B

City of Brantford

APPENDIX B

EXPANSION LANDS SUBWATERSHED STUDY

Prepared By:

in association with:

City Of Brantford

North Brantford and Tutela Heights Subwatershed Study

GMBP File: 717003

November 2020

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1. INTRODUCTION

1.1 Background

The following subwatershed study was prepared to address growth needs in the City of Brantford (the City). In December 2016, the City officially acquired lands from the County of Brant, known as the Boundary Adjustment Lands. This acquisition of new land expanded the City's boundary. With this new land and larger urban boundary, the City must decide what portions of the new lands will be brought into its urban settlement area, known as the Expanded Urban Settlement Area, to meet 2041 growth targets. In support of the addition of development lands, the following must be completed:

- An Official Plan (OP) Update, which includes a Municipal Comprehensive Review (MCR)
- A Secondary Study
- Subwatershed Study
- Master Plans, which include a Master Servicing Plan (MSP) and a Transportation Master Plan (TMP)

By completing the above-mentioned plans, the planning and engineering teams can define the Expanded Urban Settlement Area, map proposed land uses, define a long-term infrastructure plan, and provide guidelines and policies to frame growth and mitigate impacts.

The subwatershed study is part of the entire development process. This subwatershed study is being conducted so that growth planning may take into consideration the surrounding natural environment and aim to minimize any negative effects caused by development and to enhance the natural environment where feasible. This study is also being completed to comply to with the Provincial Growth Plan (PGP). The PGP contains specific requirements to expand an urban settlement area and prepare a Secondary Plan, including the requirement for subwatershed planning.

This study has been completed by the following consultant team: GM BluePlan Engineering (GMBP), Ecosystem Recovery Inc. (ERI), and Plan B Environmental (Plan B).

1.1 Scope

A subwatershed study involves long-term management and planning for the water resource and natural heritage systems within the study area. This subwatershed study will also include the following:

- Characterization of the existing drainage features, areas, linkages, and functions as well as natural features, areas, and related hydrologic functions
- Characterization of the hydrology of the existing watercourses
- General strategies for protection and/or restoration of the natural and drainage features
- Consideration of potential impacts of proposed land uses and development
- Guidance on further studies needed to complete a more thorough review and evaluation of the subwatershed, which will form the basis for an implementation and monitoring plan that will be used to help guide and direct development

This Subwatershed Study is the beginning of a multi-staged approach to fully characterize, evaluate, and implement recommendations for this subwatershed. As will become clear throughout this study, there are additional field programs required to complete the baseline of data needed to accomplish the goals of a subwatershed study. As such, this report is meant to summarize the currently available information and the field program to date, make general conclusions about impacts to the watershed, and form the foundation for future studies and implementation. Overall, this subwatershed study is meant to be a guiding document on how to successfully plan for development in the future growth areas of Brantford while avoiding or minimizing negative effects to the natural environment.

1.2 Study Goals and Objectives

The subwatershed study goals and objectives are outlined below in terms of natural hazards, water resources, and natural heritage.

1.2.1 Natural Hazards

Goal

To prevent, minimize, or eliminate the risks caused by flooding and erosion.

Objectives

- To ensure that new development lands do not create new hazards or amplify existing hazards.
- To prevent new development lands from being damaged by flooding or erosion hazards.
- To ensure that any new infrastructure (i.e. culverts, trunk sewers, drainage channels) is designed adequately to convey flows and address channel migration.
- To adapt to and mitigate the effects of climate change on the natural and built system

1.2.2 Water Resources

Goal

To protect water quality and maintenance of surface water-groundwater interactions within the study area. This includes surface and groundwater features within, upstream, adjacent, and downstream to the primary study area.

Objectives

- To implement water management measures that protect natural waterways and mitigates potential risk for adverse effects on water quality post development.
- To maintain fluvial processes and ensure that natural stream morphology is upheld.
- To suggest sustainable management practices and design standards that protect, improve, and restore water quality after development activities, that would otherwise trigger stream contamination and temperature increases.
- To protect and maintain groundwater recharge and discharge, and connections between surface water and groundwater, which is important in maintaining the stream baseflows that support aquatic and terrestrial ecosystems.

1.2.3 Natural Heritage

Goal

To conserve the natural heritage system and biodiversity, including key natural heritage features and functions, key hydrologic features, and the functional relationships between hydrologic and ecological features.

Objectives

- To protect natural heritage features and areas from possible negative impacts of development by using vegetation protection zones or buffers.
- To apply adequate land use controls and development standards that protect natural features from the possible adverse effects of development.
- To create an environmental management plan that include measures that seek to protect the natural environment prior to, during, and post construction of development.

- To recommend stormwater management strategies that mimic, as much as feasible, the natural patterns of the subwatershed area.

1.3 Study Approach

As indicated above, this subwatershed study is the beginning of a multi-staged approach working towards the completion of a fully comprehensive subwatershed plan for the subwatershed area. Figure 1-1presents the multi-staged plan for the subwatershed study process and how its three stages relate to the other planning requirements for the expansion lands.

Under a staged approach, the Phase 1 Subwatershed Study (i.e. this report) will be sufficient to outline the overall management strategy and targets within the Urban Boundary Expansion lands within the context of the MCR, OP update, and Development Charge (DC) bylaw update. It is understood that the Phase 1 Subwatershed Study will be utilized to support the MCR, OP update, and DC bylaw update, and that the Stage 2 Field Investigation, and subsequent Comprehensive Subwatershed Study update will be required before the City will be able to allow Draft Plan Approval for any new development within the Urban Boundary Expansion Lands. A more detailed explanation of this phased approach is as follows:

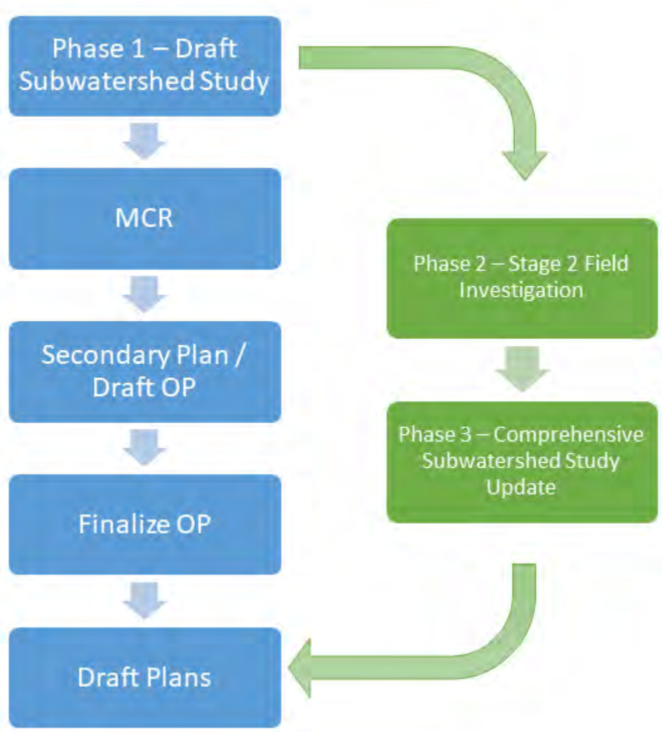


Figure 1-1 Subwatershed Planning Process

1.3.1 Phase 1 (Current Phase)

The Stage 1 field investigation has been completed to review any critical data gaps within the existing available information; however, this review has included visual investigations only, and no additional flow, groundwater, or water quality monitoring has been completed. The Phase 1 works include:

- A complete preliminary baseline characterization of the Study area utilizing best available information.

- A complete preliminary hydrologic model of the drainage system utilizing best available information.
- A complete baseline desktop analysis, utilizing best available information, of key hydrologic and hydrogeological impacts and mitigations, including stream flow and temperature regime, groundwater recharge, and total water cycle mass balance.
- General recommendations for the management of the Urban Boundary Expansion Lands including objectives, thresholds, targets, and BMPs for development, water/wastewater servicing, & stormwater management, and to support ecological needs.

Recommendations for the Stage 2 Field Investigation are required to:

- Address any identified data gaps
- Validate/confirm the baseline understanding
- Refine the study's draft recommendations

1.3.2 **Phase 2 (Stage 2 Field Program)**

Phase 2 consists of completing the Stage 2 Field Investigation as outlined in the current (Phase 1) Subwatershed Study. This investigation will be City-led, covering the entirety of the program needed to complete the Comprehensive Subwatershed Study Update for the Urban Boundary Expansion Lands. Details of the required field investigations are found in Section 5 of this report.

