Third Party Karst Peer Review

Proposed Bumstead Gravel Pit

584015 Sideroad 60 Township of Chatsworth

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May 7, 2015

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REPORT JUSTIFICATION

This report has been prepared at the request of the Ministry of Environment and Climate Change (MOECC) following anecdotal reports of karst in the vicinity of a proposed gravel pit (MOECC 2015). It responds to a Karst Investigative Study (GM BluePlan Engineering 2014) undertaken in response to these anecdotal reports, specifically relating to a dug-out pond on the property of Anne and Naohiko Kurita which is known to drain completely each spring. The presence of karst could be problematical in the extraction of overlying gravels should the karst become activated as a result of the extraction operation.

The specific requests of MOECC (MOECC 2015) are as follows:

> *" A primary concern with a karst environment in terms of land development is the potential for large quantities of storm water entering into the subsurface, specifically the bedrock, where impacts to the local bedrock aquifer resource could potentially occur…Further, it is the MOECC's position that the peer review should be conducted by a geoscientific professional with specialization in the field of Karst…the third party opinion specifically address not only the potential presence of karst, but should the risk exist, also provide a statement regarding the potential for adverse impact to the bedrock aquifer groundwater resource from the proposed pit operations."*

REPORT LIMITATIONS

This report is based in part on hydrogeological data collected and reported by Gambsy and Mannerow Limited (2013 and 2014) in support of the proposed development. The author has not undertaken separate detailed groundwater studies and, in particular, has not completed additional wells or boreholes to examine bedrock conditions or the interface between the bedrock and overlying surficial deposits. Conclusions provided in this report are based on available data and maps, a one-day field survey, and over 40 years of experience working in karst terrains, including those associated with local glacial deposits and dolostone bedrock (Guelph Formation).

It is assumed that no extraction will occur below the water table. Although the extraction license for the proposed pit is classed as a "below the water table license" (Class A, Category 1) the Site Plan Notes for the proposed operation restricts extraction to the depth of the long-term upper water table level (as determined from observation well monitoring). Further, should the water table be encountered during the operation, the Site Plan Notes require the operator to immediately adjust operations such that extraction does not occur within 30 cm (0.3 m) of the water table. The classification as a Category 1 "below the water table license" is required under the regulation since extraction is to occur within 1.5 m of the depth of the water table, even though extraction will not occur below it. Hence, all conclusions of this report are based on the fact that the shallow groundwater will not be artificially drawn down, impounded, or otherwise disturbed.

Information concerning the proposed development is provided in Gambsy and Mannerow Limited (2013). Data and information pertaining to area geology, site surficial characteristics, site groundwater elevations and characteristics, local well logs and locations, and local groundwater use are provided in Gambsy and Mannerow Limited (2013 and 2014). The results of a previous karst investigation are provided in GM BluePlan Engineering (2014). Specific information from these reports will be referred to in this peer review but will not be reproduced herein.

FIELD INVESTIGATION

The author undertook a one-day survey of the proposed site and surrounding area on April 15, 2015. The weather was mild (low teens) and cloudless, snow had been melting rapidly over the previous week. The focus of this survey was to examine surface water conditions in this portion of the upper Saugeen Watershed including evidence of any karst features. The site was approached from the south moving upstream in the Black's Creek watershed (tributary to the Rocky Saugeen River) from County Road 12 west of Markdale, past Bell's Lake then along Veterans Road South past the Kurita ponds and the proposed site. Stops were made at Walker Lake, a glacial kettle lake north of the proposed pit, the Bumstead property including the location of a reported bedrock "high" (vicinity of Test Hole TH-1A, Gamsby and Mannerow 2013) and a "well spring" that emerges on the side of a drumlin above the targeted aggregate; the Kurita dug pond complex; and a karst stream sink located west of Veterans Road South southwest of the proposed pit. Water temperature and specific conductance were recorded for each surface water feature using a YSI EC300 portable conductivity meter (Table 1).

SETTING AND GENERAL GEOLOGY

The proposed aggregate pit site is located west of the village of Berkeley and northwest of the Town of Markdale in southern Ontario (Figure 1). The proposed license area is 39.6 ha within an existing 40.47 ha (100 acre) farm property located at the northeast corner of Sideroad 60 and Veterans Road South (#584015 Sideroad 60). Other features of interest for this investigation include Walker Lake, a glacial kettle lake approximately a kilometer north-northwest of the site; a series of dug ponds on the surface of a drumlin feature south of Sideroad 60 (#584022 Sideroad 60) immediately across from the proposed pit site; a soil seepage/spring on the side of the drumlin draining into the area of the proposed pit; and two karst streamsinks located west and southwest of the proposed pit (Figure 2).

