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Shallow Subsurface Characterization to Support Placement for Infiltration Based Low Impact Development Practices

Lake Simcoe Region Conservation Authority
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1.0 Acknowledgement

Lake Simcoe Region Conservation Authority gratefully acknowledges financial support from the Province of Ontario, without which this report would not have been possible. The views represented in this report do not necessarily reflect those of the Province.

2.0 Background and Objectives

Urban Stormwater contributes to phosphorus loading of Lake Simcoe. In addition to phosphorus, urban Stormwater from impervious surfaces can contribute sediment, hydrocarbons, and metals to local water features and urbanization can cause reduced recharge to groundwater systems. As a result, the Lake Simcoe Protection Plan (2009) calls for improvements to the management of Stormwater for both existing and future development with a goal to decrease phosphorous loadings and to minimize changes to the water balance. Improved urban Stormwater management can be accomplished through several means including retrofitting existing development with low impact development (LID) and using LID for future development projects, which has increased within the watershed in recent years.

LID provides a wide range of practices that can help offset the various negative impacts of Urban Stormwater, including the reduction of recharge through infiltration based methods. Determining the most suitable locations for infiltration based LID practices requires an understanding of the shallow subsurface including the geology and hydrogeology. To help guide infiltration based LID placement, the Shallow Subsurface Characterization Project aims to provide an improved understanding of the shallow subsurface through the development of a GIS layer that identifies the suitability of locations within the East Holland River Subwatershed for infiltration based LID projects. The GIS layer has been developed using geologic and static water level data provided by the Regional Municipality of York and available through the Oak Ridges Moraine Groundwater Program. It is important to note that although some locations identified in this project may have lower suitability for infiltration based LID practices, other LID practices could be possible in these locations depending on circumstances of the site and the type of LID in question.

Based on this improved understanding of the shallow subsurface environment, the final product is a single easy-to-use GIS layer that characterizes the watershed into areas that are deemed to be of low, medium, or high suitability for infiltration based LID practices. This will allow for a quick and simple desktop evaluation of the most appropriate locations for infiltration based LID. The long term goal is for the layer to be available on the LSRCA website to municipalities, Stormwater engineers, planners, students, and anyone interested in LID within the East Holland River Subwatershed.

3.0 Disclaimers

Before using the GIS infiltration LID ranking layer (LIDSuitability.shp) please note the following disclaimers regarding the methodology, assumptions, and general limitations of the project.

- Final Layer (LIDSuitability.shp)
    - The interpretation of suitability (ranking) for infiltration based LID implementation is primarily based on geologic and groundwater data and does not account for other site specific variabilities that may affect the suitability of a specific site for infiltration. The "LIDSuitability.shp" layer, and all supporting layers used to create this final layer, can be used to guide infiltration based LID development, but should be supported by local site investigations and a specific understanding of relevant policies and the quality of infiltrating water. Specifically, the water quality of infiltrating water is not considered in this project and is a key component of understanding if infiltration is appropriate.
    - The "LIDSuitability.shp" layer is developed through a combination of the two input criteria layers (geology and static shallow groundwater level) and therefore represents an overall ranking of the suitability of locations within the subwatershed for infiltration based LID practices. As a result, where the "LIDSuitability.shp" layer indicates low suitability this does not necessarily mean that infiltration cannot occur in these locations, but instead that additional considerations should be made before LID implementation. By investigating the attributes table of the "LIDSuitability.shp" layer, the limiting factor (LimitFactr: geology and/or water level) can be determined and appropriate steps can be made to make those areas more suitable.
    - Categorization of the subwatershed based on low, medium, and high suitability for infiltration based LID is a generalization and captures considerations like the physical space available for infiltration and the potential rate of infiltration at these sites. For example, a location identified as medium suitability is expected to have a slower rate of infiltration than a location identified as high suitability. Thus, locations identified as medium or low suitability can still infiltrate, just possibly not as much as a location identified as high suitability.
- Water Level Input Layer
    - The water level data used to create the depth to water map, represents an approximate water table elevation based on single or multiple (averaged) water level measurements from wells, piezometers, and open boreholes across seasons and decades. Based purely on seasonal water level changes, the water table at a specific location may change +/- 1 m or more. Therefore, site specific investigations into the actual water level should be conducted to confirm the appropriateness of the location for infiltration based LID implementation. The depth to water data used within this project is meant to provide a general indication of possible suitability for infiltration and should be used with discretion.

- Geologic Input Layer
    - Geologic data used for the interpretation of infiltration based LID suitability does not take into consideration the possibility of thick topsoil deposits or fill materials present at surface. The geologic data is based primarily on *in situ* Quaternary deposits that may have been disturbed (removed or covered) by human activity. To confirm the geologic/soil suitability of a site, it is recommended that *in situ* infiltration testing be completed at each location where infiltration based LIDs are proposed. The TRCA 2012 guideline document "Stormwater Management Criteria" can be used to help guide *in situ* infiltration tests.
- Cross-Sections
    - Cross-sections are interpreted from geologic knowledge within the Ontario Geological Survey (OGS) surficial geology map, Oak Ridges Moraine Groundwater Program formation picks, and local borehole logs. Although the geology is simplified within the cross-sections, each identified category will experience lateral and vertical variability in sediment type and may have isolated sections of higher or lower permeable sediments. Therefore, to confirm geologic suitability of a site it is recommended that *in situ* infiltration testing be completed.

4.0 Methods

4.1 Data Collection

The Oak Ridges Moraine Groundwater Program provided the majority of the geology and hydraulic data used for this project (approximately 26,000 geologic and 2,200 hydraulic data points of 26,200 and 2,400 respectively). Additional geologic and water level data were extracted from reports within the Oak Ridges Moraine Groundwater Program, from the Regional Municipality of York, and from several LSRCA reports. When available, the desired data (e.g., borehole depth, drill date, well depth, geology, etc.) was extracted and directly transferred from the reports into an excel database. The common exception was with borehole/well UTM coordinates and well screen intervals, which often could not be directly transferred.

In many cases UTM coordinates were not directly provided, as a result they were estimated from site figures. In these circumstances the accuracy and confidence of the coordinates was approximated by measuring the distance within which the borehole may have occurred and based on this a QA coordinate code, used by the Oak Ridges Moraine Groundwater Program database, was applied (1: margin of error <=3 m, 2: margin of error 3-10 m, 3: margin of error 10-30 m, 4: margin of error 30-100 m, 5: margin of error 100-300 m, 6: margin of error 300 m – 1 km).

In several cases reports did not adequately indicate the well screen interval and only provided a drafted borehole log indicating the position of the screen. In these circumstances the screened interval was determined from the borehole log with the assumption that the screen was either 1.5 m or 3 m in length.

4.2 Geologic Input Layer Development

The Ontario Geological Survey's (OGS) Surficial Geology of Southern Ontario layer (Ontario Geological Survey 2010) was created following extensive research and is an accepted representation of the surficial geology of Ontario. As part of this project, the OGS map was enhanced by adding local borehole information from consultant reports to make local adjustments to the map. This section outlines how the OGS surficial geology was adjusted. Since much of the methodology requires interpreting rough and low quality geologic texture data to relate them to complex depositional environments, the changes made to the OGS map are subjective and are not considered any more accurate than those provided by the OGS. However, given the local context and local geologic data, it is hoped that the adjustments made to the OGS map represent the local geology more accurately.

4.2.1 Geologic Data

Geologic information from test pits and boreholes were obtained from the Oak Ridges Moraine Groundwater Program and consultants reports prepared for the Regional Municipality of York. Only geologic data with UTM coordinate confidence of less than 100 m were used to make minor adjustments to the OGS surficial geology map based on the local knowledge. Any topsoil or fill layers within these boreholes were ignored and the first layer likely to have been deposited *in situ* was considered during the adjustments of the OGS map.

Outcrop data were also available within the Oak Ridges Moraine Groundwater Program database; however, this data was originally used to develop the OGS map and therefore was only used for quality control following identification of potential adjustments to the OGS surficial geology map.

Geologic data was utilized because of the likely depth range of infiltration based LID projects and the unknown / variable topsoil depths within the area. Although LID project may infiltrate urban Stormwater through topsoil / soil deposits in some cases, it is expected that if the base of the LID is around 1 meter below ground surface (mbgs) or deeper it is more likely that they will terminate within Quaternary deposits versus topsoil within the subwatershed. Therefore, surficial geology mapping was determined to be more appropriate than soil mapping.