1.3.3 **Phase 3 (Comprehensive Subwatershed Study Update)**

Following completion of the Stage 2 Field Investigation, the Subwatershed Study will be validated and updated. At a minimum, this update will likely include:

- Detailed analysis and model development utilizing the field investigation to provide more quantitative direction on the required stormwater management targets for individual development areas.
- Outlining of appropriate implementation and monitoring plan.
- This study will need to be completed under the Municipal Engineers Act (MEA) Environmental Assessment (EA) process and will require additional Public Consultation.
- The Comprehensive Subwatershed Study Update will then form a guiding document that the City will use to manage growth within the Urban Boundary Expansion Lands.

1.4 Study Area

Figure 1-2 defines the study area to be referenced in this document. The study area encompasses two geographical areas within the new City limits. The first is what will be refered to as the North Brantford lands and is located generally north of Powerline Road and Paris Road along the north side of the City, and east of Garden Avenue along the wast side of the City. The second geographical area is referred to as Tutela Heights and is bounded generally by Mt. Pleasant Road, Tutela Heights Road, and Phelps Road. Each of these geographical areas has primary, secondary, and tertiary areas, which are described below.

1.4.1 **Primary Study Area**

The Primary Study Area for the North Brantford Area (including East Expansion Lands) is the actual expanded settlement area. This area is roughly 2,123 hectares. The Primary Study Area for Tutela Heights is also the actual expanded area and is roughly 581 ha.

1.4.2 **Secondary Study Area**

The Secondary Study Area is defined as all the lands that were acquired from the County of Brant in the North Brantford Area and in Tutela Heights, also known as the Municipal Boundary Expansion Lands (~2,700 ha). The Secondary Study Area for Tutela Heights is the same as the Primary Area.

1.4.3 **Tertiary Study Area**

The Tertiary Study Areas include all the lands that are significant to this Subwatershed Study. Lands outside of the municipal boundary are also included in this area. Specifically, the Tertiary Study Area for the North Brantford Area includes all lands that form the catchment areas of the watercourses of interest, namely Jones Creek and Fairchild Creek and their unnamed tributaries in the North Brantford Area.

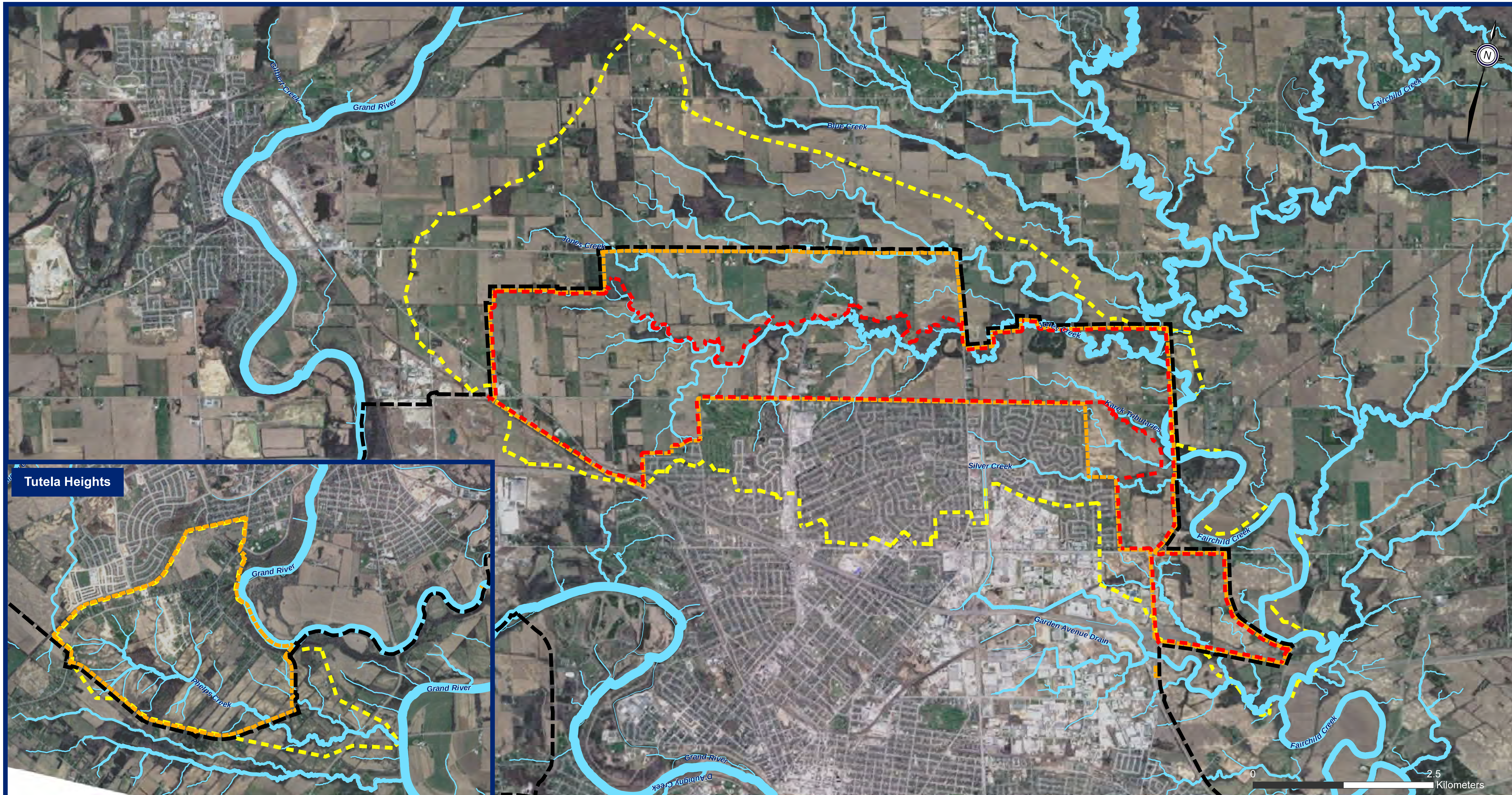
In the Tutela Heights area, the Tertiary Study Area is defined as the lands that form catchments of the tributaries to the Grand River, such as Phelps Creek which are located within the Tutela Heights area.

1.5 Background Studies and Referenced Materials

This subwatershed study relied on background data that was collected and analyzed from a variety of sources, including reports, GIS and spatial data, and existing field data. External documents referred to throughout this study will be referenced in the format "(Author, date)".

Specific references to data sources are listed in Appendix A. In general, the following information was used to guide the development of this subwatershed study:

- Previous subwatershed studies such as the GRCA Fairchild Creek Subwatershed Characterization Study
- Natural heritage and ecological studies
- Climatic data from the Ministry of Environment and Climate Change
- GRCA GIS spatial data layers
- GRCA stream gauging data
- Provincial Data Sets:
    - Southern Ontario Land Resource Information System (SOLRIS)
    - Ontario Permit to Take Water records
    - Ministry of the Environment and Parks Water Well records



Brantford Growth Plan

Subwatershed Study Area

Primary Study Area

Secondary Study Area

Tertiary Study Area

Watercourse

Municipal Boundary

Figure 1-3

Subwatershed Study Area

May 2020

717003-G-004

NAD 1983 UTM Zone 17N

2. CHARACTERIZATION OF EXISTING CONDITIONS

The following sections describe the existing conditions of the subwatershed areas in detail, including climate, land use, infrastructure, physiography and geology.

2.1 Climate

The climate of North Brantford and Tutela Heights subwatershed is comprised of four seasons, which is consistent with other areas within the Great Lakes/St. Lawrence climate zones. The Grand River Conservation Authority (GRCA) considers the North Brantford and Tutela Heights subwatersheds as part of the South Slopes and Lake Erie Counties climate zones. Winter is the longest season which spans from November to March, spring is April and May, summer is from June to September, and fall is considered October. Winters experience long, cold nights, and summers experience long days and short nights.

The proximity of North Brantford and Tutela Heights subwatersheds to the Great Lakes adds humidity to the air. In the winter, this humidity contributes largely to snowfall, known as the "Lake Effect". Yearly, on average, the region receives 98.4 mm of snowfall.