The Guelph Formation dolostone underlies a sequence of glacial deposits in this area. The Guelph Formation is a carbonate unit that is known to host significant karst features in outcrop and karst aquifers where sub-cropping (*e.g.*, Cowell and Ford 1983). Glacial deposits include tills composing a drumlinized till plain and a recessional moraine (Figure 3). These are flanked and, in places, over-topped by glaciofluvial sands, gravels and cobbles. The glaciofluvial deposits mark the location of a former meltwater channel draining water from the Georgian Bay lobe of the Late Wisconsin glacier toward the west and southwest. This channel is now marked by a large number of ponds, wetlands and small lakes, many of which form the headwater of Black's Creek, a tributary of the Rocky Saugeen River.

Surface elevations range between 400 and 430 m above sea level (asl) with the highest elevations located on drumlin tops (Figure 2). The elevation of the upper bedrock surface is between 366.2 and 397.4 m above sea level based on 11 drilled wells in the area (Table 1 in Gamsby and Mannerow Limited 2014). Estimates and recent monitoring of shallow groundwater levels at the proposed pit reveal an elevation of between 398 and 400 m asl, declining toward the northeast (Figure 4 Gamsby and Mannerow Limited 2013 and 2014). The gravel resource at the proposed pit location is between approximately 2.5 and 6.8 m thick (Gamsby and Mannerow Limited 2013).

FINDINGS

There are numerous surface water features located within the glacial deposits of the Black's Creek watershed. These features (ponds, wetlands, lakes, streams) represent the modern day remnants of a much larger meltwater channel system that drained south and southwest across this portion of the Horseshoe Moraines Physiographic Region (Figure 3). The presence of well-rounded cobbles located on the upper surface of the drumlin located on the Kurita property indicates that at high flow, the entire area would have been inundated, including the drumlins and all or part of the Gibraltar Moraine to the northwest of the proposed pit.

No bedrock outcrops were observed anywhere in the study area which supports the available well data that the bedrock surface consistently underlies the surficial glacial deposits. Gamsby and Mannerow Limited (2013) reported a possible bedrock high at about 3 m depth on the western edge of the Bumstead property based on auger refusal (a planned monitoring well location – TH-1A). This would place the bedrock surface at this location at between about 401 to 403 m asl based on Ontario Base Map contours. If so, this would be the highest known bedrock surface elevation in the area.

Surface water temperature and specific conductance (conductivity) were recorded at several locations (Table 1). Both of these parameters are useful in karst investigations. In general, groundwater within karst systems is characterized by temperatures that approach the average annual regional air temperature (approximately 6^{o} to 7^{o} C in this region). Temperature is often a good indicator of the presence of karst groundwater, however, the differentiation is best when air temperatures are at relative extremes (mid-winter and mid-summer).

Conductivity is a measure of the capacity of water to conduct electricity based on the total ions dissolved in the water. In the case of carbonate solution (limestone, dolostone) this is dominated by the products of solution (Ca^{++} and $HCO3^{--}$). In southern Ontario, typical conductivities for karst systems are in the range of about 400 to 1000 µS/cm (micro semens per centimeter), increasing given longer bedrock residence times (e.g., karst flow). Low conductivities typically represent rainwater/snowmelt and higher values indicate solution of other salts as well such as halite (rock salt). It should be pointed out that all surface waters contacting glacial deposits in southwestern Ontario typically exhibit some degree of carbonate solution.

1. Walker Lake

Walker Lake is a glacial kettle depression located within coarse gravel and cobble deposits in the upper portion of the meltwater channel system (Figure 3). The lake is not fed by surface streams but from shallow local groundwater and, given its position the surrounding topography, its surface is probably controlled largely by the local groundwater surface. This is reflected in a very stable water elevation, even during very dry years such as 2012 (Mr. Doug Crocker, pers. comm.). Lake overflow is directed through a wetland on the northern shore where it eventually collects into a small ephemeral stream. This stream fills a small downstream kettle that, during the spring melt period, overflows into a poorly developed channel that allows the water to infiltrate into the underlying cobble both within the channel and below a lower ephemeral wet pond a couple of hundred meters downstream of the upper overflow pond.