4.2.2 OGS Surficial Geology Map Local Interpretation

The data outlined in Section 4.2.1 was used to make modifications to the OGS surficial geology map based on local knowledge from within the study area. For each borehole the surficial geologic units, not considered to be fill or topsoil, were investigated to determine if the geologic texture (e.g., sand, silt, clay, etc.) matched the OGS mapped depositional environment (e.g., fine-textured glaciolacustrine deposit etc.). When the borehole geologic texture was determined to not match the OGS depositional environment a change was made to the OGS map based on the following circumstances:

- There is evidence from one or more boreholes that the top *in situ* geologic unit does not agree with the OGS mapped depositional environment.
- The proposed new surficial geology/depositional environment exists on the OGS map within ~800 m of the borehole in question. Therefore, even if multiple boreholes disagree, if there is not an appropriate depositional environment within a reasonable distance, no change was made.
- There are no boreholes that agree with the OGS mapped depositional environment between the disagreeing borehole(s) and the new OGS unit; if there are, no change was made. However, if the number of boreholes that disagree greatly outnumber the boreholes that agree, then a change may still have been made.
- The adjustment will include a buffer around the boreholes that indicate an adjustment should be made. The geometry of the added unit aimed to match the depositional environment in question; as a result, the buffer around the boreholes may extend a significant distance from the borehole in question.

After all boreholes were investigated and the OGS surficial geology map was modified, a final quality control comparison was made to make sure the original outcrop geology used to create the OGS surficial geology map didn't disagree with any of the proposed changes. The adjustments were then finalized within the OGS surficial geology layer for use in this project. In total ~7 km^2 of the subwatershed surficial geology mapping was modified based on interpretations from local borehole logs. This represents approximately 3% of the entire East Holland River Subwatershed.

4.2.3 LID Infiltration Suitability: Geology Criteria

Although LID practices can be implemented in all geologic settings, for infiltration based LID practices specific geologic units / sediment textures are more appropriate (e.g., sand and gravel), while finer grained sediments (e.g., silt and clay) are less appropriate due to the lower permeability, which limits infiltration and recharge. Therefore, the adjusted surficial geology map discussed in Section 4.2.2 was used to create a simplified GIS layer that categorizes / ranks each surficial depositional environment as high (blue), medium (orange), or low (grey) suitability for LID infiltration practices based on the sediment permeability. The categorization of each depositional environment was determined through a general understanding of the likely permeability of that deposit as well as the interpreted permeability provided with the OGS surficial geology map. The OGS depositional environments will be categorized as follows:

- High Suitability / Rank (Blue)
    - Coarse-textured glaciolacustrine deposits
    - Ice contact stratified deposits

    - Glaciofluvial deposits
    - Alluvial deposits
    - Eolian deposits
    - Organic deposits
- Medium Suitability / Rank (Orange)
    - Silty to sandy till
    - Glaciolacustrine-derived silty to clayey till
    - Human-made deposits/Fill (only mapped in one location of the subwatershed near Ballantrae)
    - Fine-textured glaciolacustrine deposits

As noted above, no geologic depositional environment was categorized / ranked as low suitability (grey) for infiltration based LID implementation. This is a result of local uncertainties in the mapped geology due to the unknown distribution of fill within the study area, beyond the one mapped deposit near Ballantrae. It is likely that much of the urbanized area of the subwatershed has some depth of fill overlaying the *in situ* deposits outlined in the updated OGS surficial geology map; therefore, locations identified as less appropriate for infiltration (e.g., silt and clay deposits) may in fact be suitable for infiltration based LIDs. In addition, there are LID design aspects that may be implemented in order to make deposits with lower permeability more acceptable for infiltration, such as removing the low permeable material and replacing with more permeable sediment. Therefore, all geologic deposits may be suitable for infiltration depending on fill material / depth and LID design.

Due to geologic uncertainty surrounding fill depth and locations, it is highly recommended that *in situ* site investigations be completed to get the best understanding of the local sediment permeability and suitability for LID implementation. The provided geologic layer for infiltration based LID location suitability is meant as a higher level guidance tool to compare a number of possible sites for infiltration.

4.2.4 Geologic Cross-section

The data outlined in Section 4.2.1 in addition to test pit and outcrop data were used to create several geologic cross-sections that provide insight on the sediment variability with depth. The geologic data obtained from boreholes, test pits, and outcrop locations within 100 m of the cross-section line were used to interpret the subsurface geology from 0 mbgs to 8 mbgs. These geologic cross-sections are an indispensable complement of the surficial geology map/GIS layer. Both the map and cross-section are two-dimensional representations of reality but together they allow the user to visualize the three-dimensional structure of the shallow subsurface of the area.

Previous subsurface layer interpretations completed by the Oak Ridges Moraine Groundwater Program were used to guide interpretations and ensure agreement with the conceptual geologic model and the regional stratigraphic interpretation of the area (Kassenaar and Wexler 2006). As a result, existing picks for the tops of the Halton Till, Oak

Ridge Moraine, and Newmarket Till Formations by the Oak Ridges Moraine Groundwater Program were added to the cross-sections. However, interpretations of more recent shallow / surficial sediments had not yet been completed. Therefore, borehole, test pit and outcrop data as well as the modified OGS surficial geology map were used to interpret these shallower, previously uncharacterized, sediments based on their predominant texture and expected permeability. In addition, the stratigraphic units identified by the Oak Ridges Moraine Groundwater Program were reinterpreted based on their predominant sediment texture and expected permeability for consistency.

4.3 Water Level Input Layer Development

4.3.1 Water Level Data

Groundwater level data used to create the depth to water map were obtained from the Oak Ridges Moraine Groundwater Program, which includes wells from the Water Wells Information System (WWIS) database, the provincial borehole database, and WRIP (Well Resources Information Project by the Ministry of Natural Resources and Forestry and Conservation Ontario). This database was supplemented by available water levels from consultant reports submitted to the Regional Municipality of York and Lake Simcoe Region Conservation Authority. In addition to the water level data, surface water elevations from features such as lakes, wetlands (identified as open water only), and rivers (with Strahler Class 4 and higher) were used to further supplement the dataset. Groundwater and surface water data were collected both within and just outside the study subwatershed in order to minimize boundary effects when creating the depth to water map.

Groundwater level data was obtained from wells / boreholes (open hole) that have a horizontal location accuracy of +/- 300 m or less (QA code 1 to 5) and a screen top that was shallower than 20 mbgs. Only wells / boreholes shallower than 20 mbgs will be used as they are considered representative of the shallow groundwater system. The primary unconfined aquifer unit (Oak Ridges Moraine (ORM)) within the study subwatershed exists within the 20 m range. Where the ORM aquifer doesn’t exist from surface to 20 mbgs, the Newmarket Till typically occupies this entire depth range, and although the Newmarket Till is considered more of an ‘aquitard’ layer, the static groundwater level within this unit likely represents that of the shallow groundwater system since it is the surficial until in many locations.

4.3.2 Water Level Data Management

From the available groundwater data a total of 2,435 water level locations within the East Holland Subwatershed met the parameters outlined in Section 4.3.1. During data management and water level QA/QC following the first depth to water map iteration (outlined below in Section 4.3.3) a total of 67 groundwater level locations were removed from the database for a variety of reasons including;

- location identified as erroneous due to high water level above ground surface (i.e., greater than 2 m above ground surface);
- location had nested wells and deeper well screens were not required in the dataset;
- water level created a 'bullseye' in the groundwater elevation map and disagreed with surrounding groundwater and surface water elevations; and
- the water level was only ever recorded as dry.

Some of the groundwater level data came from monitoring wells with multiple water level measurements over time. For wells with more than one water level measurement an average was taken to determine one static water level for that well, regardless of date. As a result, the interpolated depth to water map will represent a median water level that reduces the influence of seasons and drier or wetter years. Groundwater elevations were easily converted between meters below ground surface (mbgs) and meters above sea level (masl) using a surveyed elevation or digital elevation model (DEM) derived elevation.

It should be noted that the water level values provided within the Oak Ridges Moraine Groundwater Program database includes some inherent assumptions. The Oak Ridges Moraine Groundwater Program assumed a stick up (the distance above ground surface of the top of the well casing where water level measurements are assumed to have been taken) of 0.75 m above ground surface if a stick up value was not provided. This assumption was used for all water level measurements except in the case of open hole water levels provided by drillers, which were assumed to be measured from ground surface. In contrast, since groundwater levels obtained from consultant reports submitted to York Region and LSRCA were considered to be from reliable sources and since water levels were provided in meters below ground surface, instead of meters below casing / top, no such assumption was required. All groundwater elevations were determined by subtracting the depth to water from the ground surface elevation obtained from a 1 m DEM.