The below Canadian Climate Normals chart (Figure 2-1) presents the average temperature and precipitation from 1981 to 2010 in the City of Brantford. The region experiences most of its precipitation as rain in the month of July, with an average of 95 mm. The overall yearly average amount of precipitation is 867.3 mm.

The highest average temperature also occurs in July at 27.2° C. The lowest average temperature occurs in January at -10° C. The overall yearly average temperature is 8.1 ° C.

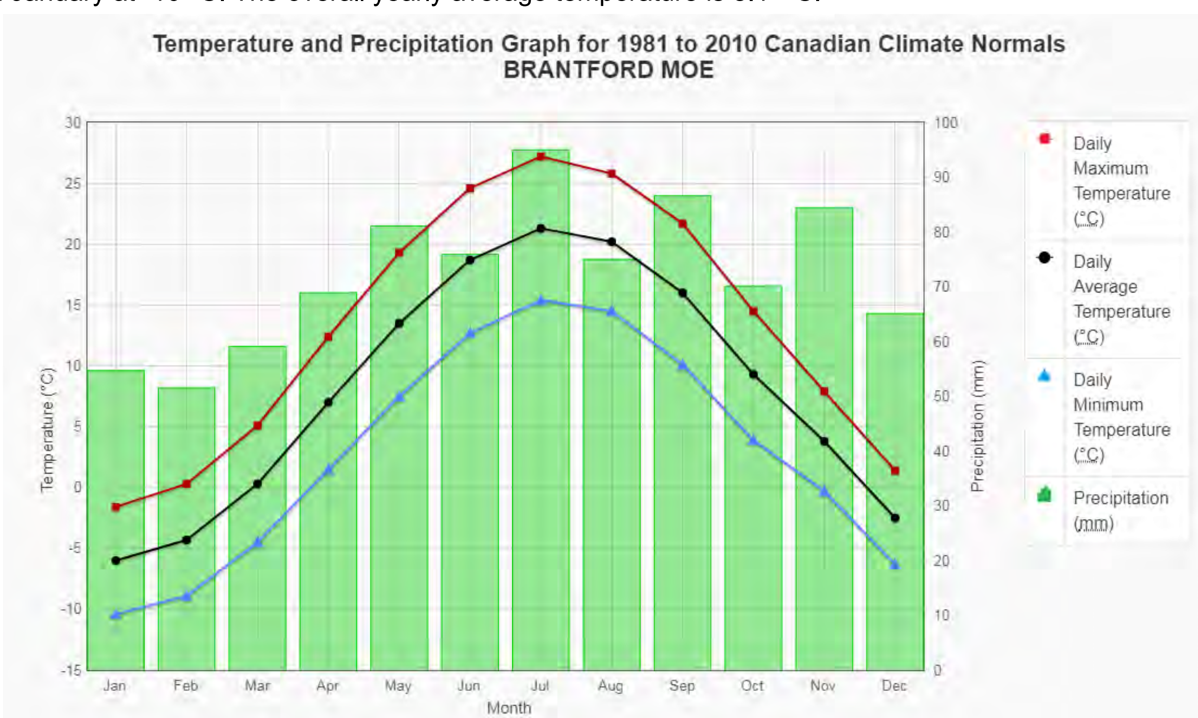


Figure 2-1: Monthly Average Temperature and Precipitation for Brantford, ON

[1]Government of Canada, Canadian Climate Normals 1981-2010 Station Data

2.2 Existing Land Use

2.2.1 Municipal Planning Data

Approximate existing land cover for North Brantford and Tutela Heights areas are presented as a map format in Figure 2-3. This land use information was taken from the City's Official Plan layer. Most of the boundary expansion lands consist of agricultural and industrial land.

2.2.2 Southern Ontario Land Resource Information System – SOLRIS

In addition to the Official Plan data, land use information was reviewed from the Southern Ontario Land Resource Information System (SOLRIS, Version 2.0). This database provided regional land cover and land use inventory information for the landscape between 2009 and 2011 through use of the Landsat 7 Satellite's Enhanced Thematic Mapper. This dataset provided information that was used to break down specific land use areas within the study area, as shown in Figure 2-2.

Land use within the North Brantford area is mainly agricultural (43%). Forests and wetlands make up approximately 8% of the land use. Urban areas, including pervious and impervious built-up areas, and impervious undifferentiated areas and transportation areas account for a total of 44% of the area. Most of the built-up area is concentrated below Powerline Rd.

Land use within the Tutela Heights area is also mainly agricultural (37%). Forests and wetlands make up roughly 12% of the land use. Urban areas, including pervious and impervious built-up areas, and impervious undifferentiated areas and transportation areas account for a total of 49% of the area. Most of the built-up area is concentrated around Conklin Rd.

A map of the study area illustrated with the SOLRIS dataset is shown in Figure 2-4.

