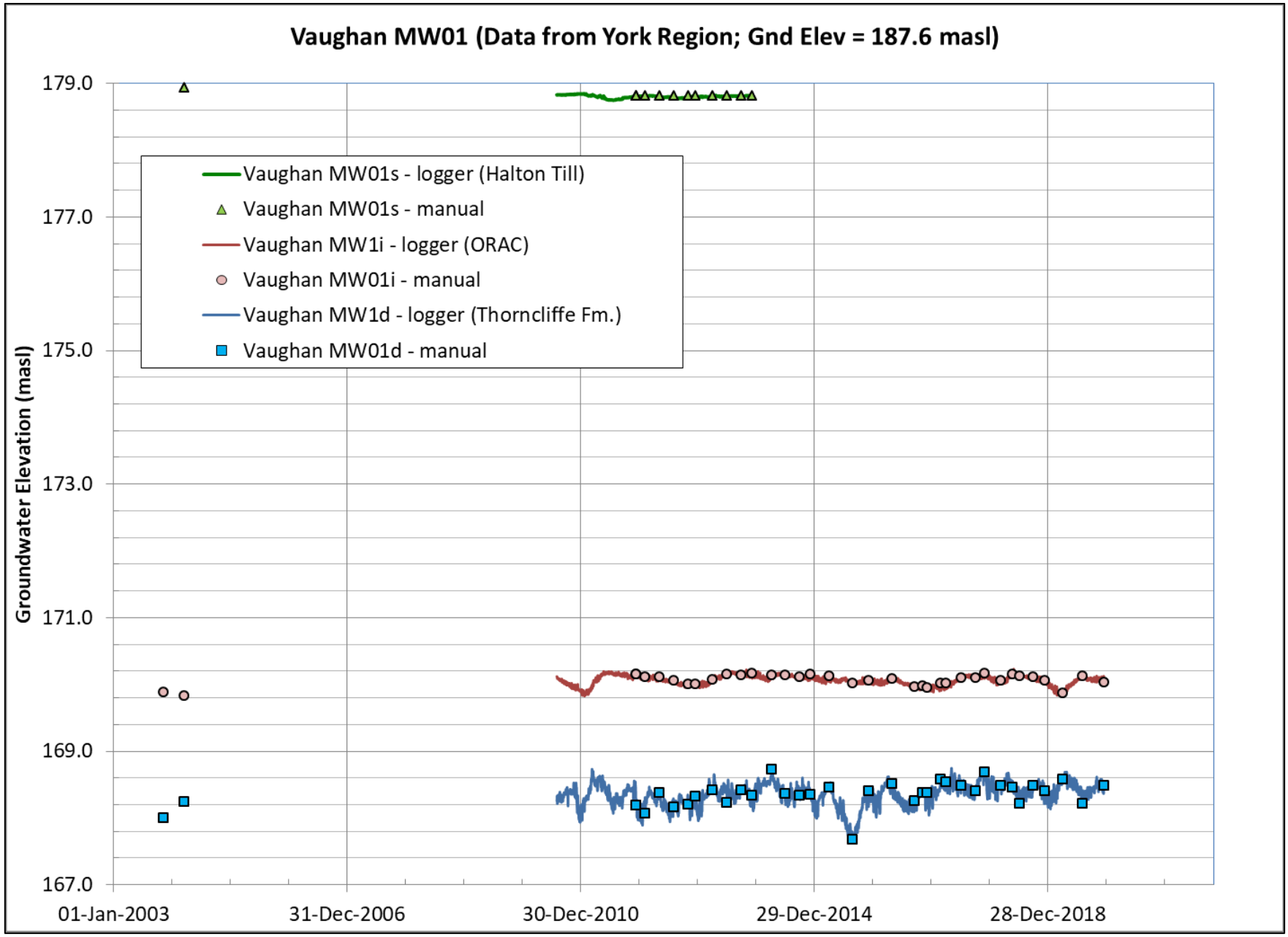


Figure 23: Observed groundwater levels at Vaughan MW01 location. Data from York Region.