Surface water elevation data was obtained from wetland, water course, water body, and York breakline GIS layers. Each polygon and line feature was simplified by reducing the number of nodes while ensuring the new polygon/line had no more than a 0.5 m offset at any one point from the original feature. The nodes of these simplified polygons/lines were then converted to points for the purpose of this analysis. Some data from this combined dataset were filtered out to remove any overlapping or very close data points, to ensure the data was not duplicated. This was specifically important for the York breakline and water body points as these data sources have duplicate features within them.

The York breakline layer represents locations where there are rapid changes in elevation, such as shorelines; therefore, it duplicates data from the other surface water layers (i.e., wetlands, water courses, and water bodies). Although the York breakline layer can capture other features of rapid elevation changes only those identified as 'shorelines' were used in the analysis. Where shorelines from the York breakline layer and other surface water layers overlapped the most accurate data points, when compared to a 2017 ortho image, were kept for the analysis. In many cases the more accurate data was from the York breakline layer and therefore many of the surface data points used are from this dataset.

Elevation data was assigned to each surface water feature point using a 1 m DEM. Since some elevations for water bodies represent elevated shorelines, an average elevation of each water body feature was calculated and assigned to any surface water body points within that feature with an elevation higher than the average. Those with lower elevations than average were left as is. This was completed to try and ensure the depth to water map wasn't artificially raised.

4.3.3 Depth to Water Map and QA/QC

Using the data identified in Section 4.3.1 and further described in Section 4.3.2, a depth to water map was created for the East Holland River Subwatershed. The first iteration of the depth to water map used several interpolation methods to create a groundwater elevation map including inverse distance weighted (IDW) and Kriging, while triangular irregular networks (TIN) was used to help build the surface and identify data points that were outliers. Generated groundwater elevation surfaces were then reviewed by overlaying the source data points in order to identify any abnormal spots within the surfaces.

Identified 'abnormal' data points from surface water features were removed without further investigation. However, 'abnormal' data points from groundwater sources were further investigated to rationalize the removal of these more representative depth-to-water measurements. Investigations into the screen depth, borehole geology, location confidence codes, surrounding groundwater well measurements, and nearby permits to take water were conducted and those boreholes with any, or a combination, of following issues were confirmed for removal:

- very deep well screen that was accidently included in dataset;
- significantly different water levels from surrounding wells;
- deeper well screen than surrounding wells (i.e. likely not representative of shallow system);
- deeper well of a nested system (i.e., shallower screen likely more representative of shallow groundwater system);
- and / or screened in bedrock or other confined unit that does not likely represent shallow groundwater system.

In addition to the identified 'abnormal' data points, all surface water features that were identified as Stormwater Management Ponds from ortho images or an existing LSRCA database were removed as they are unlikely to represent the groundwater table since they are fed by urban Stormwater. Similarly, all surface water features and wetlands that were smaller than 1000 m^2 were removed from the analysis as they were considered to be too small to consistently represent the groundwater table. Finally, surface water data points that were identified as not matching the ortho image from 2017 were also removed from analysis.

The second iteration of the depth to water map used the QA/QC'd dataset from the first iteration (as identified above). Interpolation of groundwater elevation was completed using IDW, Kriging, Natural Neighbor, and Spline, while TIN was used again to identify outliers. Interpolated groundwater elevation surfaces were compared to select a final methodology and a few final 'bad points' were eliminated.

The Natural Neighbor interpolation method was selected for the final iteration since it works well with clustered / scattered data points, can manage large datasets, is a similar weighted average method to Kriging, and produced a nice smooth groundwater elevation surface that visually looked more appropriate. The final groundwater elevation surface was run with Natural Neighbors, with a 10 m cell size, and was used to generate a depth to water surface by subtracting it from a 10 m DEM. Where the water table was higher than the DEM it was normalized to make the water depth 0 mbgs. In addition, any water levels interpolated to be greater than 20 mbgs are likely artificially deep, since the depth of investigation was ~20 mbgs, and therefore any water levels > 20 mbgs were adjusted using the following methodology which was developed in-house:

$$\text{Final depth} = 20\text{ m} + (\text{interpolated depth} - 20\text{ m})*10\%$$

This adjustment method was selected instead of confining the deepest water level to a maximum of 20 mbgs because it allows the original values to be easily recovered if required in the future. The final depth to water surface was used to create the water level suitability for infiltration based LID outlined below in Section 4.3.4.

4.3.4 LID Infiltration Suitability: Water Level Criteria

For proper infiltration based LID design there needs to be adequate 'space' for infiltration of the received Stormwater. As outlined in the TRCA 2012 guideline document "Stormwater Management Criteria" there should be ideally 1 m between the seasonally high water level and the base of the infiltration facility. As a result, any area within the subwatershed identified by the depth to water map as having a water level shallower than 1 mbgs is considered low suitability / rank (grey) within this study. Locations with water levels between 1 mbgs and 2 mbgs are considered to be moderate suitability / rank (orange). Finally, water levels deeper than 2 mbgs are considered high suitability / rank as they have adequate 'space' for infiltration and are sufficiently deep to capture many, but not all, of the seasonal high water levels.

4.4 Final LID Infiltration Suitability Layer

The final infiltration based LID location suitability GIS layer was created by combining the two input layers of shallow subsurface geology and water level outlined in the above sections (4.2 and 4.3, respectively). A union of the attributes fields of the two input layers produced a comprehensive attribute table that identifies not only the land use classification of each location but also if it is a location for expected future growth, an ESGRA or SGRA, a regulated wetland, or a flood plain as well as the, surficial geology, water level range, and the individual ranking based on each input criteria (geology – GeolRank and water level – WLRank).

All rankings from the two input criteria were used to create the final infiltration based LID location suitability / ranking (FinalRank) for each polygon within the surface. Where any of the two input criteria identified a polygon as "Low Suitability" the final ranking indicated a low (grey) suitability for infiltration based LID practices. Following classification of all low suitability locations any "Medium Suitability" locations from the two input criteria were assigned as medium (orange) suitability for infiltration based LID practices in the final ranking, given that polygon had not already been assigned as low suitability. Finally, all remaining locations where the two criteria agreed and identified the polygon as "High Suitability" then the final ranking indicated a high (blue) suitability for infiltration based LID practices.

4.5 Data Validation

During all stages of the methods outlined above, consultation with technical stakeholders was conducted in order to obtain feedback on the GIS layers and geologic cross-sections being created. Following consultation the GIS layers were revised to incorporate any recommendations received. Technical stakeholders that were consulted included; Oak Ridges Moraine Groundwater Program personnel, York Region staff, and Stormwater Management and Watershed Restoration professionals at LSRCA. In addition, two presentations of the project were made, prior to completion, in order to promote the project and solicit feedback from technical personnel. Presentations were made at the Oak Ridges Moraine Groundwater Program Meeting on November 2, 2018 and at the Ontario Geological Survey (OGS) / Geological Society of Canada (GSC) Regional-Scale Groundwater Geosciences in Southern Ontario Open House on February 28, 2019.

5.0 Results and Discussion

Following interpretation of the surficial geology, based on the suitability for infiltration based LID practices, a suitability map was created for the East Holland River Subwatershed (Figure 1). Since a large amount of the surficial geology within the subwatershed is composed of deposits with significant amounts of silt and clay, much of the area is considered to be medium suitability for infiltration, with respect to the geology input criteria. The exception to this is within the southern edge of the subwatershed, along the Oak Ridges Moraine (ORM) physiographic unit, and in isolated locations throughout the subwatershed where sandy deposits or recent alluvial deposits exit.

When considering local geology it is also important to remember that geologic deposits vary with depth. Therefore, what is mapped at surface may not be the same at depth and as a result LID projects may be infiltrating urban Stormwater into different sediments than those found at surface and mapped by the OGS. Based on the generalized cross-sections developed for the East Holland River Subwatershed (Figure 2, Figure 3, Figure 4 and Figure

5), it is obvious that across most of the subwatershed investigated there are similar geologic deposits between ground surface and 8 mbgs. However, in some cases lower permeable deposits are layered with higher permeable deposits within the 0-8 mbgs making interpretations of the suitability for infiltration based LID practices using only surficial geology more difficult and supporting the need to conduct *in situ* field investigations where infiltration based LID projects are proposed. It is important to remember that these cross-sections provide a general understanding of the variability of sediments with depth but that each type of deposit will display internal variability and may have isolated sections of higher or lower permeable sediments.