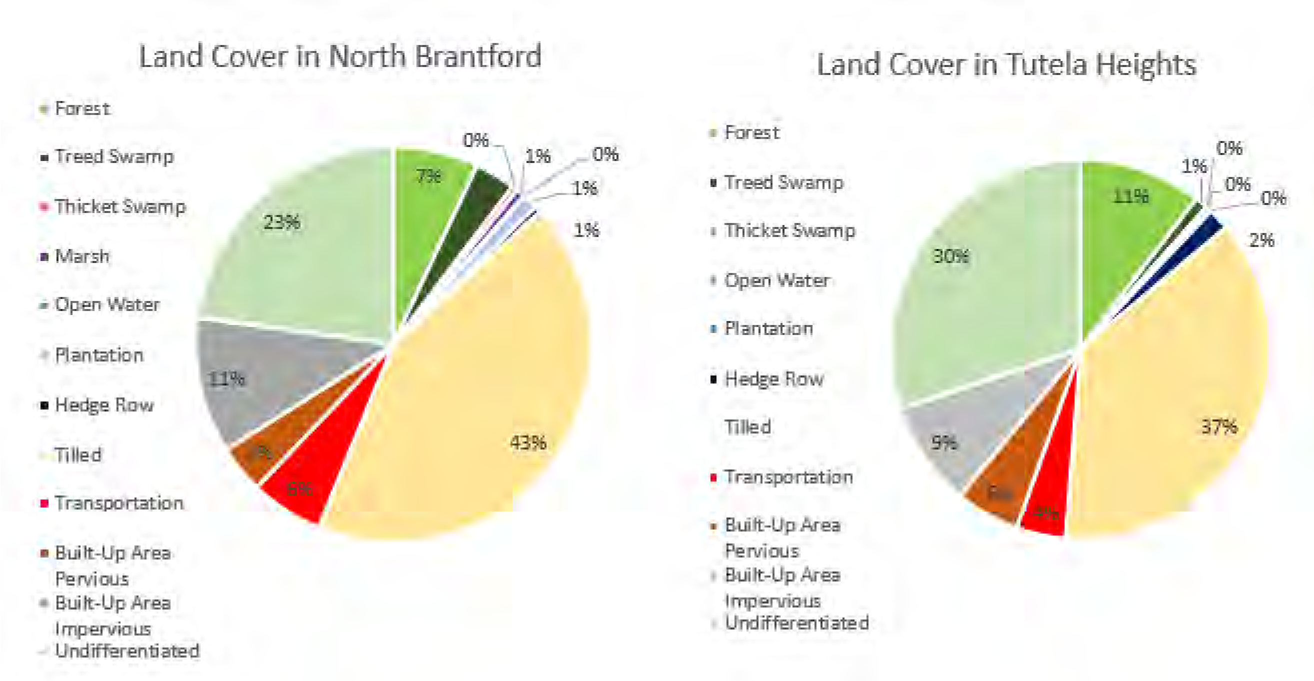


Figure 2-2: SOLRIS Land Classification in North Brantford and Tutela Heights

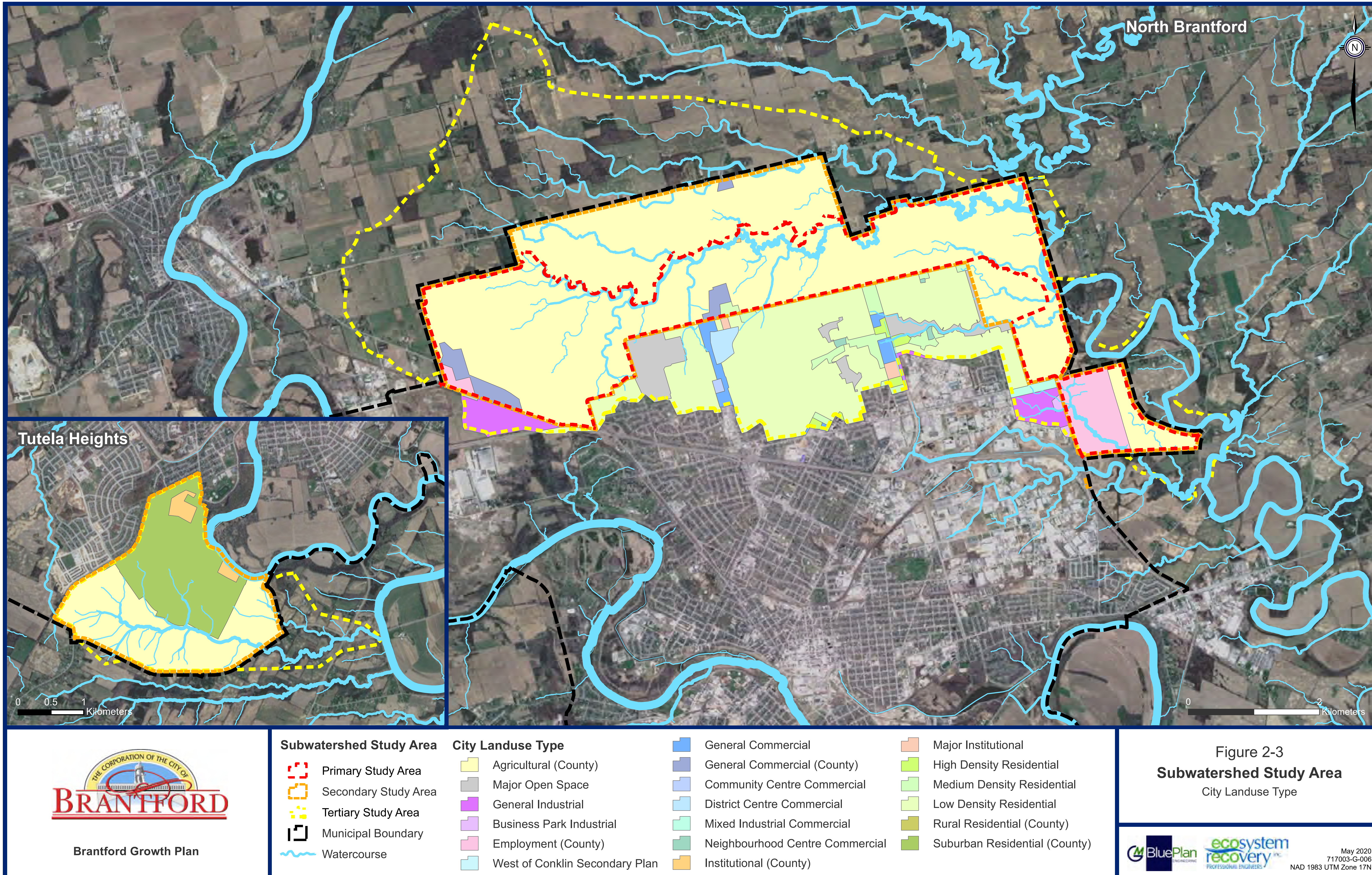
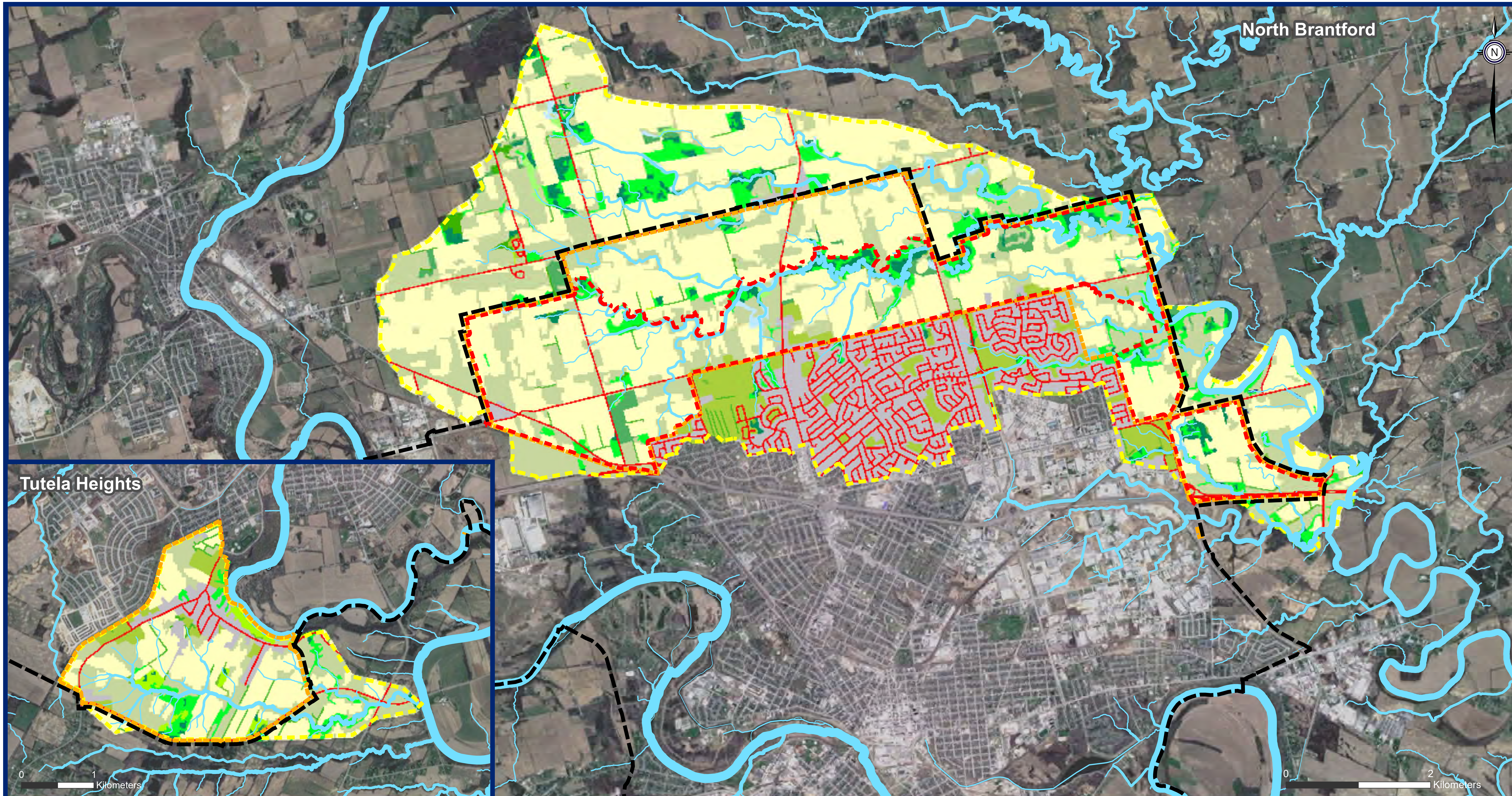


Figure 2-3
Subwatershed Study Area
City Landuse Type



Subwatershed Study Area

- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary
- Watercourse

SOLRIS Landuse Type

- Forest
- Coniferous Forest
- Mixed Forest
- Deciduous Forest
- Treed Swamp
- Thicket Swamp
- Marsh
- Open Water
- Plantation
- Hedge Row
- Tilled
- Transportation
- Built Up Area - Pervious
- Built Up Area - Impervious
- Undifferentiated

THE CORPORATION OF THE CITY OF BRANTFORD

Brantford Growth Plan

Figure 2-4
Subwatershed Study Area
SOLRIS Landuse Type

GM BluePlan ENGINEERING
ecosystem recovery INC. PROFESSIONAL ENGINEERS

May 2020
717003-G-005
NAD 1983 UTM Zone 17N

2.3 Existing Urban Infrastructure

As noted above, the tertiary study area includes built-up areas within the existing urban settlement area, which drain to and/or receive drainage from the secondary study area. With some exceptions, these areas are serviced with water, wastewater, and stormwater infrastructure. Existing City infrastructure is described and assessed in detail in the Master Servicing Plan and is summarized below. Private water, wastewater, and stormwater infrastructure within the study area are also discussed.