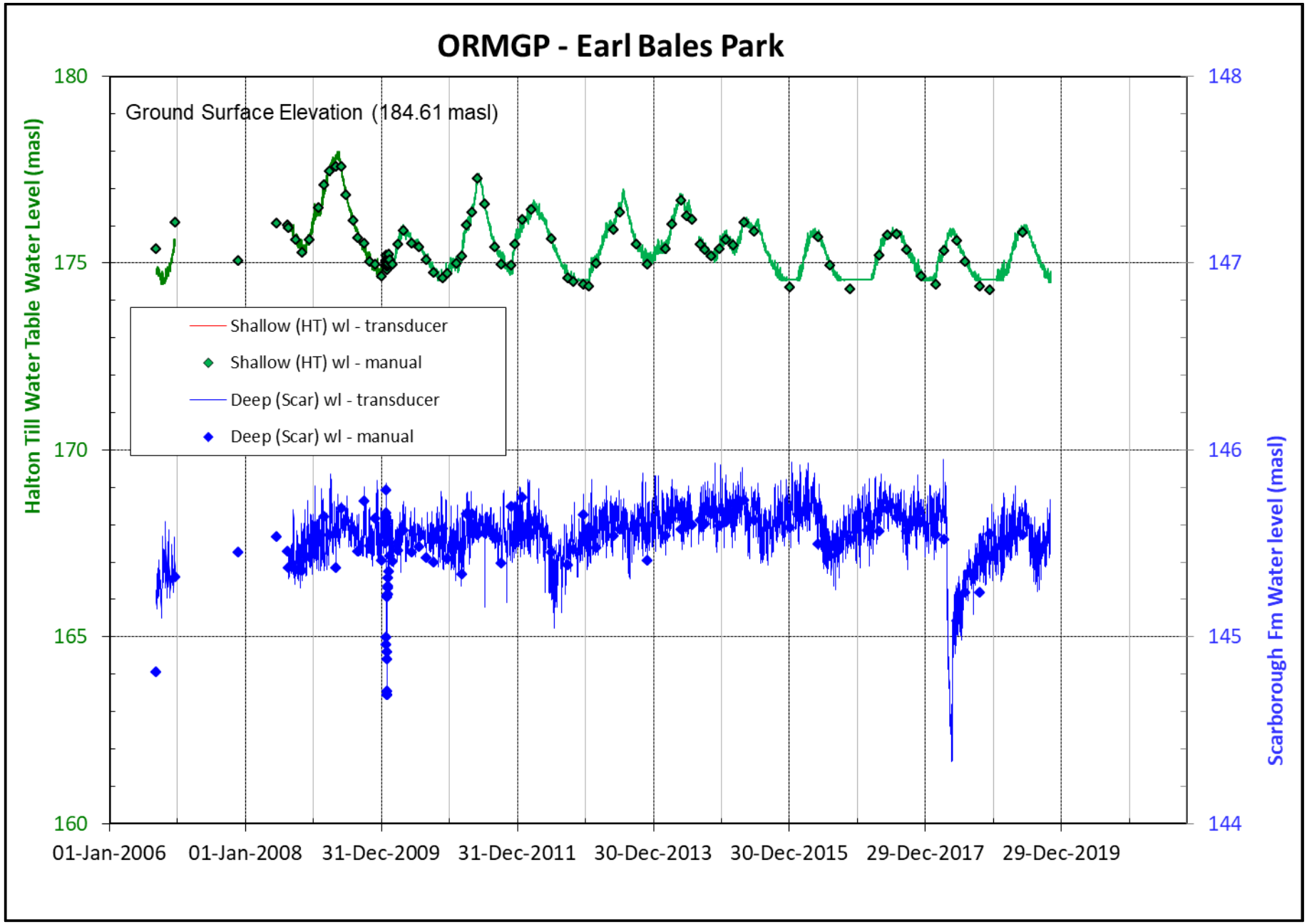


Figure 24: Observed groundwater levels at Earl Bales Park. Data from ORMGP.