Following interpretation of the depth to water, based on the suitability for infiltration based LID practices, a suitability map was created for the East Holland River Subwatershed (Figure 6). Based on fairly deep water levels (>2 mbgs) within much of the subwatershed, a significant amount of the area appears to be suitable for infiltration, based on the depth to water input criteria. The exception to this is within the north of the subwatershed where there is a large wetland that has waters at or near ground surface in addition to some other isolated locations throughout the subwatershed with shallower low suitability water levels.

Consideration of all input criteria, discussed above, allows for the creation of a final infiltration based LID location suitability map that considers the main factors that will affect the suitability of a location for infiltration (Figure 7). Within the East Holland River Subwatershed this final infiltration based LID location suitability map shows a moderate amount of highly suitable locations for infiltration. The highly suitable locations for infiltration based LID are primarily in the south of the watershed within the ORM or other sandy surface geology deposits across the watershed that contain permeable sediments suitable for infiltration and have relatively deep water levels. Where the final suitability map identified moderately suitable locations this is typically a result of the geology and the high clay / silt content of surficial sediments within much of the watershed. Where the final suitability map identified low suitability, this is a result of high water levels since no geologic material was identified as 'low suitability' (see Section 4.2.3). Based on this project, the primary limitation to infiltration based LID practices within most of the East Holland River Subwatershed is the low permeability geologic materials (high silt and clay content). However, this factor does not rule out the use of LIDs since geologic limitations can be overcome through alternative designs and in fact local geologic variabilities or fill materials may result in adequate permeability for infiltration at specific sites.

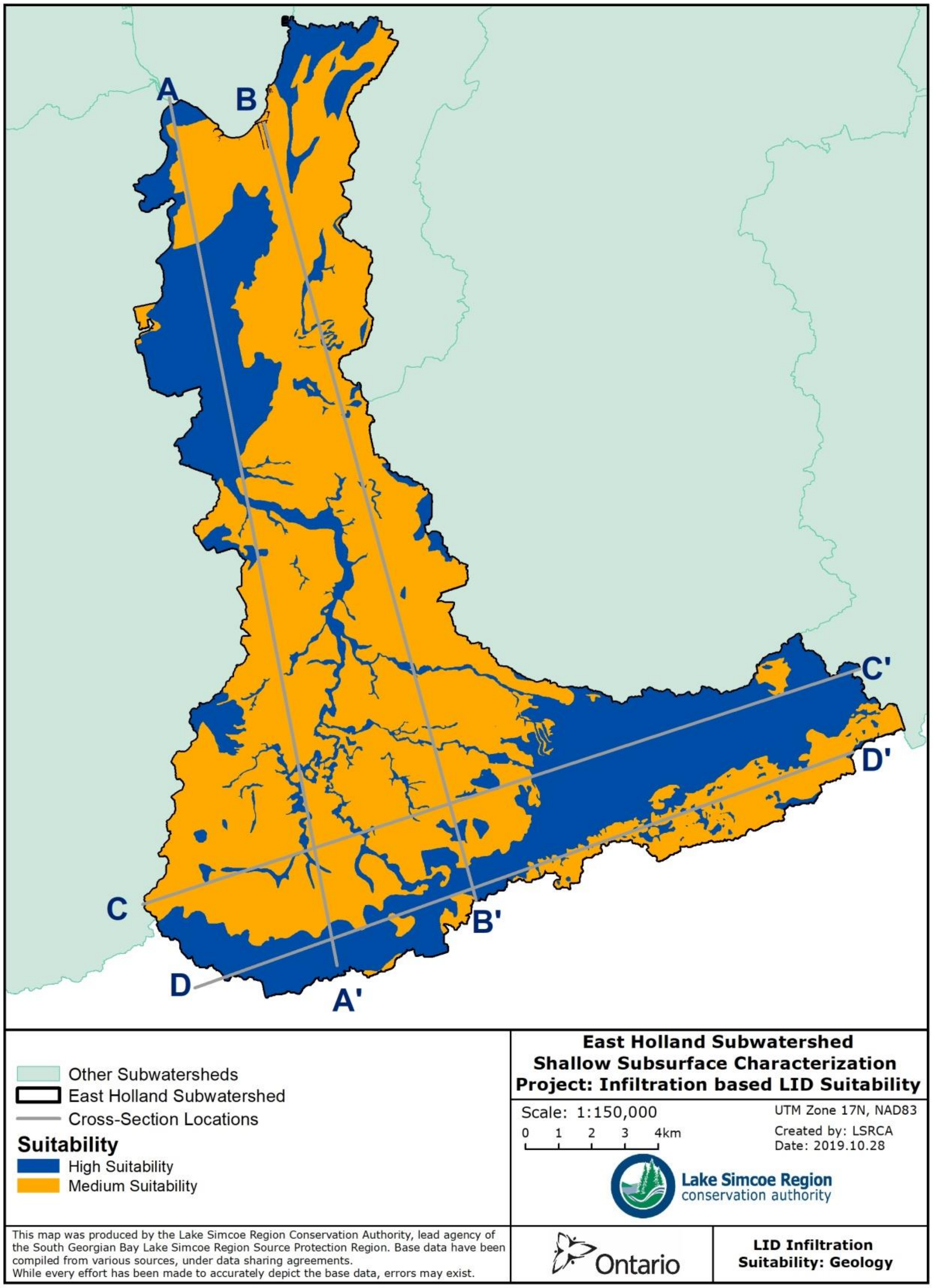

Figure 1 – Infiltration based LID location suitability for the East Holland River Subwatershed based on surficial geology

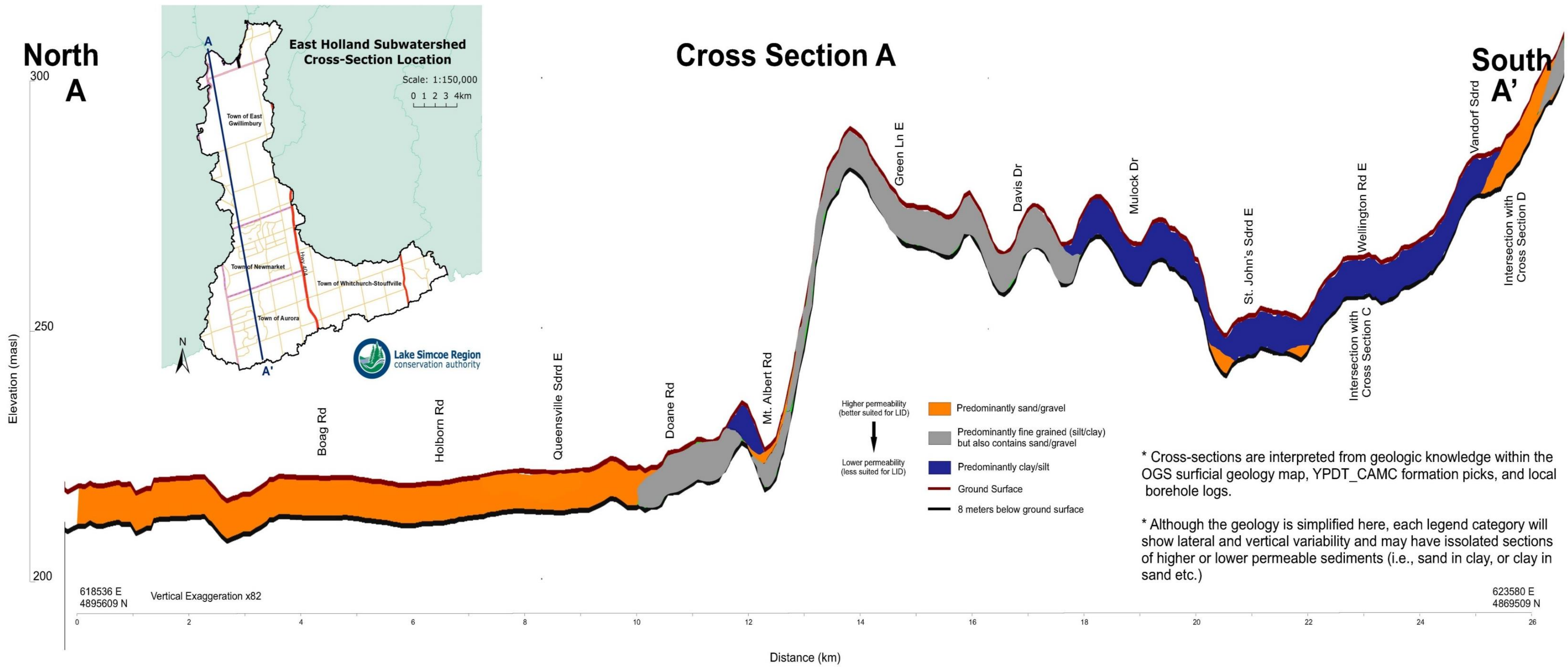

Figure 2 – N-S geologic cross-section (A) along Yonge St. Geology is simplified and interpreted based on texture and suitability for infiltration based LID