2.3.1 Water and Wastewater Infrastructure

In general, City of Brantford drinking water is distributed from the Holmedale Water Treatment Plant, and wastewater is directed to the Brantford Wastewater Treatment Plant for treatment and returned to the Grand River. Both plants are located outside of the study area and have minor potential for impacts to the subwatershed characterization and analysis. One neighbourhood within the pre-2015 City boundary near the intersection of Powerline Road and King George Road receives water from the main City system but utilizes on-site septic systems for wastewater disposal. In Tutela Heights, existing built-up areas are serviced by a separate water system that is currently connected to the County of Brant's Mt. Pleasant water system and utilize on-site septic systems for wastewater disposal. Figure 2-5 and Figure 2-6 show the locations of City and County water distribution and wastewater infrastructure relative to the study area, as well as install dates for the watermains and gravity sewer mains. Most of the watermain and gravity sewer main along Powerline Road close to the Primary Study Area boundary was built in the 1970's. Tutela Heights is a newer area, and its storm sewers were constructed in the 2000's. Throughout the City of Brantford, there are areas of older infrastructure, especially closer to the downtown core.

Other areas within the secondary and tertiary study area are serviced by on-site wells and septic systems.

2.3.2 Stormwater and Drainage Infrastructure

Figure 2-7 shows stormwater infrastructure within the study area including storm sewers, ditches, culverts, detention ponds, and oil grit separators.

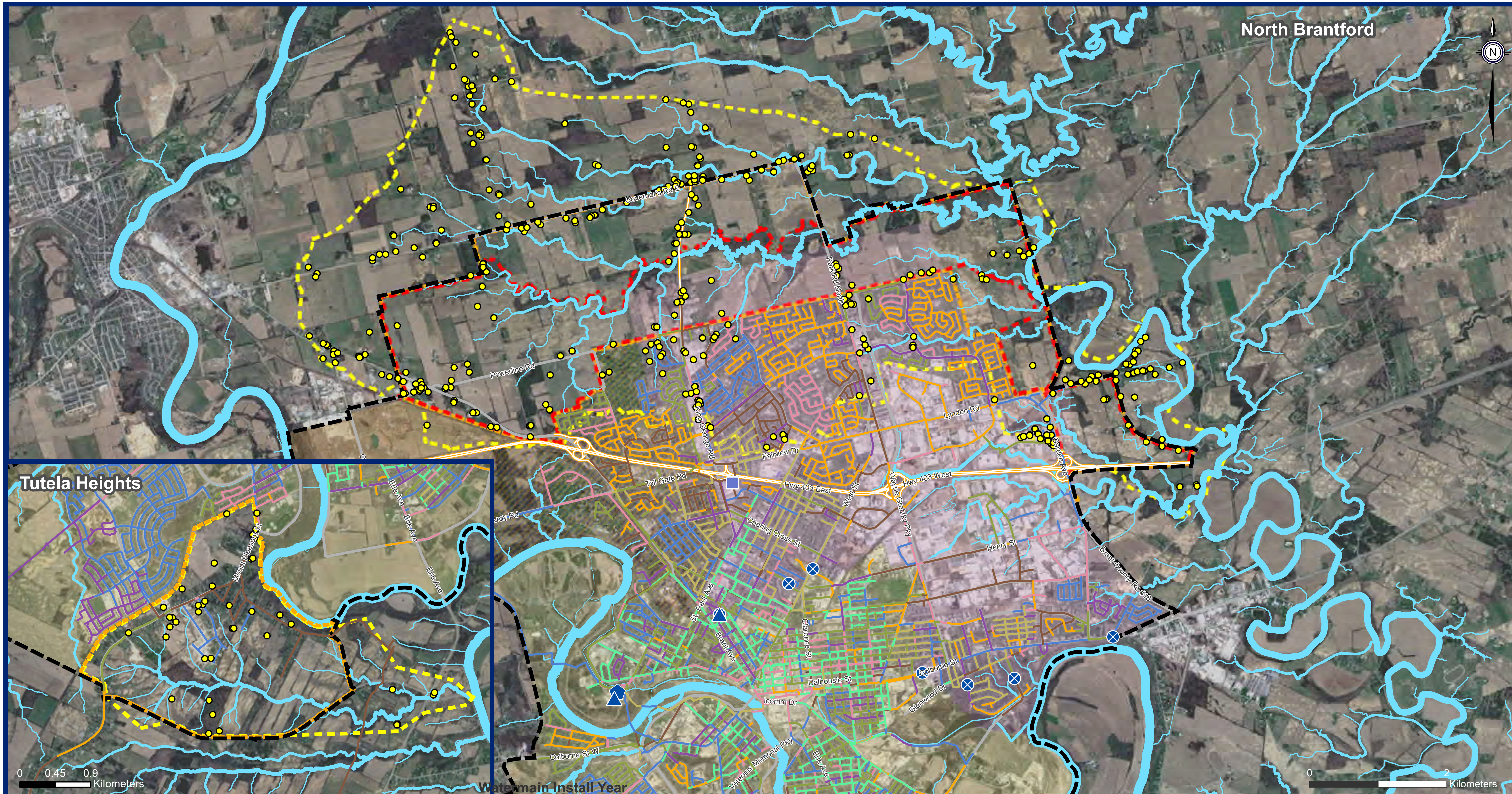
The drainage system within the existing urban settlement area generally reflects standard practices at the time of development. Therefore, while newer areas have been developed with quantity and quality control practices such as detention ponds and oil grit separators, older areas generally did not incorporate these practices and tend to discharge uncontrolled to watercourses. In some areas, watercourse stabilization projects have been undertaken to address accelerated erosion due to uncontrolled urban drainage. In addition, in older areas many watercourses were enclosed or significantly altered.

Like the watermains and gravity sewer mains, in North Brantford the area along Powerline Road closest to the Primary Study Area boundary shows storm sewer infrastructure that was installed in the 1970's. Storm infrastructure in Tutela Heights was constructed in the 2000's.

In some areas, on-site stormwater management quantity and/or quality controls have been put in place. The City does not currently have an inventory or GIS database of these privately owned and operated systems.

2.4 Tile Drainage

The study areas are predominantly agricultural and are serviced by an extensive tile drain network. Figure 2-8 shows the location of all known tile drains within the study area.



General Features	Watermain Install Year		Water Features		Pressure Districts
Watercourse	1900-1949	1980-1989	Well	Pressure Reducing Valve	Pressure District 1
Primary Study Area	1950-1959	1990-1999	Water Treatment Plant		Pressure District 2/3
Secondary Study Area	1960-1969	2000-2009	Pumping Station		Pressure District 4
Tertiary Study Area	1970-1979	2010-2017	Elevated Tank / Reservoir		Pressure District 4 Expansion
Municipal Boundary	Secondary Study Area				