Glacial kettles and associated ponds are often confused with karst sinkholes and at times both conditions can exist – a kettle that either overflows into karst or is directly drained by karst. There is no indication of karst processes affecting Walker Lake. Evidence against karst affecting this system includes the long-term (year-to-year and season-to-season) stability of water levels and the observation of continual infiltration into the coarse cobble surface deposits. If significant karst were present it would be marked by one or more distinct free-flow sinkpoints (as observed elsewhere in the area, see Section 4, below).

The first three entries in Table 1 provide temperature and conductivity of the lake and its two downstream overflow ponds. The low temperatures in the downstream ponds are indicative of direct snowmelt from the surrounding wooded area (discontinuous cover of snow was present in the area of the ponds, Photo 1). The higher temperature in the Lake reflects direct warming from the sun which can have relatively rapid responses as the lake is shallow and has little circulation. Low conductivity measurements are also consistent with snowmelt. Slightly higher levels in the downstream overflow pond likely reflect some dissolution of carbonate as the meltwater contacts carbonate boulders and cobbles of the surface deposits.

2. Bumstead Property

Two features of interest in the vicinity of the proposed pit include the area in the western portion of the property where the bedrock is interpreted to be within a few meters of the ground surface and the spring/seepage on the side of the drumlin adjacent to Sideroad 60 (Figure 2).

The ground surface at proposed monitoring well location TH-1A is flat, revealing no indication of draping or sloping of surficial material over a bedrock high or rock knob. The nearest test hole (TH-A) was dug to a depth of over 6 m below ground surface with no indication of bedrock (Gamsby and Mannerow 2013, Figure 3 and Appendix B).

The “spring” described in Gamsby and Mannerow (2013) is a broad area of seepage emanating from glacial deposits on the side of the drumlin. It is located immediately below the road (SIderoad 60, Figure 2). Some of the seepage is captured in a stilling well (galvanized pipe) for agricultural uses (Photo 2). Overflow water drains down the side of the drumlin onto the surrounding meltwater plain where the flow infiltrates into the coarse cobble and gravel material. There is no ponding at this location and the sands and gravels are known to be over 5 m deep in this area[1].

The conductivity of the water is amongst the highest of all those sampled likely reflecting some interaction with carbonate materials in the stony silty to silty sand till composing the drumlin. The chemistry of this spring could also be affected by winter salting of the adjacent Sideroad. The low temperature indicates that the water is not sourced from deep flow, being characteristic of local snowmelt.

3. Kurita Ponds

The Kurita Pond complex has been described in some detail in GM BluePlan Engineering (2014). The ponds were dug over 50 years ago with the intention of developing some type of fish pond operation. The fourth pond was recently deepened by the current owners in order to enhance swimming opportunities. There is anecdotal information of some type of “cave” occurring at the site of the lowest pond when it was being excavated (Anne Kurita, pers. comm.).

The suspicion of karst at the location of the lowest pond was raised because of these anecdotal reports and because this pond in the only one of the five to completely dry out each year. Water stops flowing from the upper ponds in late spring and this pond is reported to always be dry by mid-May. Two circular shallow depressions at the base of the pond remain wet/damp throughout most of the year (Anne Kurita, pers. comm. and GM BluePlan Engineering 2014).

A portion of the berm holding this lower pond roughly parallels Veterans Road South and is notched to control the water level in the pond. At the time of the site visit, the pond surface had dropped below the notch but some flow/seepage was still occurring through the berm immediately below the notch. A recently deepened ditch along the road eventually directs runoff to a new culvert under Veterans Road South immediately to the south (flowing toward the west). The berm sat on a flat surface that was collecting water at a level approximately 50 cm or so above the base of the road ditch. It was evident that this water at the front of the berm was being fed, at least in part, by seepage through the berm. Evidence for this included ponded water along the foot of the berm, an absence of residual snow and visible laminar movement suggesting some active seepage from the berm (Photo 3).

The chemistry of the five ponds (Table 2) is not consistent with water sourced from karst. Temperatures are well above the regional annual average temperatures reflecting local seepage due to warming by direct exposure to the sun. Some variation in temperature amongst the ponds reflects variable shading from surrounding vegetation, for example the upper two ponds were the warmest and also had the least amount of shade. Conductivity is consistent with water in contact with carbonate-bearing fine-

[1] TH-4 (Gamsby and Mannerow Limited 2013, Appendix B) was 2.2 m deep and it was placed at the bottom of an existing dry dug pond that was at least 3 m deep (Pearl Bumstead, pers. comm.).

grained till. There is no consistent trend in conductivity from the highest to the lowest pond likely reflecting variable contributions from snowmelt.