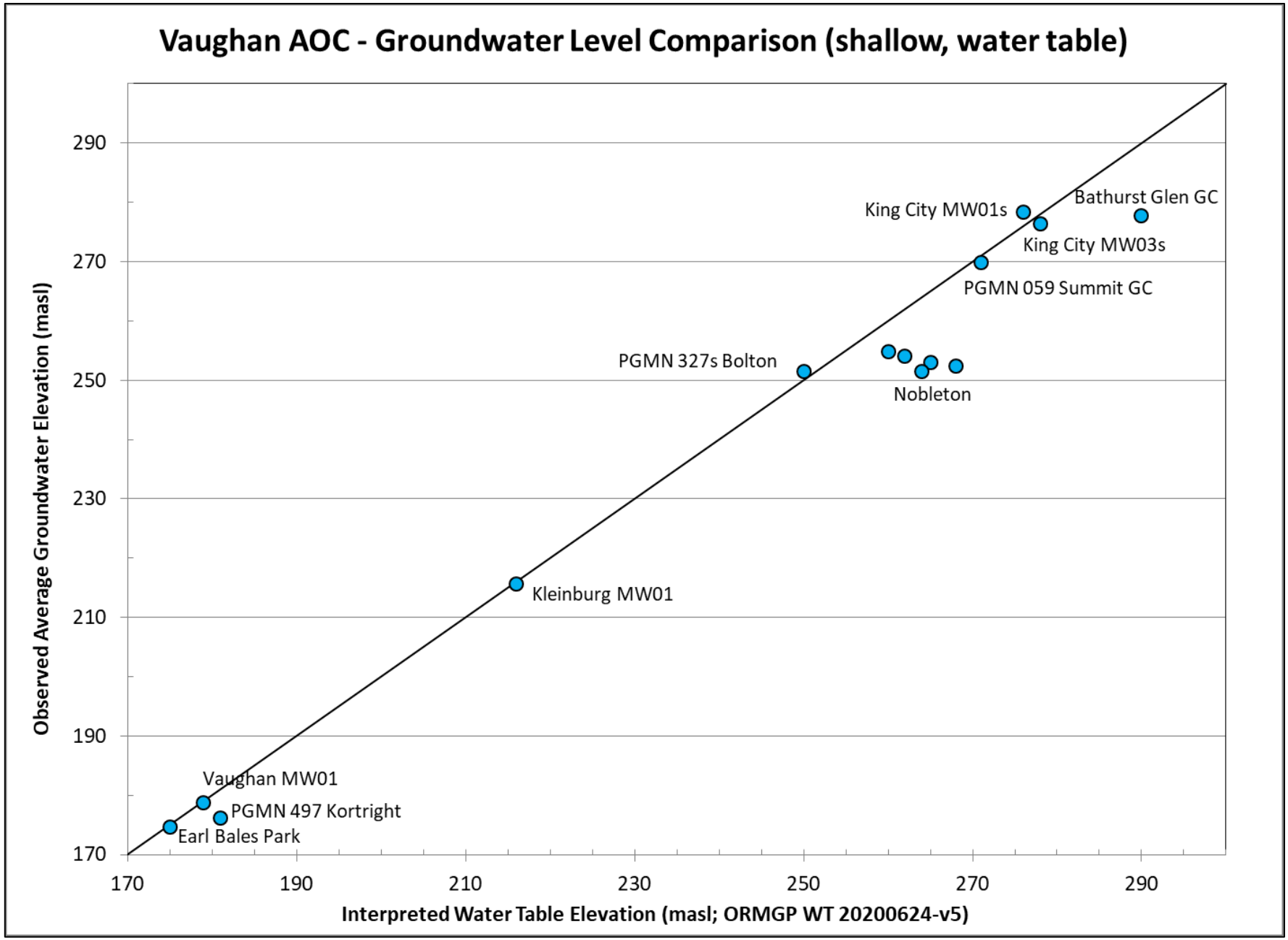


Figure 25: Interpreted average water table elevation versus observed groundwater elevation at long-term monitoring location.