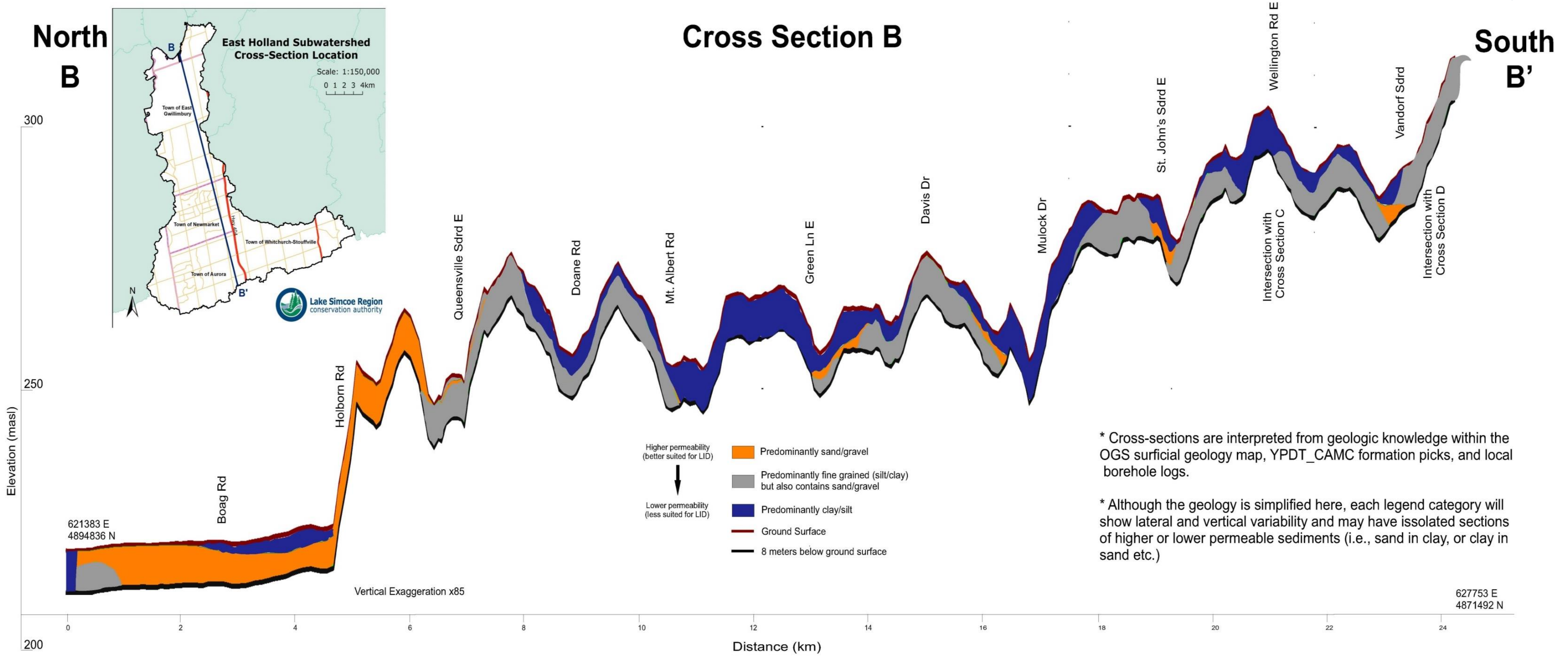

Figure 3 – N-S geologic cross-section (B) within East Holland River Subwatershed. Geology is simplified and interpreted based on texture and suitability for infiltration based LID

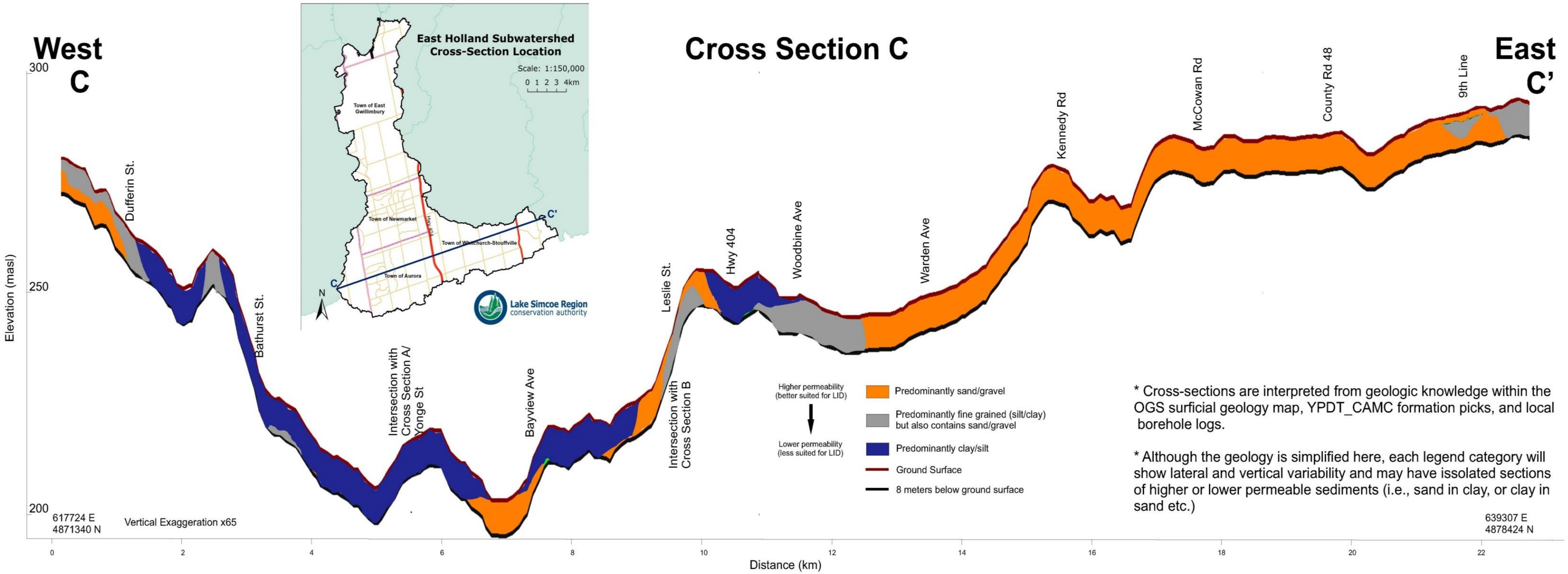

Figure 4 - W-E geologic cross-section (C) along Wellington Rd E. Geology is simplified and interpreted based on texture and suitability for infiltration based LID