4. Karst Sinkholes

Two active karst streamsinks (sinkhole draining a surface stream) were observed in the meltwater system to the west of the Veterans Road South (Figure 2). These are small karst systems typical of post-glacial karst in the Guelph Formation as observed by the author elsewhere. The streamsink immediately west of Veterans Road South was flowing approximately 2 L/sec (estimated) with water derived from a wetland pond to the southeast (Photo 4). The streamsink west of Concession Road 3B was taking a higher flow sourced from a dug-out pond located on the north side of Sideroad 60.

In both cases, surface water collects on the till plain then overflows via a stream channel that eventually sinks. The sinking point is opportunistic usually relating to a zone of higher permeability in relatively shallower soil. Fracture plains within the upper bedrock were opened by late glacial isostatic rebound and the water follows these fractures, expanding them by solution forming small caves. The fact that the water was free-flowing into the bedrock and not ponding/infiltrating indicates that the fracture system/cave is not controlled by the bedrock groundwater table but is in vadose zone (partly air-filled) forming a karst flow regime within the bedrock to a lower base level.

Soil and debris obscured the bedrock-till interface so the actual bedrock elevation is difficult to determine. Surface elevations are about 405 m asl at the sink nearest Veterans Road South and closer to 400 m asl at the sink west of Concession Road 3B. Assuming at least 2 – 3 m of till, the bedrock surface at these sinkpoints would be in the range of about 398 to 402 m asl. This is consistent with the highest bedrock elevations observed in well logs and the bedrock high on the Bumstead property. Neither of the sinkpoints were associated with visible bedrock highs but located on the gently rolling till plain.

Conductivity of inflow water at the streamsink west of Veterans Road South (Table 1) is indicative of snowmelt, warmed by direct sunshine and flowing over carbonate-rich tills.

DISCUSSION

The presence of two active streamsinks on the till plain west of Veterans Road South indicates that karst is active in the area and confirms that at least portions of the Guelph Formation in this area can be characterized as a karst aquifer. These streamsinks capture surface water and drawdown shallow groundwater in overlying surficial sediments in the vicinity of the sinkholes and conduits. The depth of surficial material in the vicinity of the sinkholes is estimated to be in the order of only 2 to 3 m, increasing the opportunity for bedrock capture of surface water.

Areas dominated by deep surficial materials including the drumlin east of Veterans Road South and where deep (5 to 15 m) meltwater channel deposits overlie the till do not show any evidence of the direct capture of surface waters via karst systems. This is, in part, evidenced by the numerous surface ponds, lakes, and streams (*e.g.*, Walker Lake, Bells Lake) that appear to hold water throughout the hydrological season. Although some leakage of water from these systems and their associated shallow groundwater (in surficial sediments) likely "leak" into the underlying bedrock, there is no evidence of significant karst capture and active conduit development. Gamsby and Mannerow Limited (2013) describe the upper shallow aquifer as "confined to semi-confined" based on the presence of fine grained sediments (till) overlying the bedrock. This interpretation is consistent with the evidence, at least in areas of deep tills (*e.g.*, drumlin) and gravel overlying till.

Monitoring of groundwater levels in the shallow aquifer (meltwater deposits) over four years by Gamsby and Mannerow indicate a consistent pattern of water table elevations (*e.g.*, compare May to May periods) and direction of flow (northeast). Although the groundwater level in one well on one occasion (MW-2, October 2011) was recorded as "dry", this is a function of the well depth. Over the course of data collection, levels in this well are consistent in behaviour relative to other wells and to itself. If the shallow groundwater was being drained by a significant karst conduit, the behaviour of these levels would be more erratic over the course any given season (*i.e.*, dropping below some or all wells during each dry season) and possibly by displaying a depression in elevation along the potentiometric surface ("groundwater trough"). This is not the case and along with surface physical conditions, there is no evidence to suggest shallow groundwater on the Bumstead property is directly controlled by underlying karst.