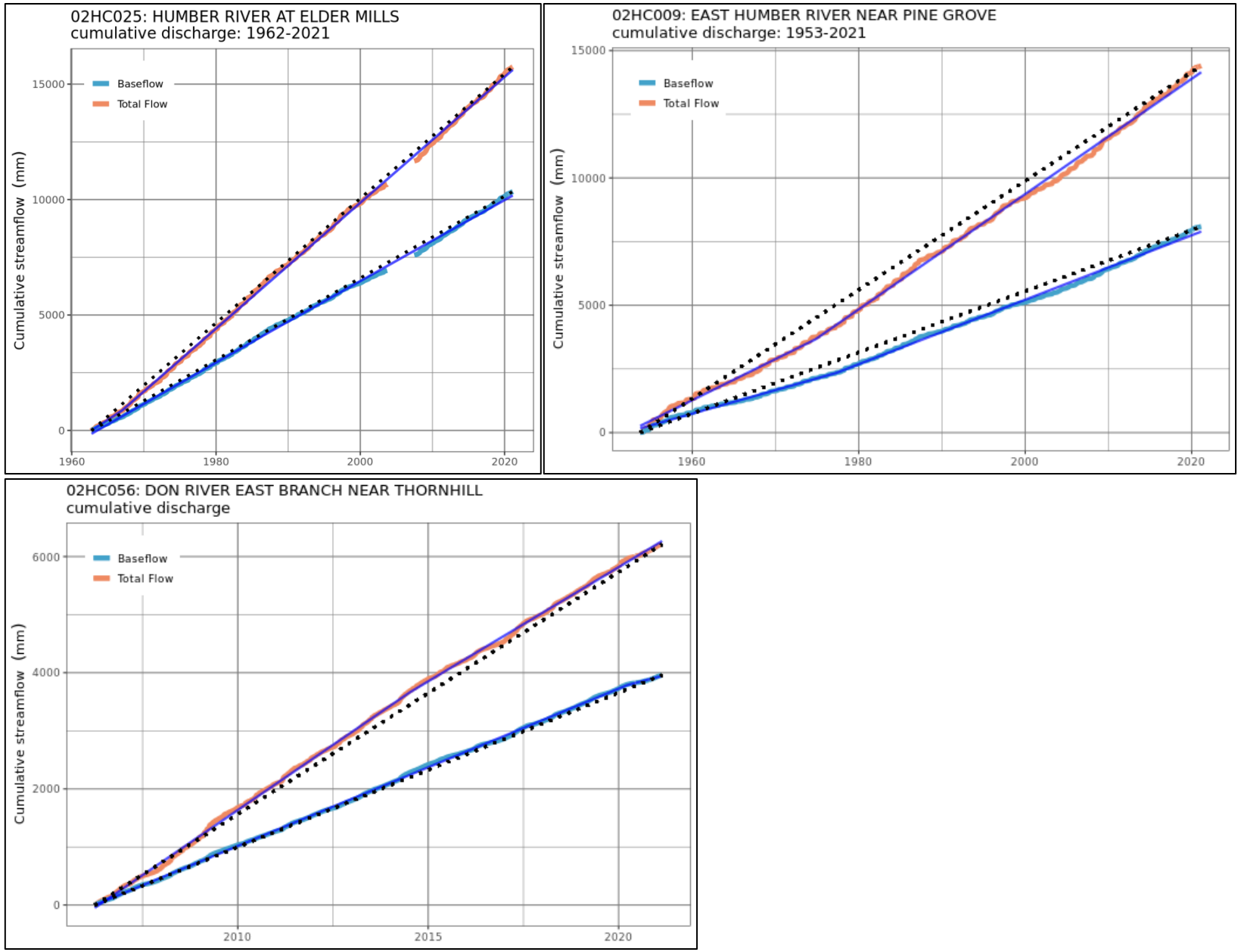


Figure 26: Cumulative discharge curves for three Environment Canada streamflow gauges situated within Vaughan. Cumulative discharge figures prepared using streamflow hydrograph analysis tools located at www.oakridgeswater.ca.