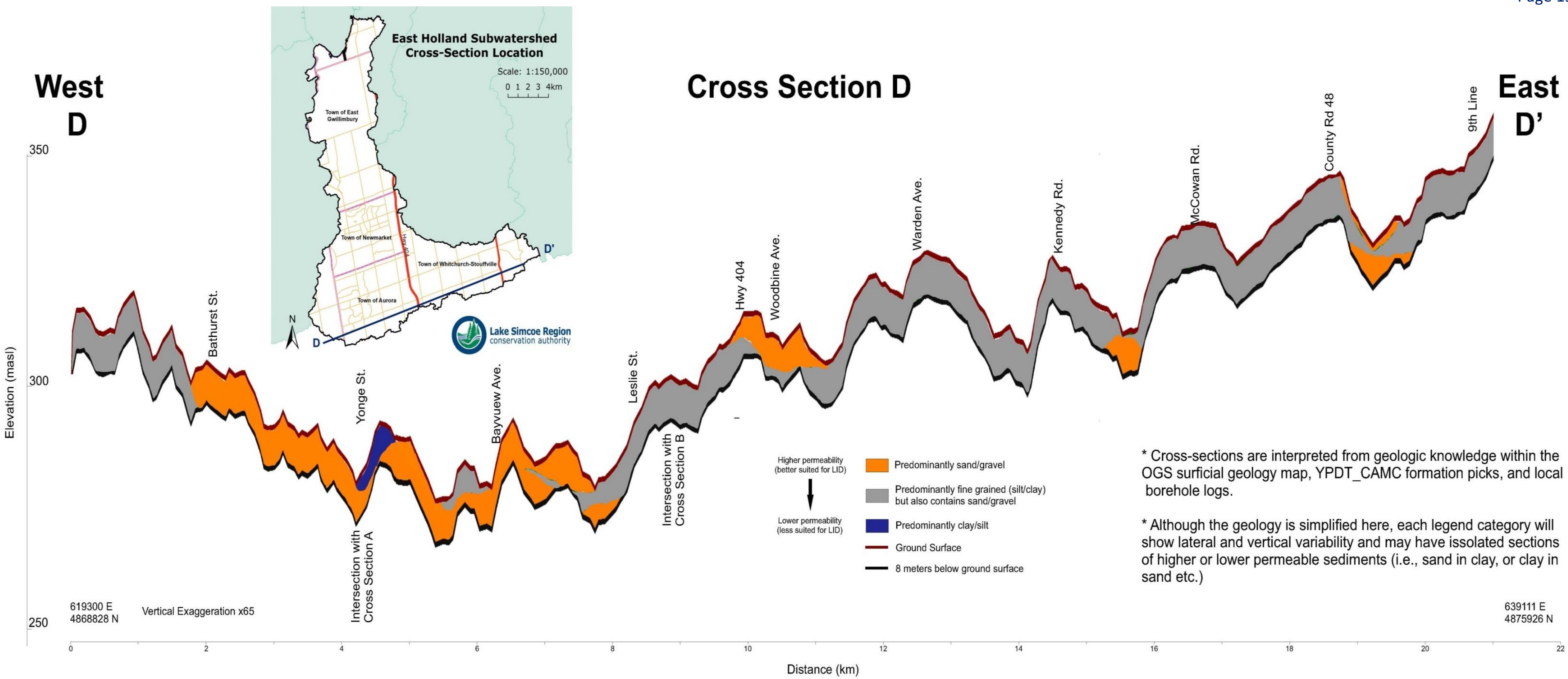

Figure 5 - W-E geologic cross-section (D) within East Holland River Subwatershed. Geology is simplified and interpreted based on texture and suitability for infiltration based LID

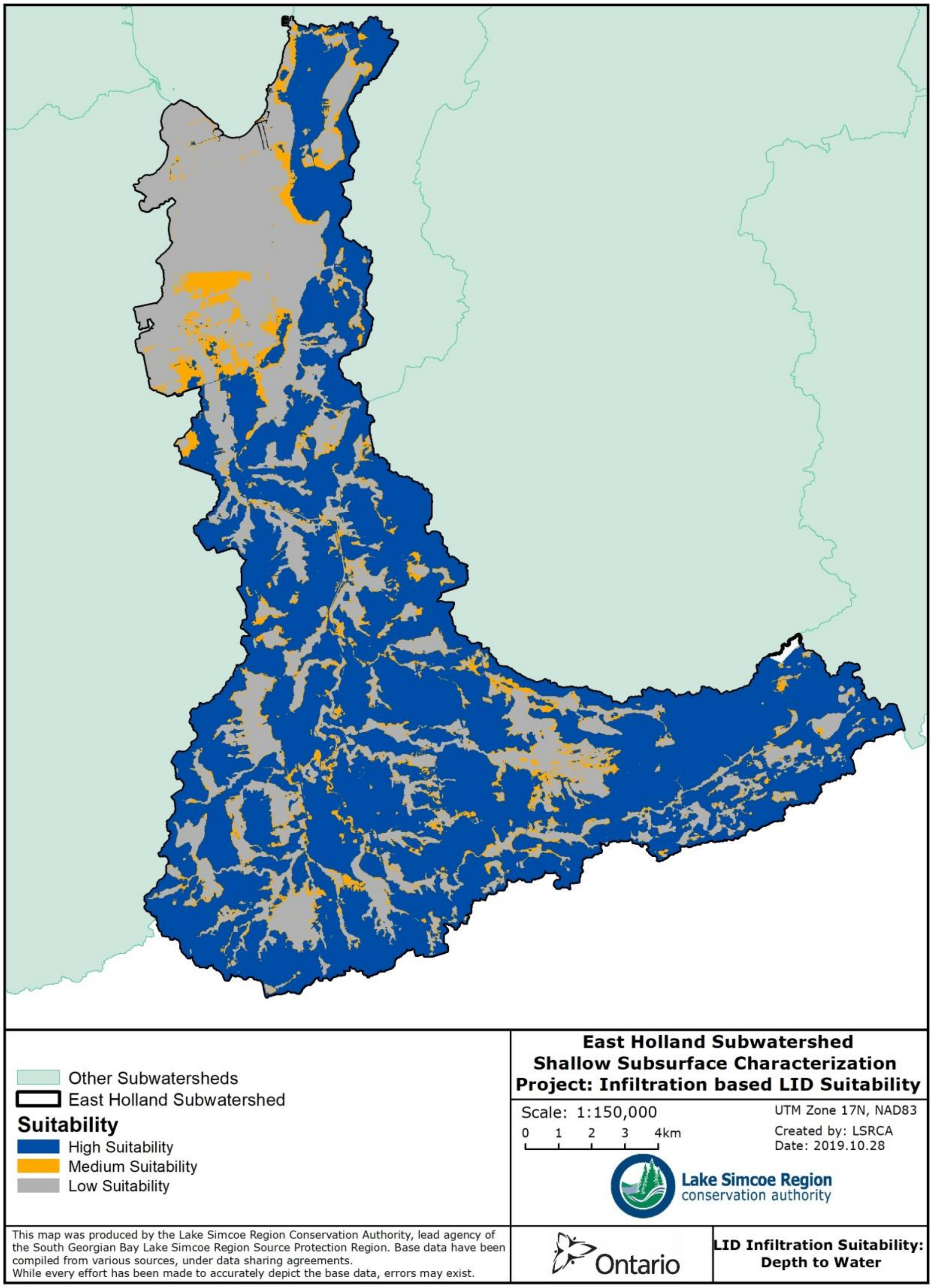

Figure 6 – Infiltration based LID location suitability for the East Holland River Subwatershed based on depth to water