The question of a karst hydraulic connection between the drumlin, particularly the Kurita ponds, to bedrock underlying the area of the proposed pit can also be answered in the negative. The spring emanating on the side of the drumlin on the Bumstead property is a surficial spring as evidenced by its chemistry/temperature and its character as a broad area of seepage. It is not derived from bedrock. However, even if it did, it free drains onto the top of the meltwater deposits and is not part of a continuous bedrock conduit (hydraulic) connection.

In regards to the suspected karst draining of the lower pond on the Kurita property, it is my opinion that drainage from this pond is not due to karst. If a bedrock karst cave existed beneath this pond and this cave was hydraulically connected to a karst aquifer, drainage from the pond would be more rapid and obvious signs of sinking would be observed. The pond slowly drains ever year with no apparent change in the form of the basin. Continual drainage into a bedrock crevice even over a fifty year period would have gradually resulted in the development of true flowing sinkhole with an actively eroding/deepening depression as a result of receiving flowing water similar to those found west of Veterans Road South (*e.g.*, Photo 4). The bottom of the pond retains it form and the lowering of the pond's level is described as always being gradual without evidence of surface "flow" into any part (Anne Kurita, pers. comm.). Further, if the two lowest shallow depressions in the bottom of the pond were feeding karst, one or both of these depressions would completely dry out during the dry part of the hydrological year and not remain "damp" as reported.

Water levels in this pond are controlled by flow over a V-shaped notch in the berm, percolation through the berm), stopage of surface flow into the pond, evaporation, and seepage into sediments below the pond. It should be noted that this pond, unlike the upper ponds lies at the intersection of the till and an overlying glaciolacustrine deposit (Figure 1 in GM BluePlan Engineering 2014 and Feenstra 1994 – see

Figure 3, Unit 12). Although the upper glaciolacustrine deposit is also fine-grained, surface water could leak along the interface of the two deposits.

CONCLUSIONS

Although the Guelph Formation underlying this area can be characterized, at least in part, as a karst aquifer, there is no evidence of a direct hydraulic connection between surface water and the shallow groundwater system with deeper karst conduits in the area of the Bumstead property. Other surface water features on the former meltwater channel and on deeper tills such as the drumlin that crosses Sideroad 60 near its intersection with Veterans Road South, also do not offer evidence of karst influence.

In regards to the lowest pond on the Kurita Property, the findings of this report are consistent with that of GM BluePlan Engineering (2014).

Specifically with regard to the question posed by MOECC, in my opinion, there is no concern that large quantities of stormwater in the area of an operating pit will affect the local bedrock aquifer resources via karst drainage. This opinion is expressed based on the fact that groundwater in the pit will not be impounded or diverted and, further, that the underlying till will not be removed or otherwise disturbed.

RECOMMENDATIONS

1. Excavating operations in the proposed gravel pit should not disturb the underlying till deposit;

2. Groundwater monitoring wells will be maintained and monitored throughout the period of extraction. Any significant lowering of levels and/or the appearance of groundwater depression will be reported to MOECC and MNR as soon as detected and confirmed. “Significant” is to be defined by a hydrogeologist but would involve levels below those previously recorded during the driest year of record and not attributable to ambient factors such as drier than normal climatic conditions: and

3. In order to accommodate recommendation #2, monitoring well MW-2 should be deepened by about 1 m prior to the commencement of operations.

REFERENCES

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Feenstra, B.H. 1994. Quaternary geology, Markdale area, Markdale-Owen Sound, southern Ontario. Ontario Geological Survey, Preliminary Map P3251: scale 1:50,000.

Gamsby and Mannerow Limited. 2013. Level 1 hydrogeological study, proposed aggregate extraction pit, 584015 Sideroad 60, former Township of Holland, Township of Chatsworth. Unpublished Report Prepared for Pearl and Brian Bumstead, September 2013: 11 pg + appendices.

Gamsby and Mannerow Limited. 2014. Addendum to hydrogeological study, proposed Bumstead aggregate pit inventory of private water supply wells, west half of Lot 27, Concession 7, former Township of Holland, Township of Chatsworth. Unpublished Report Prepared for Pearl and Brian Bumstead, June 2014: 7 pg + appendices.

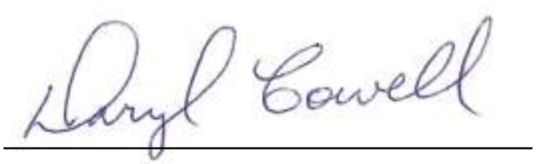
GM BluePlan Engineering. 2014. Karst investigative study – Kurita property, 584022 Sideroad 60 – Lot 28, Concession 7, former Holland Township, Township of Chatsworth. Unpublished Report Submitted to Cuesta Planning Consultants, November 25, 2014: 9 pages.