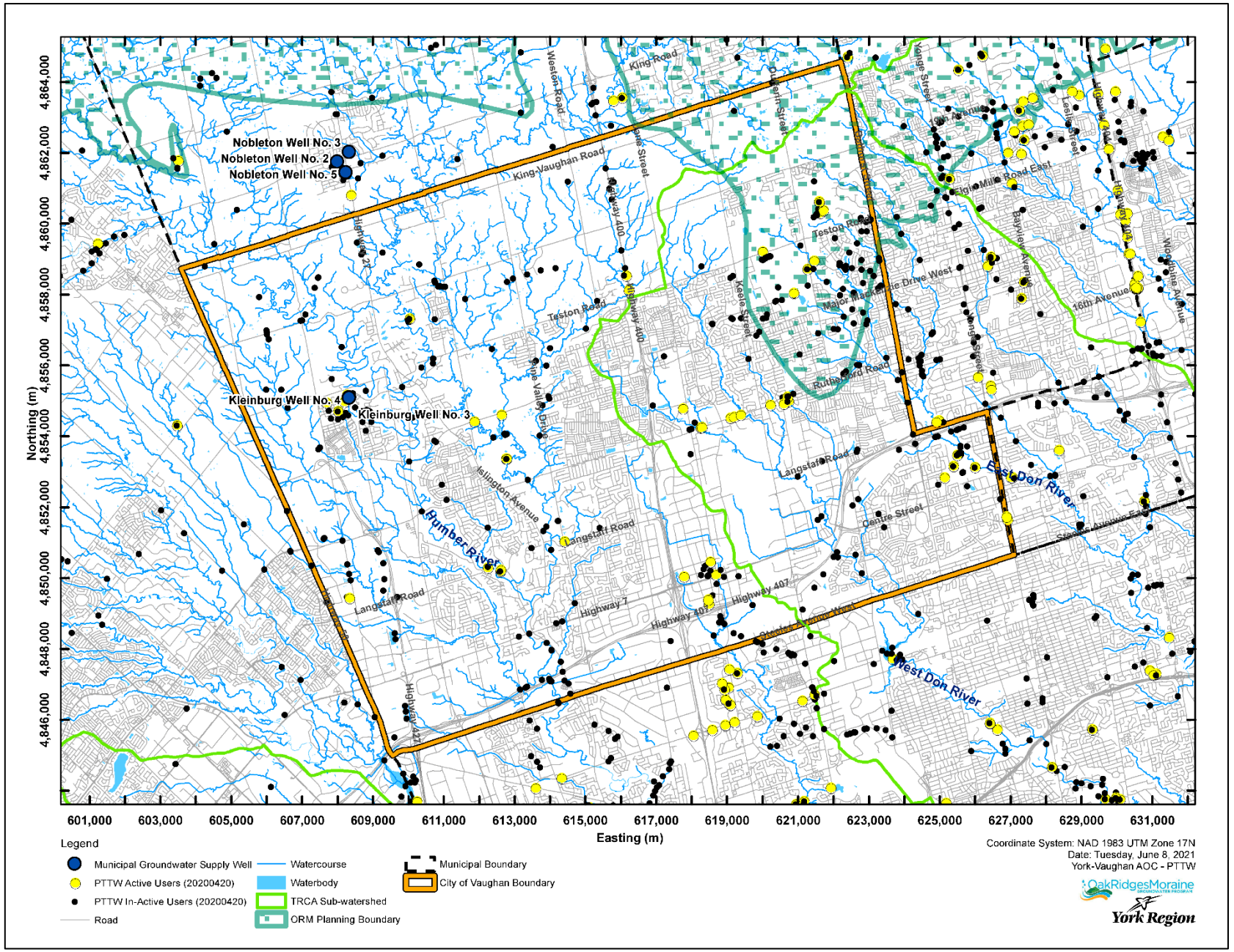


Figure 27: MECP Permit to Take Water (PTTW) locations (as of 20-April-2020; MECP database).

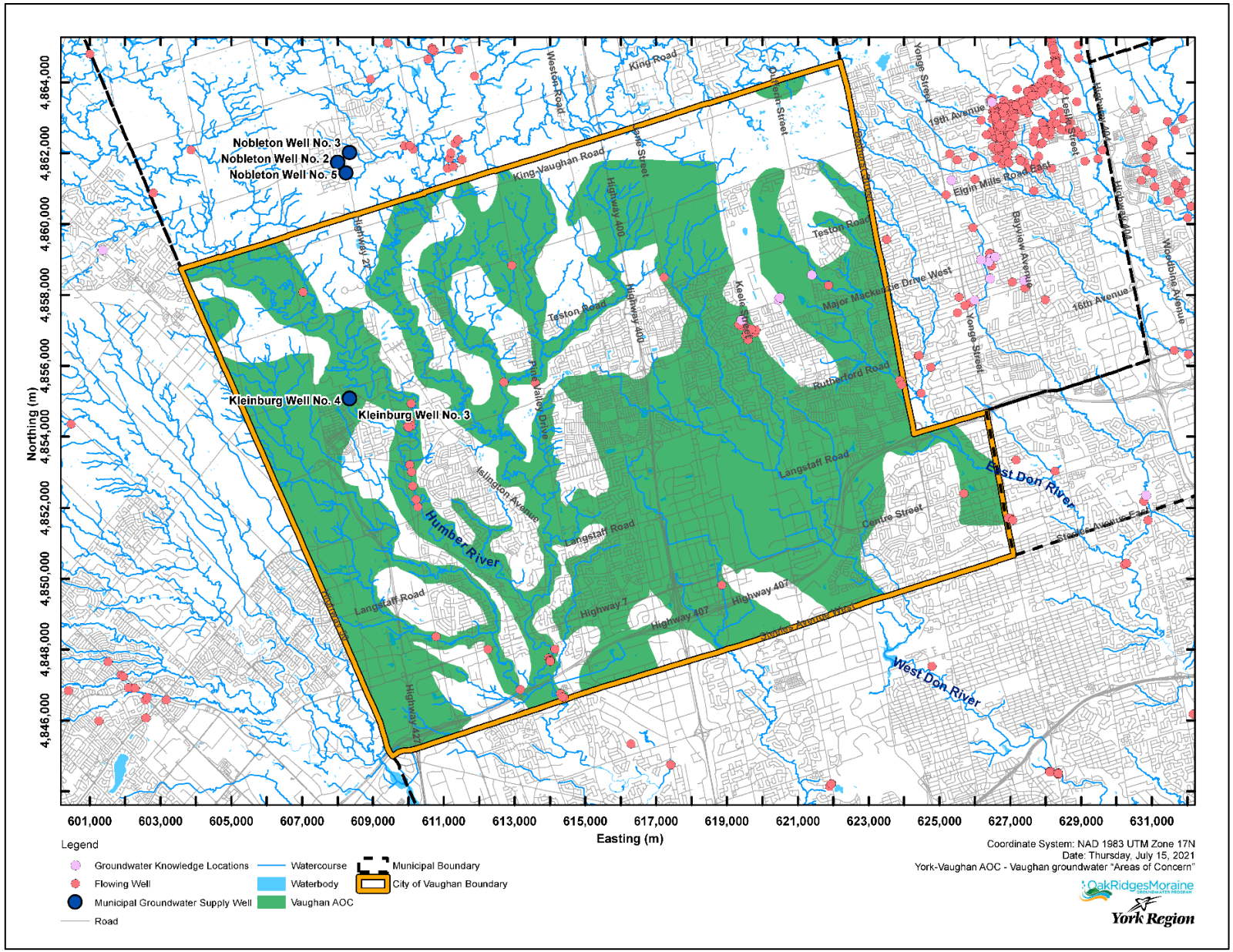
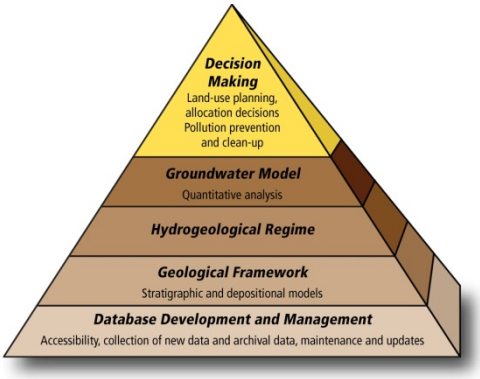