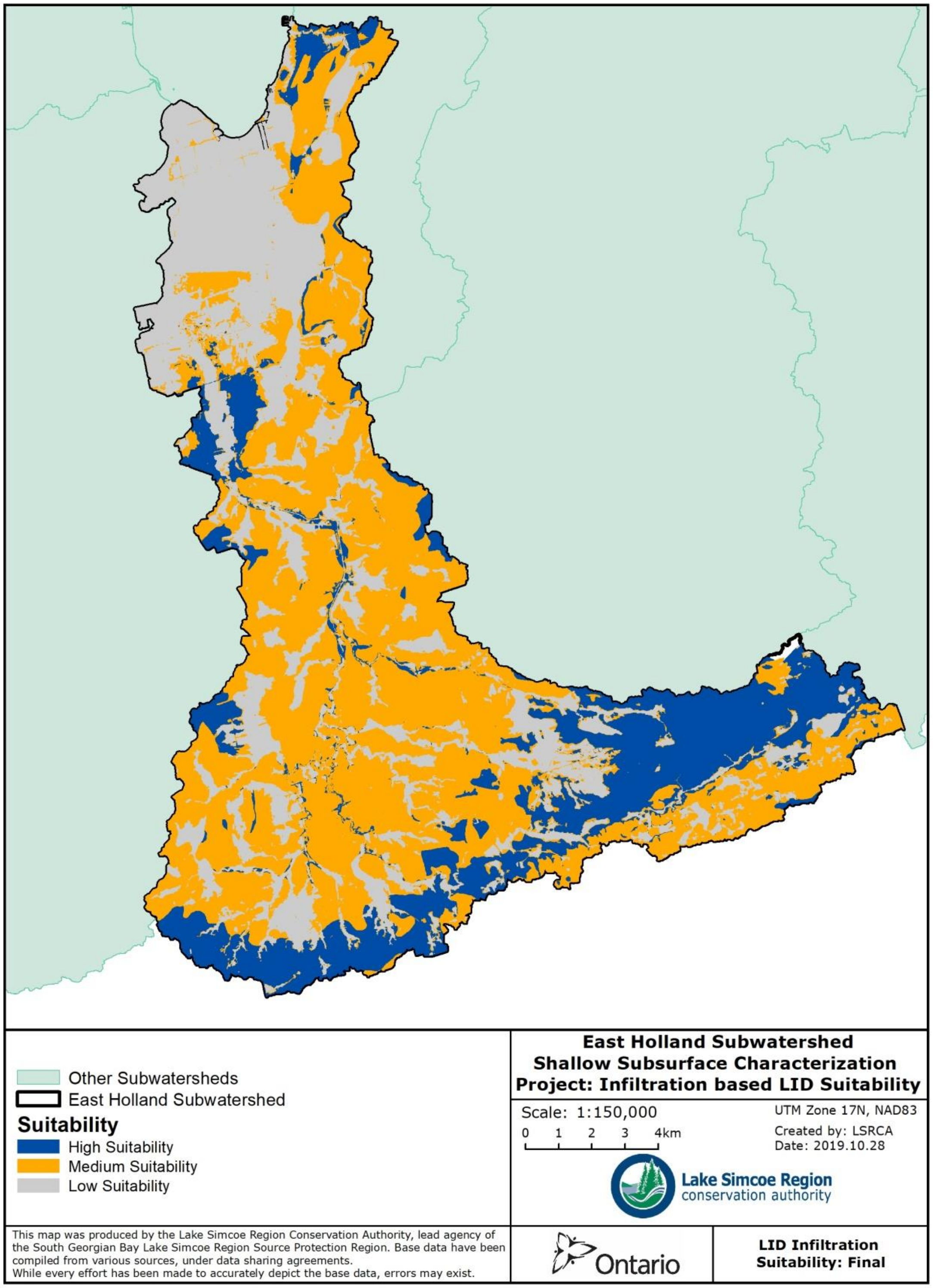

Figure 7 – Final infiltration based LID location suitability for the East Holland River Subwatershed based on both input criteria (shown in Figure 1and Figure 6)

6.0 How to use Infiltration based LID Suitability Layer

The final infiltration based LID location suitability layer can be used to help guide selection of a site for infiltration based LID projects / retrofits by referring to the grey-orange-blue classification scheme. Locations considered to be highly suitable for infiltration are blue, those slightly less suitable for infiltration and that likely require more consideration before the location is selected are orange, and locations considered the lowest suitability and that require further investigation before selection are grey.

Further investigation into the suitability of a location should first start with a look at the attributes table, followed by site specific field investigations to confirm suitability. Since two different input criteria are considered in the final infiltration based LID location suitability layer it may be that only one of these input criteria are considered ‘unsuitable’ for infiltration based LID practices and the other is favourable. The only input criteria that may physically limit the ability to implement an infiltration based LID project is the depth to water, as shallow water levels (<1 mbgs) are much more difficult to offset through design considerations than geologic limitations, although not impossible.

In order to determine which input criteria is the limiting factor, data in the attribute table can be used by clicking the location / polygon in question with the “identify” tool (Figure 8). There is a specific attribute field called ‘LimitFactr’ that identifies the criteria(s) that are considered the limiting factor. In addition, each input criteria has an attribute field that indicates the infiltration based LID suitability / ranking based purely on that criteria alone. The geology suitability / ranking can be found under the GeolRank field while the depth to water suitability / ranking can be found under the WLRank field (Figure 9). Each of these fields indicate if the suitability / ranking is low (grey), medium (orange) or high (blue), thus identifying why that specific location may be ranked as being a low (grey) or medium (orange) suitability for infiltration based LID practices.

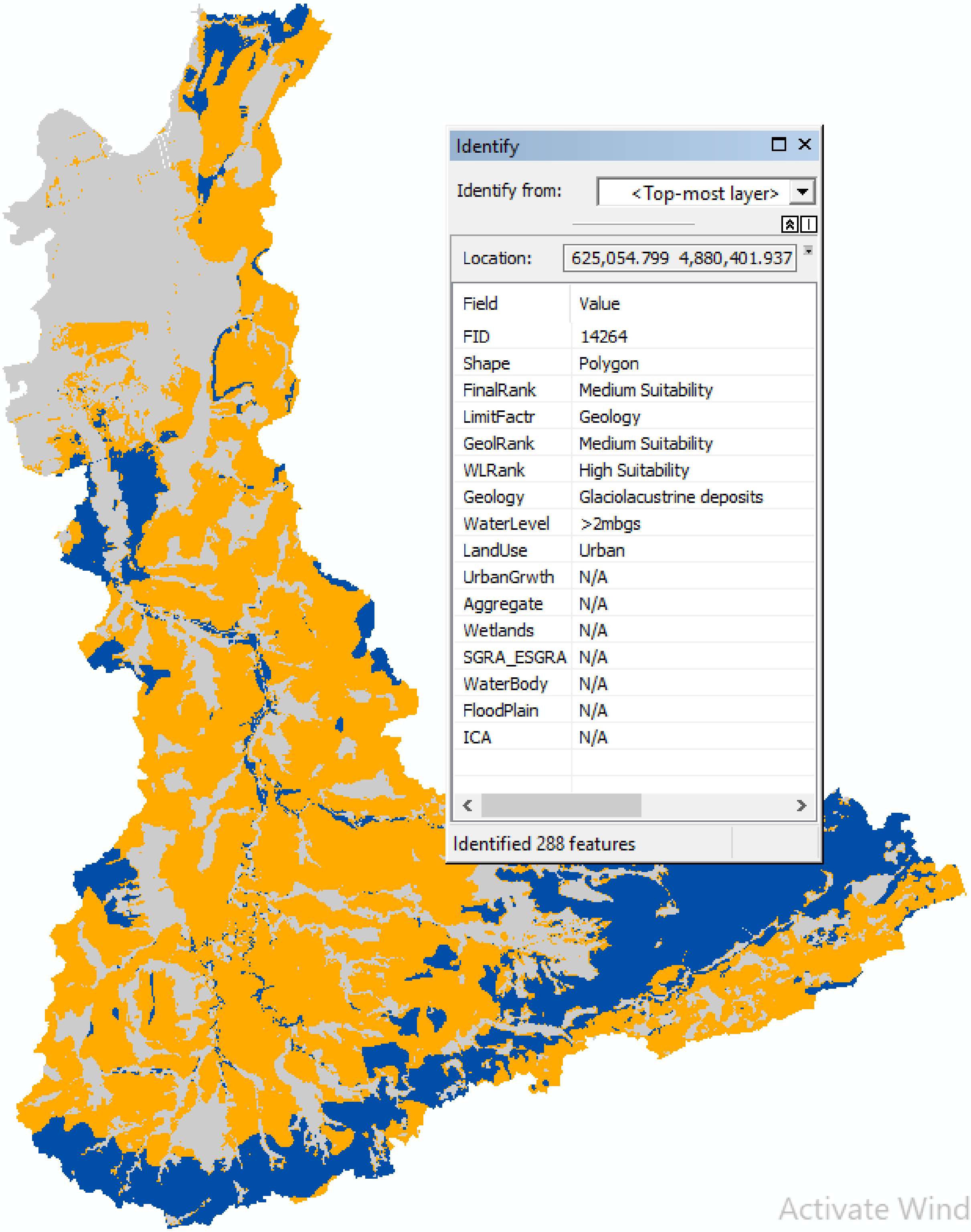

Figure 8 – Final infiltration based LID Suitability layer with attribute table information for a Site in Newmarket shown using the Identify tool

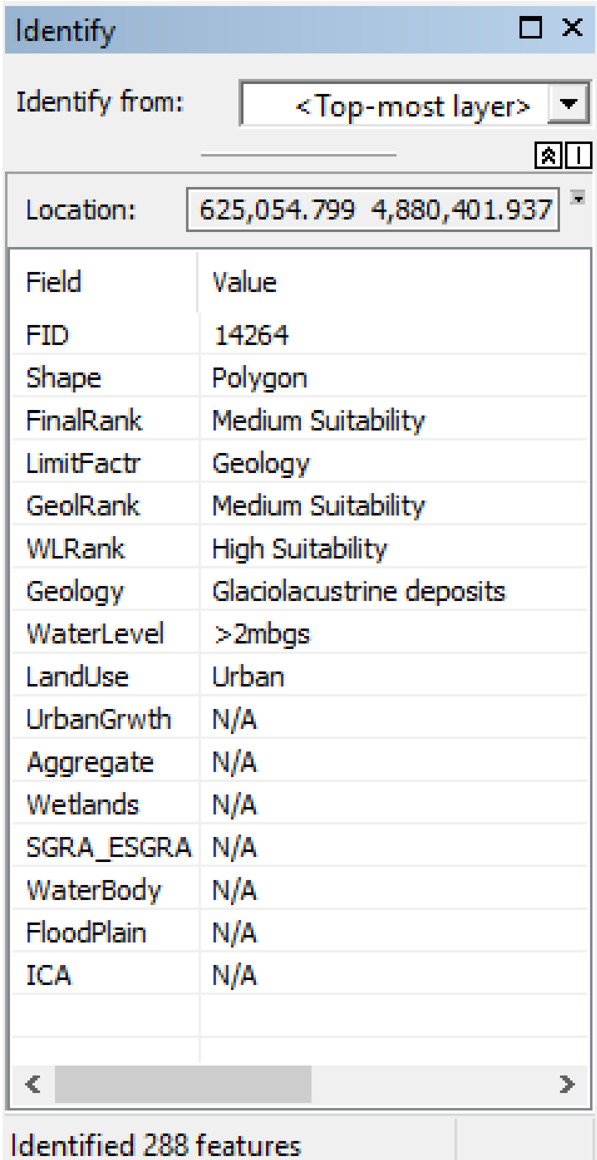

Figure 9 – Attribute table information presented through the Identify tool in ArcMAP

The attribute fields that are revealed with the "identify" tool also provide information on the presence or absence of a water body, aggregate pit, flood plain, wetland, ESGRA / SGRA, issue contributing area (ICA), or expected growth locations. In addition, these attribute fields indicate the current land use categorization, the water level depth range, and the surficial geology. A full list and description of the attribute fields in the LIDSuitability layer are provided below and can be seen in Figure 9.