MOECC 2015. Letter from Bruce Harman to Bob Aggerholm ; comments on Karst Investigative Study, Proposed Bumstead Aggregate Pit. February 20, 2015: 2 pages.

ACKNOWLEDGEMENTS

During the course of the site survey, the author was given full access to all locations of interest and would like to thank the following: Mr. Douglas Crocker and his wife Sharon Moore for access to their lands associated with Walker Lake including a personal tour by Mr. Crocker; Mrs. Pearl Bumstead, applicant for the proposed aggregate extraction operation; Anne and Naohiko Kurita owners of the dug ponds across from the proposed pit; and Mr. Randy Cook who directed me to the streamsink located southwest of the Kurita property. These people provided frank and open discussions of their understanding of their properties and the situation. At no time did I sense being given misleading or otherwise erroneous information.

Respectfully submitted:



Daryl W. Cowell, P.Geo (#0791)
May 8, 2015

TABLE

Table 1. Suface Water Temperature and Conductivity Results

Feature	Temperature (°C)	Specific Conductance (μS/cm)
Walker Lake	7.9	168
Walker Lake First Outlet Pond	4.9	152
Walker Lake Second Outlet Poind	4.2	235
Bumstead Well Spring	4.6	560
Kurita Upper Pond	13.8	494
Kurita Second Pond	12.5	492
Kurita Third Pond	10.5	512
Kurita Fourth Pond	11.3	468
Kurita Lowest Pond	11.2	382
SW Streamsink	16.2	440

FIGURES

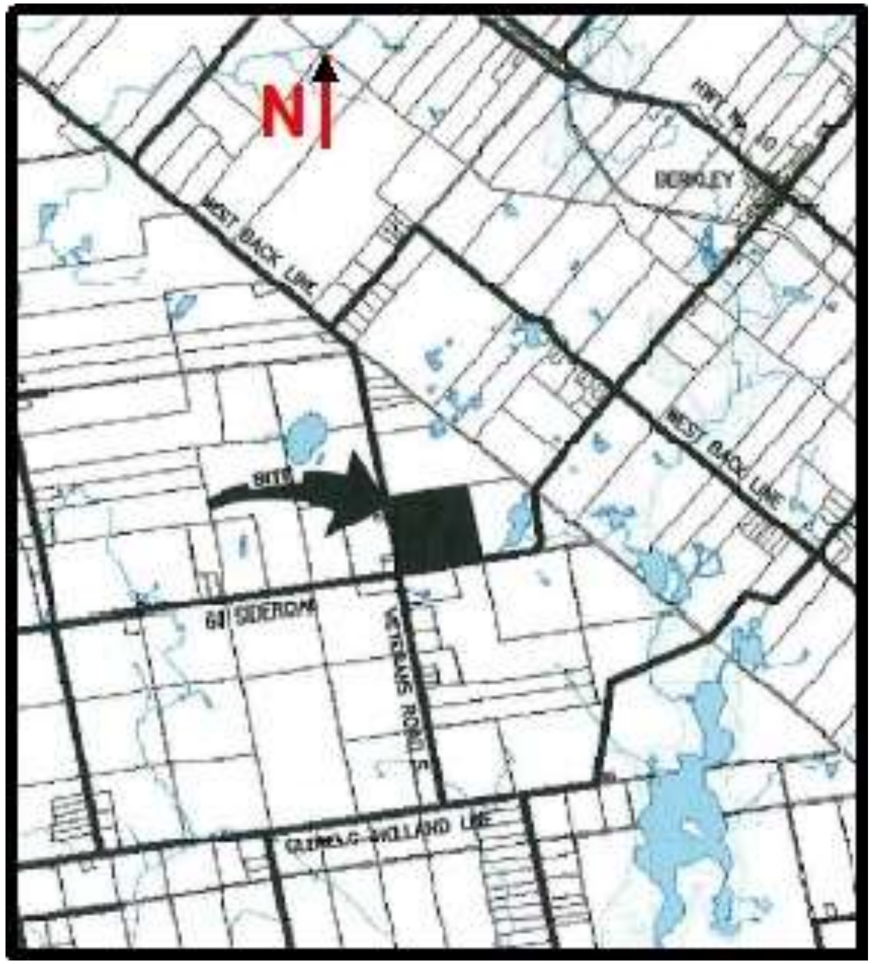


Figure 1. Location of Bumstead farm property (from Gamsby and Mannerow Limited 2013)