Figure 28: Vaughan study area groundwater "Areas of Concern" (shaded). Given understanding of groundwater flow system presented in this memo, shaded area generally conforms to where interpreted water table is < 4 m below ground surface. Note that the ORAC is interpreted to occur throughout much of the City of Vaughan area.

Appendix A: Oak Ridges Moraine Groundwater Program

The Oak Ridges Moraine Groundwater Program (ORMGP) was initiated in 2001, driven by the encroachment of development onto the Oak Ridges Moraine and the recognition of an absence of high-quality environmental data and analyses, particularly with respect to groundwater. Since inception, the program has provided partner agencies with an actively managed water-related database and the regional geological and groundwater context for on-going day-to-day water resource management activities (e.g., development review, PTTW review, watershed management, source water protection, etc.). The framework for the program is succinctly summarized in the adjacent figure, taken from the Council of Canadian Academies 2009 report "The Sustainable Management of Groundwater in Canada."



Mandate

The mandate of the ORMGP partnership is to provide a multi-agency, collaborative approach to collecting, analyzing, and disseminating water resource data as a basis for effective stewardship of water resources. The ORMGP builds, maintains, and provides to partnered agencies the regional geological and hydrogeological context for ongoing groundwater studies and management initiatives within the partnership area.

As such the program will:

- Build and maintain a master database of water-related information that is accessible to all partner agencies;
- Build and maintain a digital geological construction of the subsurface layers that is accessible to all partner agencies;
- Build and maintain a numerical groundwater flow model(s) that can be used to address any number of issues that arise at any of the partner agencies;
- Coordinate and lead investigations that will acquire new field data that will strategically infill key data gaps;
- Provide technical support to Source Water Protection Teams to ensure that interpretations used in source water are consistent with the regional understanding;
- Provide technical support to planning authorities to ensure that Official Plan policies are developed in a manner which makes them consistent with up-to-date groundwater science as derived from the project; and
- Provide technical support to all partnered agencies for addressing other Provincial legislation.

Further information regarding the program can be found at www.oakridgeswater.ca.