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Brantford Growth Plan

Figure 2-5

Existing Urban Infrastructure

Water

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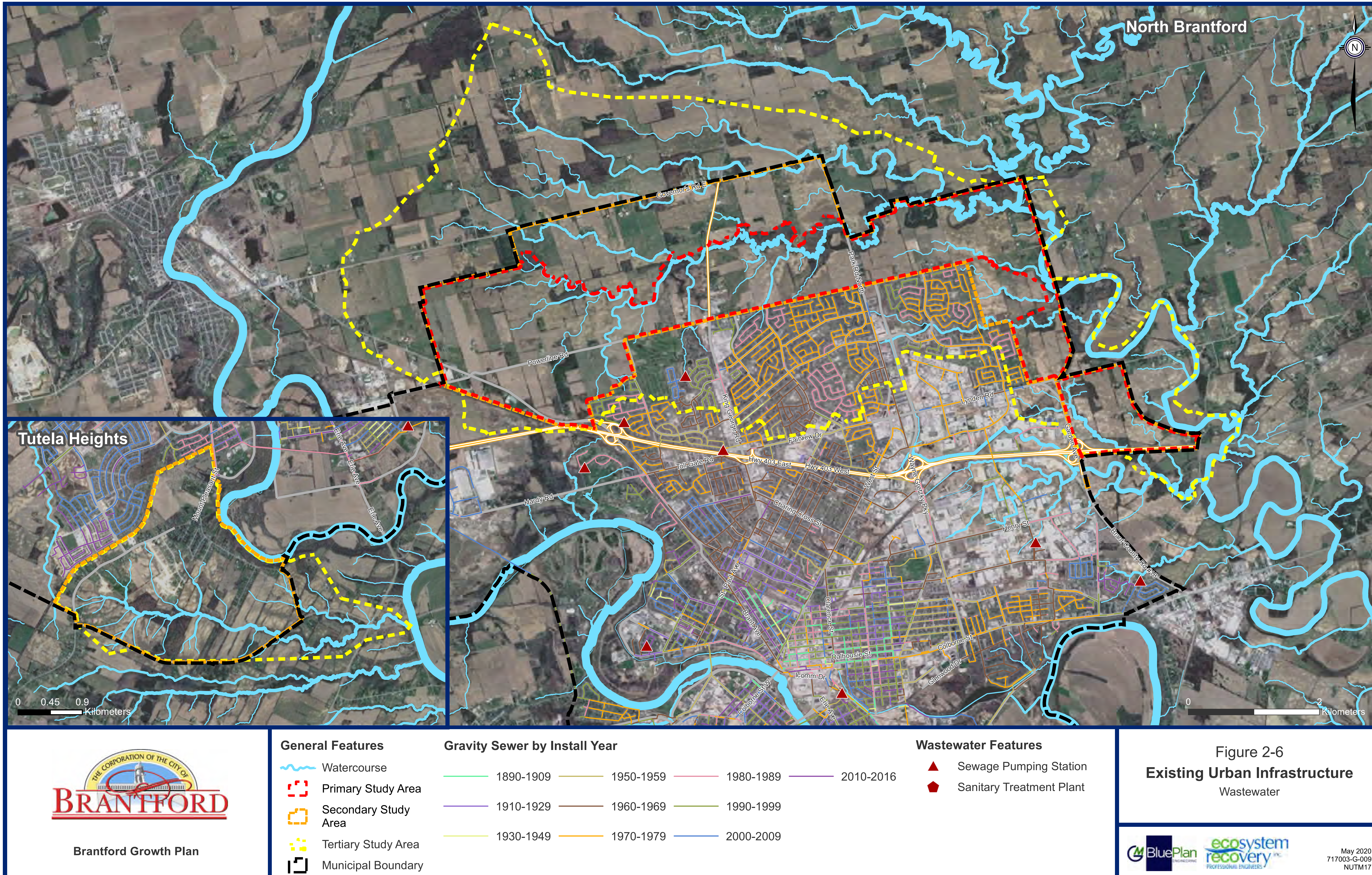
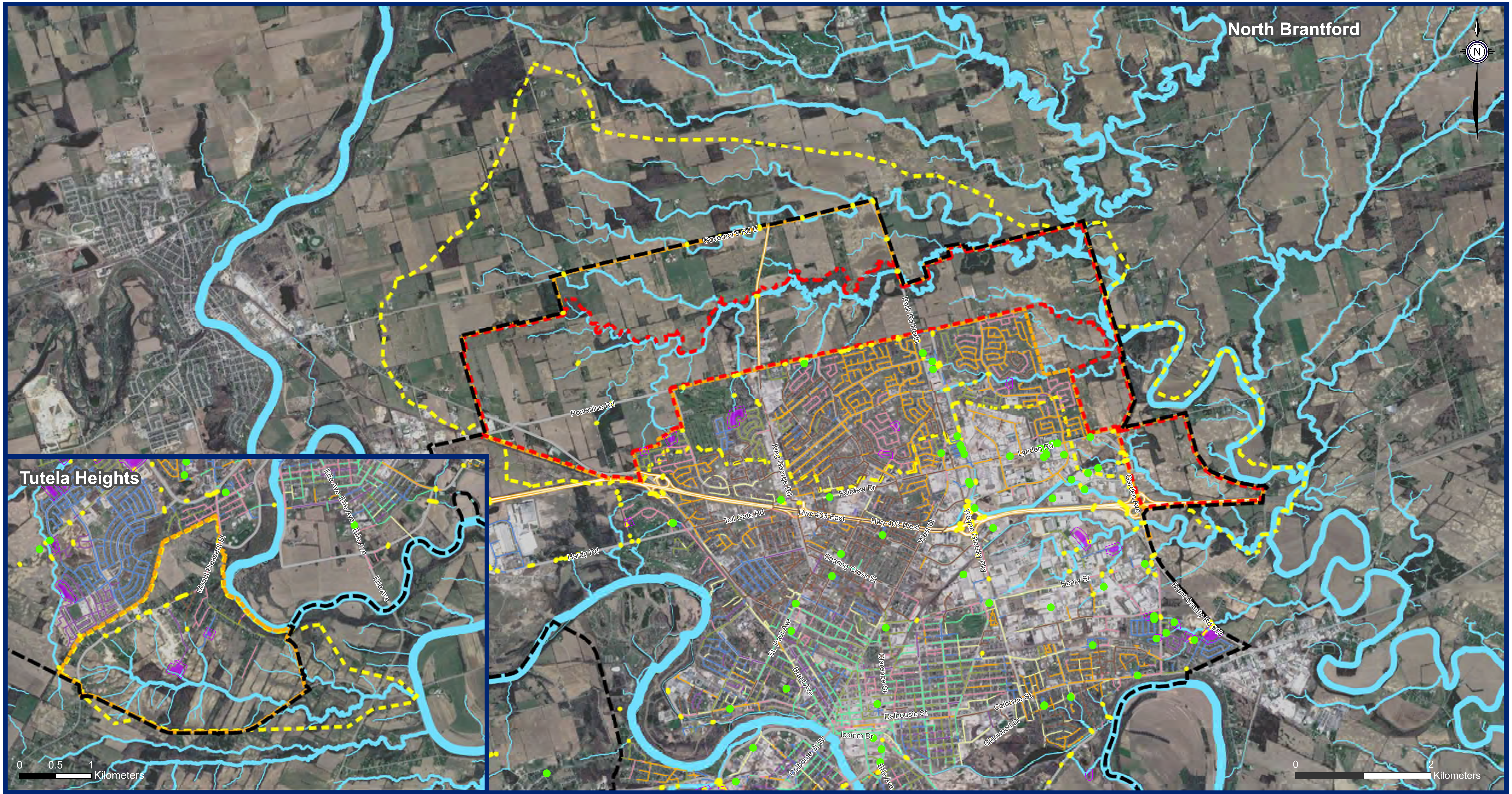


Figure 2-6
Existing Urban Infrastructure
Wastewater



Brantford Growth Plan

General Features

- Watercourse
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary

Stormwater Features

- Stormceptors
- Detention Ponds
- Culvert

Storm Sewers by Install Date

- 1900-1939
- 1940-1959
- 1960-1969
- 1970-1979
- 1980-1989
- 1990-1999
- 2000-2009
- 2010-2016