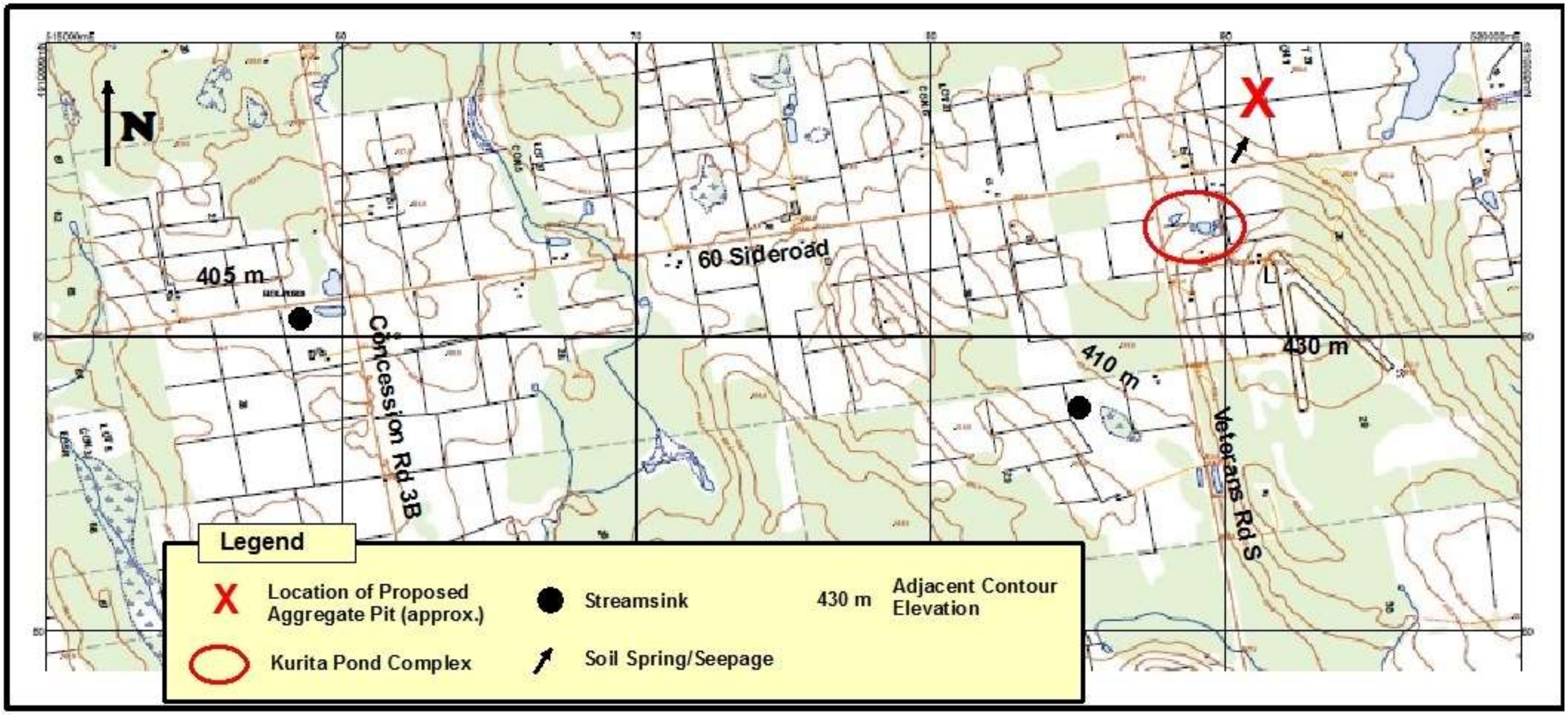


Figure 2. Section of Ontario Base Map #1017515049050 showing study area and major surface features investigated.