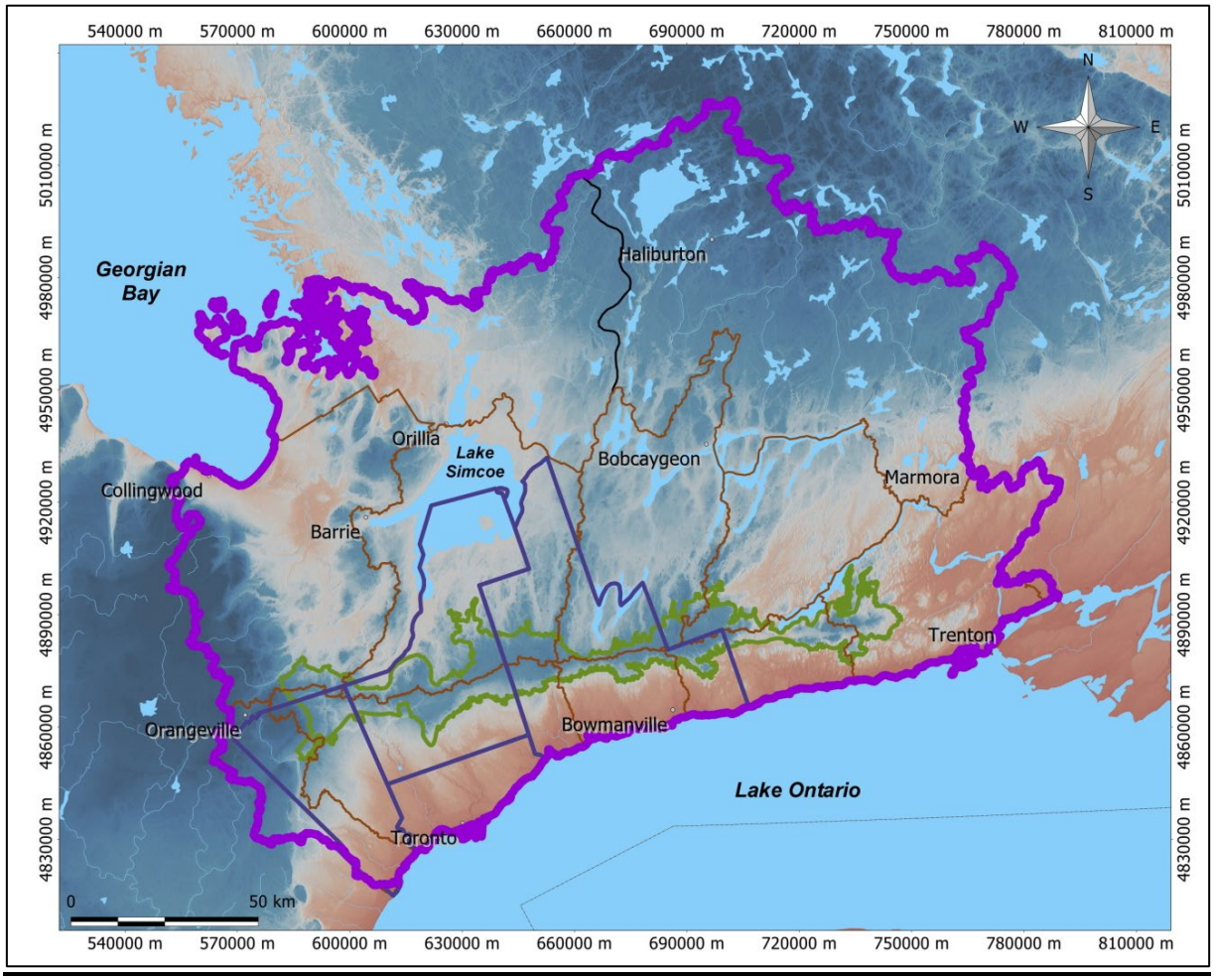


Figure A1: Oak Ridges Moraine Groundwater Program (ORMGP) area. Note that for data management purposes the program area comprises the entirety of three Source Water Protection Regions: 1) Credit/Toronto/Central Lake Ontario (CTC); 2) Southern Georgian Bay – Lake Simcoe (SGBLS); and 3) Lower Trent (TCC). Focus of work is largely directed to the GTA municipalities (York, Peel, Durham, and Toronto) and their associated Conservation Authorities (CA).

Appendix B: Areas of Concern Mapping Qualifying Statement

The purpose of this map is to provide generalized information for discussion and planning purposes only. It is intended to act as a flag of possible areas where hydrogeologic conditions exist that the user (planners, project managers, decision-makers) should be made aware of, as these conditions may have cost implications. It must not be used for actual design purposes. Due diligence must be exercised in any site-specific undertaking. This map was prepared utilizing existing information which was available at the time the mapping was conducted. New information may alter the interpretation shown. The information sources used, and the assumptions made regarding the preparation of this mapping are included in the accompanying descriptive text. Locations situated outside of mapped Areas of Concern may contain unknown conditions that are of concern.

Appendix C: Water Table Metadata (v20200624)