Attribute Field: **FinalRank** - Classification of the East Holland River subwatershed for infiltration based LID suitability (low, medium, high) based on all input criteria, as outlined in Section4.4.

Attribute Field: **LimitFactr** - Identifies the input criteria(s) (geology, water, or land) that is/are causing the FinalRank attribute to be that colour / ranking.

Attribute Field: **GeolRank** - Classification of the East Holland River subwatershed for infiltration based LID suitability (low, medium, high) based on the surficial geology input criteria, as outlined in Section 4.2.3.

Attribute Field: **WLRank** - Classification of the East Holland River subwatershed for infiltration based LID suitability (low, medium, high) based on the depth to water input criteria, as outlined in Section 4.3.4.

Attribute Field: **Geology** - General geologic description of the surficial geology from the OGS surficial mapping, with slight local adjustments made as outlined in Section 4.2.2and no consideration for potential overlaying fill.

Attribute Field: **WaterLevel** - Approximate range of the depth to water (mbgs) for each polygon.

Attribute Field: **LandUse** - Identification of the land use category for all polygons within the subwatershed (e.g. natural heritage feature, industrial, urban, agriculture, etc.).

Attribute Field: **UrbanGrwth** - Identification of polygons that are classified as locations for future growth (i.e., designated settlement).

Attribute Field: **Aggregate** - Identification of polygons that contain aggregate activities, classification as a pit or quarry and further identified as active or not active (i.e., surrendered).

Attribute Field: **Wetlands** - Absence or presence of wetlands and where known, classification as swamp or marsh (etc.) and if regulated.

Attribute Field: **SGRA_ESGRA** - Absence or presence of ESGRA or SGRA.

Attribute Field: **WaterBody** - Absence or presence of surficial water body.

Attribute Field: **Floodplain** - Absence or presence of floodplains and classification as engineered or regulated spillway.

Attribute Field: **ICA** - Absence or presence of issue contributing areas (ICAs) as identified in the South Georgian Lake Simcoe Source Water Protection Plan.

Further information about the final LIDSuitability layer can be found in Section 4.0(Methods) as well as the metadata. Before using the final layer to help guide selection of a site for an infiltration based LID project it is important to remember that this GIS layer is meant as a guide and a 'first-look' at possible locations for infiltration based LID retrofits and requires confirmation through *in situ* field investigations. Further, the disclaimers identified in Section 3.0 should be considered as they outline the limitations and assumptions of the methodology and analysis, which includes limitations such as: water quality, which was not considered when ranking the subwatershed for infiltration based LID practices; the depth to water estimates are long term averages and may not represent the season high at a site; and geologic interpretations do not consider the presence or influence of possible fill materials.

7.0 Other Considerations

Geology and water level are considered here to be the two most important factors for determining the suitability of a location for infiltration based LID projects; however, they are not the only factors to consider when choosing a site or designing a project. Other important factors to consider are land use and policy.

When land use is considered, you can better understand where infiltrating water quality may be compromised (e.g., runoff from some industrial businesses or aggregate pits) and where there is already significant / adequate groundwater recharge which may not require further supplement (e.g., natural heritage areas). As a result, it is important to evaluate the type of industry and the associated water quality to ensure it is appropriate for infiltration before initiating LID retrofits and projects. On the other hand, when policies are considered they can help you understand where regulated lands are and locations that may not allow / encourage infiltration.

Although land use and policies do not physically impact the success of LID projects they do impact where LIDs can or should be placed based on regulations, need or desire for infiltration in an area, and water quality. But it should also be noted that land use and policies are not consistent and may change over time (unlike the local geology), so an area initially thought of as less suitable based on land use / policy may become more suitable for infiltration at some other time.

The complexity and variety of land use and policies within the East Holland Subwatershed, plus the tendency of land use and policies to change over time, makes it difficult to incorporate these factors into the suitability layer. It is recommended that specific land use and policy considerations be made on a project by project basis and may consider the following land uses / policies:

- Source Water Protection Issue Contribution Areas
- Water courses and waterbodies
- Aggregate Site
- Ecological Land Classification Wetland
- Floodplain (regulated areas)
- Wetlands and wetland setbacks (regulated areas)
- Developed areas (e.g. commercial, residential, urban, industrial, institutional etc.)
- Significant Groundwater Recharge Areas (SGRA)

- Ecologically Significant Groundwater Recharge Areas (ESGRA)
- Expected locations of growth
- Natural heritage
- Agricultural lands

8.0 Conclusions

Consideration of surficial geology and depth to water allow for a comprehensive categorization of the East Holland River Subwatershed for infiltration based LID location suitability. These two input criteria (geology and depth to water) are considered the main factors that affect the suitability of a location for infiltration and understanding these site conditions is identified in the 2012 TRCA Stormwater Management Criteria report as the critical first step to develop a Stormwater management plan. Based on the final infiltration based LID location suitability map that considers the two input criteria, the most appropriate locations for infiltration based LID practices within the subwatershed are sites on Oak Ridges Moraine sediments (in the south of the watershed) or on other sandy geologic deposits (spaced throughout the watershed). However, regardless of the lower permeability of sediments, infiltration based LID projects within these lower permeable sediments (e.g. in Newmarket and Aurora) are expected to be successful if adequately designed or if local fill materials provide more suitable surficial sediments for infiltration. Groundwater levels are the most important factor to consider for infiltration based LID practices as they are difficult to overcome through design or land development. Luckily, water levels throughout much of the subwatershed are suitable for most infiltration projects.

It is important to remember when utilizing and interpreting the final and input infiltration based LID location suitability layers that the analysis for determining suitability does not consider water quality of infiltrating water or the presence and influence of geologic fill, that the depth to water interpretation is based off an average approximate water level and may be several meters higher or lower, and that areas ranked as low suitability are not necessarily unsuitable for infiltration based LID practices but instead are areas where further consideration should be made before an infiltration project commences. It is also important to note that those locations identified as lower suitability only considered the suitability for infiltration based LID practices and that LID provides a wide range of practices that can help offset various negative impacts of Urban Stormwater beyond reduced infiltration. The other LID practices would be highly suitable in many more locations than identified for infiltration based LID practices in this report.

The goal of this project was to help guide infiltration based LID placement within the East Holland River Subwatershed by providing an improved understanding of the shallow subsurface and developing a GIS layer that ranks areas within the East Holland subwatershed based on their suitability for infiltration based LID practices. As a result, the final GIS layer is meant as a first look that allows for a quick and simple desktop evaluation of the suitability of locations for infiltration based LID retrofits and should be combined with further site investigations to confirm suitability.

9.0 References

Kassenaar, J.D.C and Wexler, E.L. 2006. Groundwater Modelling of the Oak Ridges Moraine Area. CAMC-YPDT Technical Report #01-06.

Ontario Geological Survey. 2010. Surficial Geology of Southern Ontario; Ontario Geological Survey, Miscellaneous Release – Data 128 – Revised.

Toronto and Region Conservation (TRCA). 2012. Stormwater Management Criteria: Version 10. 126 pp.

9.0 Acronyms

DEM –digital elevation model
ESGRA – ecologically significant groundwater recharge area
GIS – geographic information system
GSC – Geologic Society of Canada
ICA – issue contributing area
IDW - inverse distance weighted
LID – low impact development
mbgs – meters below ground surface
masl – meters above sea level
OGS – Ontario Geological Survey
ORM – Oak Ridges Moraine
SGRA – significant groundwater recharge area
TIN - triangular irregular networks
UTM – Universal Transverse Mercator
WRIP – Well Resources Information Project
WWIS - Water Wells Information System