Figure 2-7
Existing Urban Infrastructure
Stormwater

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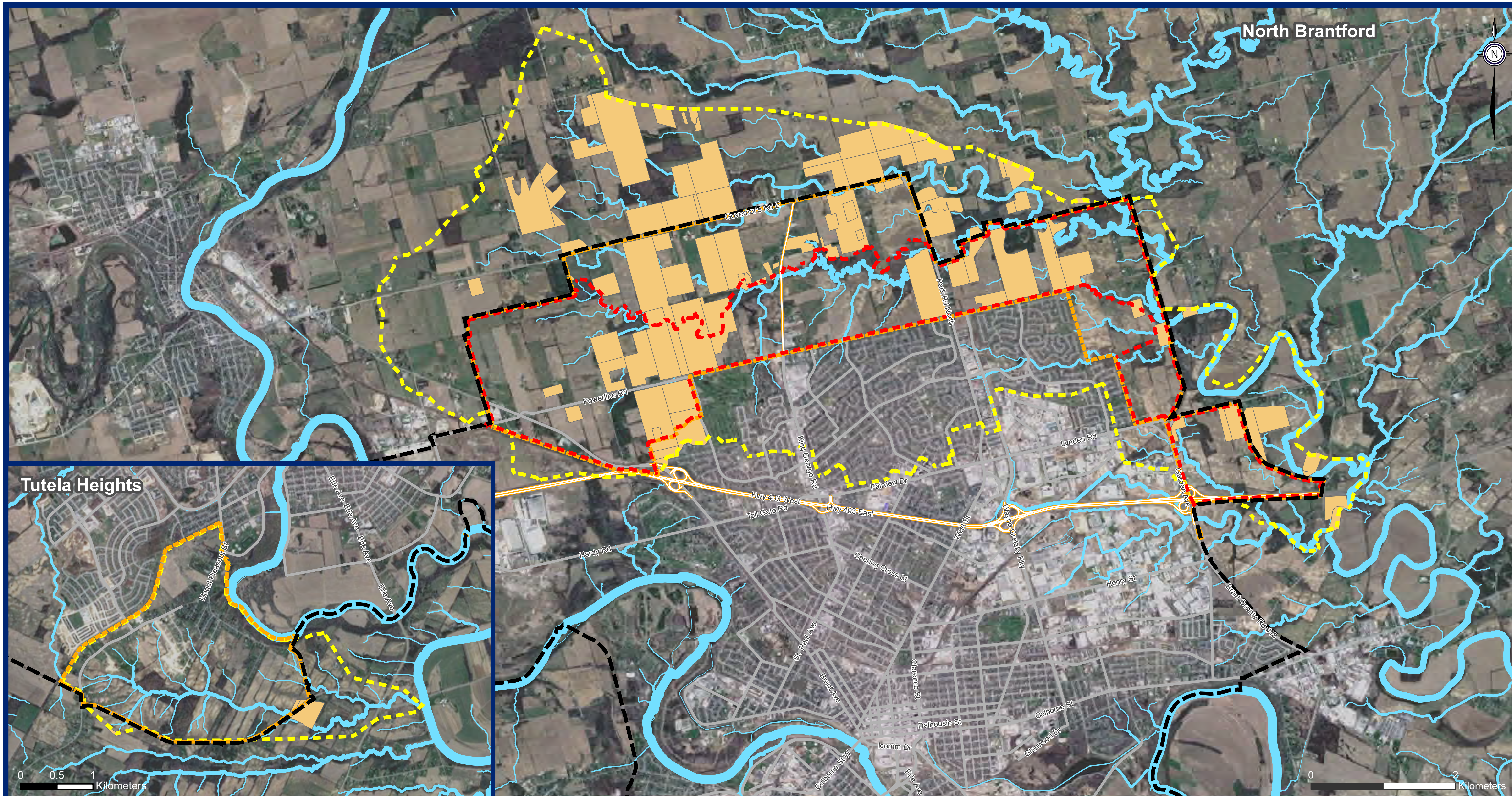

Brantford Growth Plan

General Features

- Watercourse
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary
- Tile Drained Areas

Figure 2-8
Tile Drained Areas

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2.5 Physiography and Geology

2.5.1 Physiography

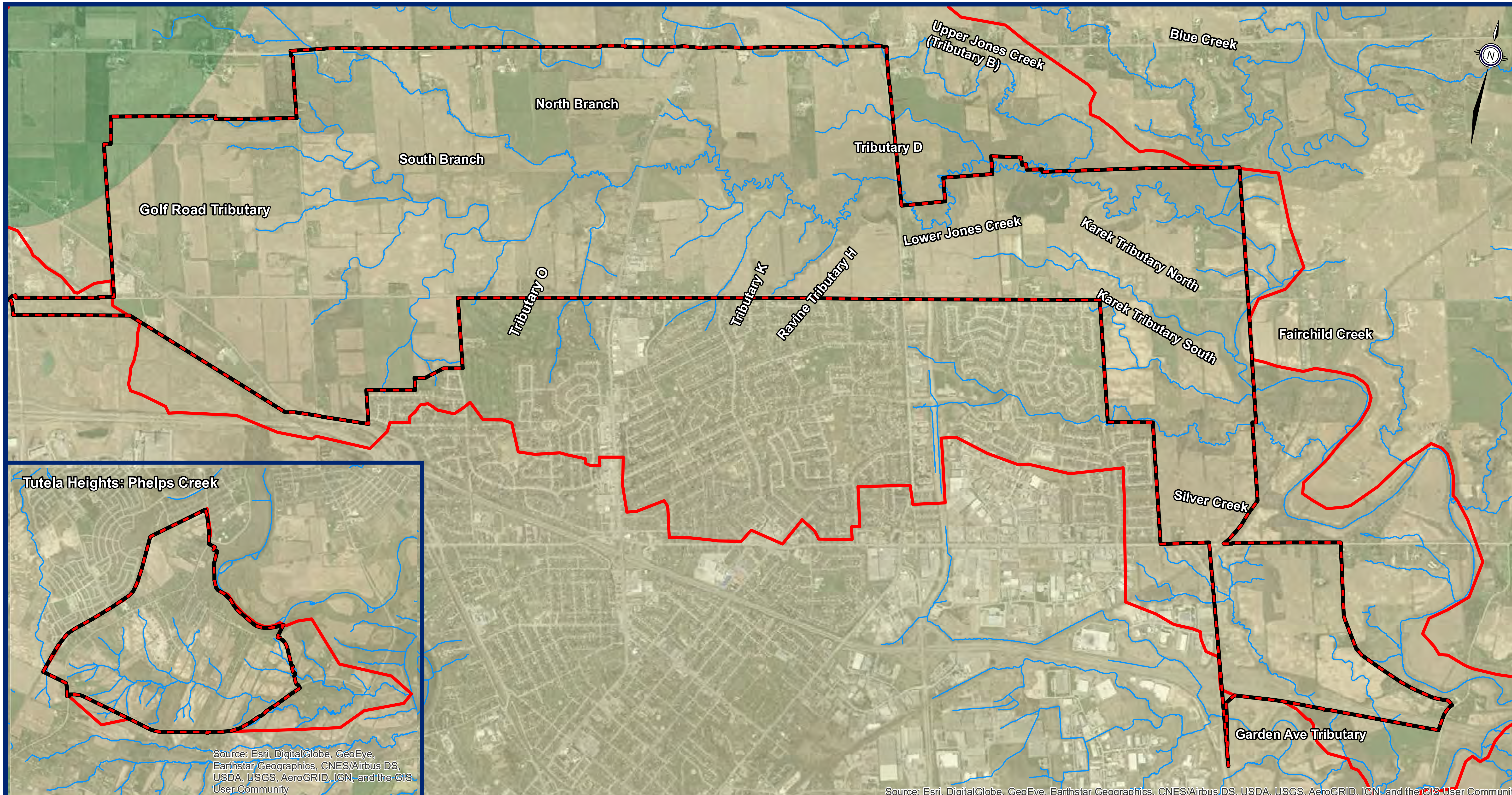
The physiography of an area refers to spatial groupings of similar landscape characteristics (i.e., landforms, rock or sediment type) that have a common geologic or evolutionary history. The physiography of the study area is available from Chapman and Putnam (1984, 2007); additional insight was provided in MacVeigh et al., (2016) based on work completed by (Holysh, 2001) for the Grand River watershed.

Topography within the Lower Jones Creek subwatershed, which flows through the North Brantford area begins at approximately 278 metres above sea level (masl) at the west subwatershed boundary (i.e., Paris Galt Moraine), is 243 masl at the tip of the most westward drainage feature and is 198 masl at the confluence to Fairchild Creek. The landscape is generally graded from west to east; this is reflected in the predominant west to east orientation of the Jones Creek drainage network. The main channel of Jones Creek incises into a valley that gradually deepens and widens in the east direction (valley widths range from 15 – 100 m); the valley slopes (north and south facing) are classified as steep and over-steep slopes (based on GRCA mapping, 2018). Tributaries of the main branch of Jones Creek have incised into these valley walls.