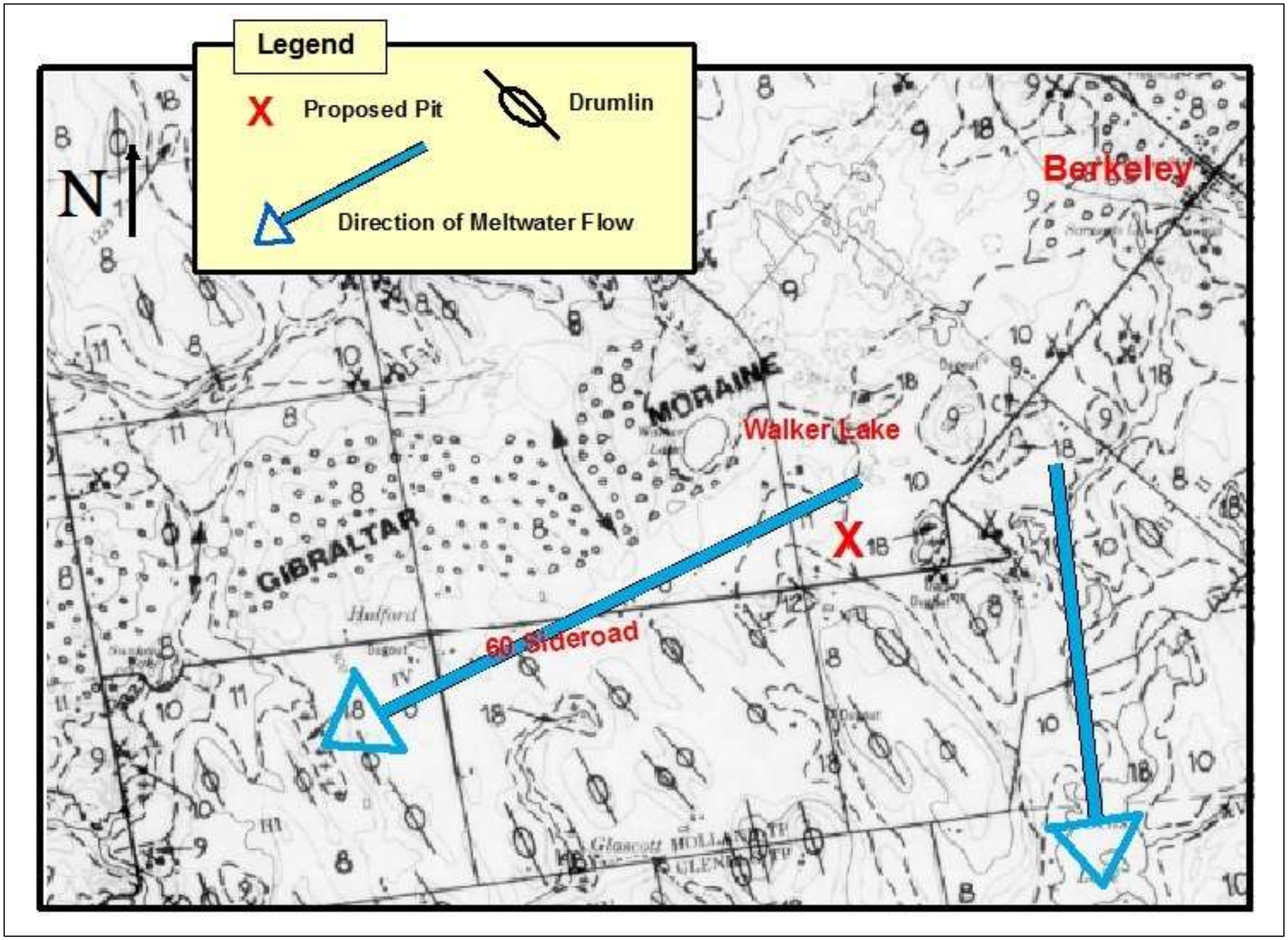


Figure 3. Section of Ontario Geological Survey Map P3251 (Markdale Sheet, Feenstra 1994) showing major surficial geology features. The number legend is as follows: 8 = undifferentiated till (sandy/silt, bouldery); 9 & 10 = glaciofluvial sand and gravel; 12 = glaciofluvial sand and silt; and 18 = peat and muck (wetlands).

PHOTOS

Photo 1. Downstream pond fed by snowmelt and overflow from Walker Lake. This pond typically dries out by the end of April (D. Crocker, pers. comm.)

Photo 2. Stilling well and seepage flow channel leading toward meltwater channel gravels.

Photo 3. Lowest pond on the Kurita property showing position of the berm relative to the road ditch and percolating seepage.

Photo 4. Streamsink on till plain immediately west of Veterans Road. Water enters from bottom left and Disappears into bedrock below figure.