NAME	Water Table Surface and Depth to Water Table - June 2020
Description	The Water Table surface reflects the elevation (in mASL) of the saturated water table. The map can be used to estimate the direction and gradient of groundwater flow in the shallow sediment/rock beneath any area.
Type	Raster - Gridded on 100 m Cells. 50 m cell working resolution resampled to 100 m cell final grid.
Geographic Extent	Entire ORMGP Area (+25 km buffer).
Maintenance Standard	Periodically updated as new wells come into ORMGP database
GEOREFERENCING AND ACCURACY	
Horizontal Datum	North American Datum 1983
Vertical Reference	Well elevations set to MNR DEM (2006 Version 2 - 10 m cell resolution) based on well locations (see Horizontal Accuracy below)
Spatial Projection	NAD83 UTM Zone 17N
Horizontal Accuracy	Based on accuracy of well locations - see ORMGP Database Manual
DATA SOURCES AND RESTRICTIONS	
Access Constraint	
Use Constraint	None - in accordance with ORMGP Disclaimer
Citation	Oak Ridges Moraine Groundwater Program (2020) Water Table.
Agency Originator	Oak Ridges Moraine Groundwater Program (ORMGP)
Agency Distributor	Oak Ridges Moraine Groundwater Program (ORMGP)
Online Link	
METHODOLOGY	
Data source: wells	The Water Table was created by contouring the static water levels from all wells (ORMGP database, as of 20200624) where the bottom of the well is less than 20 m deep. Wells up to 50 m deep were incorporated within the Oak Ridges Moraine boundary. It should be noted that the measured static water levels reflect measurements from wells that were drilled in all seasons as well as in wetter and dryer years. So the water table presented here is the average water table. For wells with more than one measurement all water levels are averaged. Given the dynamic nature of the groundwater system, it should be noted that the actual water table at any given time of year may be on the order of up to 2 or 3 metres higher or lower than reflected in the map.
Data source: water bodies (lakes)	Each of Lake Ontario, Lake Simcoe and Georgian Bay were extracted from the 'Ontario Hydrographic Network - Water Bodies' dataset (20110623). These were converted from polygons to points and assigned a standard elevation (Georgian Bay - 176 masl; Lake Simcoe - 219 masl; Lake Ontario - 74 masl).
Data source: rivers	The river network was found in the 'Water Virtual Flow - Seamless Provincial Data Set, 2008'. This dataset was divided into two sets based upon the river segment Strahler Code: one set comprised of Strahler Codes greater than 3; and the second set comprised of Strahler Codes of either 3 or 2. Both sets were converted from polylines to points and tagged with elevations based upon the 'MNR DEM 10m v2' surface for the ORMGP study area. Strahler Class The sampling distance for this dataset was approximately 100m (along-stream). Points found within Georgian Bay, Lake Simcoe or Lake Ontario were removed (these would have been part of the original virtual flow network).
Rasterization	Each of the input datasets (i.e. shallow groundwater levels, water body shoreline points and river network points (Strahler Code > 3) were rasterized at a 50m resolution, then combined and averaged (for points falling within any particular raster cell).
Point density (for areas above Niagara Escarpment and north of Canadian Shield)	Because the water table appeared to be quite deep in some areas to the north and above the escarpment a routine was run to see if additional stream points could assist to reasonably raise the water table. A point density surface was created using bins/grids of 1000, 2000 and 5000m. The 2000m grid density surface provided a balance between the loose (1000m) and tight (5000m) surfaces (i.e. large unsampled areas versus small unsampled areas). Areas west of the escarpment and north of the Canadian Shield were found to have a low density of points to reasonably reflect the water table surface.
River network (Strahler codes 3, 2; for areas above Niagara Escarpment and north of Canadian Sheild)	Based upon the vectorized 2000m density surface, additional river network points (Strahler Codes 3 and 2) were added and rasterized to 50m resolution.
Interpolation	Interpolated in Surfer using Kriging (with the 'auto' model setting, i.e. 64 point search).
Depth correction (to curb Water Table from being above ground surface)	To select a reasonable depth for Water Table 'correction', an examination of the distribution/count of values across the depth range of 0 to 0.5m was undertaken. Given the fairly constant set of counts across the range, a 0.5m 'correction depth' was selected. At a 50m resolution, the Water Table was 'corrected' to a depth of 0.5 m below the DEM (DEM-0.5) in all areas with a negative depth values (i.e. the uncorrected surface exceeds the DEM).
Source/Cautions	The database of wells in the ORMGP includes all of the MOECC water well records as well as additional geotechnical/hydrogeological wells that have been entered into the database from other sources (consultant reports, Ontario Geological Survey, consultant databases, partner agency staff, etc.). Water levels are measured at nearly all wells at the time of drilling. The recorded static water level may or may not effectively reflect the water table position, depending upon when it was measured. Usually upon completion of drilling the well is pumped to estimate well capacity - sometimes insufficient time has passed to record a 'true' static water level (i.e. the well has fully recovered after pumping).
ATTRIBUTES	
REPLACES OR UPDATES	Oak Ridges Moraine Groundwater Program (2019) Water Table.
SIGNIFICANT CHANGES FROM PREVIOUS VERSION	Wells incorporated in the ORMGP database since the previous version of this dataset have been included within the interpolation process.
CONTACT INFORMATION	
Contact	Mike Doughty (mdoughty@owrc.ca)