The Tutela Heights area is in the headwaters of Phelps Creek, a Grand River tributary. The topography of the Phelps Creek watershed begins at approximately 230 masl at the west watershed limit and is approximately 222 masl at the tip of the headwaters (west); the elevation decreases to 204 masl in Phelps Creek at the downstream Tutela Heights boundary, and 191 masl at its confluence with the Grand River. The landscape is generally graded from west to east; this is reflected in the predominant west to east orientation of the Phelps Creek drainage network; tributaries flow towards the main channel from both the north and south. GRCA (2018) mapping shows steep slopes along some of the Phelps Creek tributaries and particularly near the confluence with the main channel; this suggests that the tributaries incise into the Phelps Creek valley. Phelps Creek flows through a relatively unconfined valley setting within the Tutela Heights area.

The North Brantford area is located predominantly within The Norfolk Sand Plain physiographic region **(**Figure 2-9**).** The headwater area (west) of the Jones Creek subwatershed drains the Paris-Galt Moraine, one of the dominant moraine complexes of the Horseshoe Moraine; the Paris-Galt Moraine has been identified as supplying cold water to Jones Creek (MacVeigh et al., 2016). Tutela Heights is situated entirely within the Norfolk Sand Plain Physiographic Region (Chapman and Putnam, 1984). Descriptions of the physiographic regions are provided below:

> **The Norfolk Sand Plain** is characterized by coarse sands and silts that are associated with deltaic sediment deposited into Glacial Lakes Whittlesey and Warren by glacial meltwaters from the Grand River as the glaciers receded from the area (Chapman and Putnam, 1984). The sand lies over portions of the Galt Moraine and is bisected by river valleys. The sediment allows for greater infiltration and groundwater movement (MacVeigh et al., 2016).
>
> **The Paris - Galt Moraine** is described as a rugged stony ridge of loose loamy till near Brantford (Chapman and Putnam, 1984). MacVeigh et al. (2016) indicate that the moraines are a broad ridge of hummocky topography that is aligned in a general north-east to south-west direction from the Town of Erin to northwest of Brantford; the topography is often very hilly with steep irregular slopes, basins, and closed depressions referred to as kettles, which hold water in the spring and summer months. The flanks of the moraine include a substantial amount of sand and gravel from outwash plains and spillways associated with the moraine system (Blackport Hydrogeology and ARI, 2009). There are numerous swampy stretches, and cold-water watercourses which are fed by groundwater throughout this area (GRCA, 2008).



Brantford Growth Plan

- Study Area
- Tertiary Study Area
- Drainage Network

Physiographic Units (UNIT, REGION)

- 5, Horseshoe Moraines
- 22, Norfolk Sand Plain

0 2 Kilometers

Figure 2-9
Watercourse Characterization
Physiography

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2.5.2 Surficial Geology

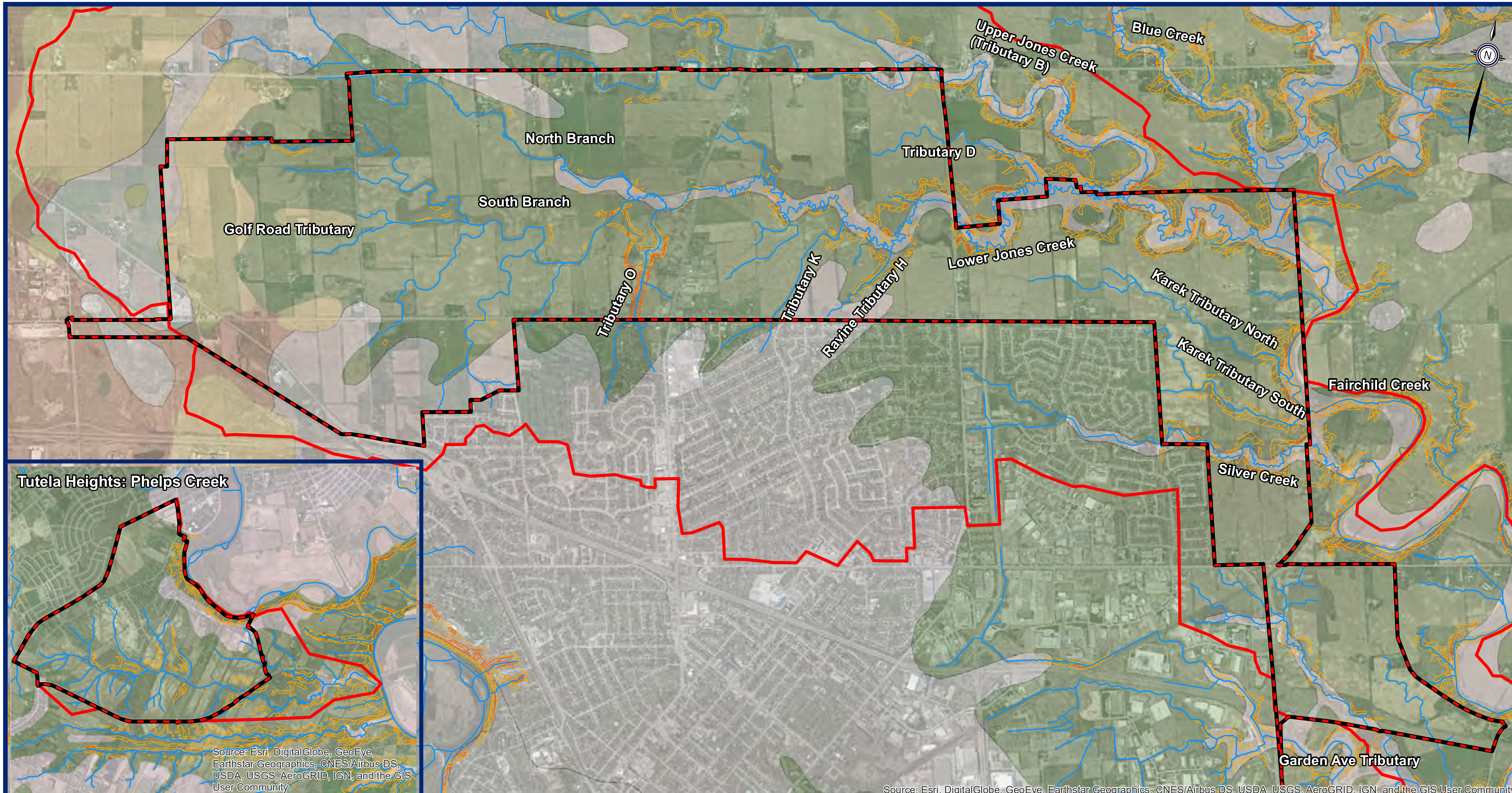
Surficial geology, also referred to as Quaternary geology, describes the material that was deposited, and the depositional features that formed, during the last glaciation which ended ~ 10,000 years ago. Figure 2-10illustrates the surficial geology of both the North Brantford and Tutela Heights study areas which include three main sediment types as mapped by the Ontario Geological Survey (OGS, 2010). A geologic description of each sediment type, and how it relates to groundwater recharge, storage, discharge, and general movement for those key surficial geology units situated within the study area is as follows:

Sand (Modern alluvium) – modern alluvium consists of clay, silt, sand, gravel, may contain organic remains. This material can generally be reworked by flows that are conveyed through the channel. Excess flow above the threshold of sediment mobility could result in a response to channel form and function. Due to erosion, excess sediment loading into the watercourse could lead to excess deposition in downstream channel locations which may affect aquatic habitat and channel stability.

Modern alluvium occurs in the North Brantford area, along the main branches of Jones Creek, Fairchild Creek and several of its tributaries within the study area. Modern alluvium has not been mapped along Phelps Creek in the Tutela Heights area.

Clay (Fine-textured glaciolacustrine deposits) – these deposits consist primarily of silt and clay, with minor sand and gravel deposits, and may be massive to well-laminated. Erosion of clay materials is influenced less by hydraulic stress than by chemical weathering processes and are prone to long term channel bed lowering when this material is exposed on the channel bed. The massive well laminated clays dominate the tablelands immediately surrounding Jones Creek and, Fairchild Creek in the North Brantford area, and Phelps Creek within the Tutela Heights area. The unit is characterized as consisting of tight soils with low permeability and is poorly drained; the area is dominated by surface runoff with very little infiltration to groundwater (MacVeigh et al., 2016). Due to this high proportion of low permeability silt and clay deposits, the watercourses are considered to have a flashy system during storm events (MacVeigh et al., 2016).

Till (Wentworth Till) – stony, silt, sand till deposit with a gravel core (MacVeigh et al., 2016). The till deposit, which is located within the Galt Moraine system, corresponds to the headwaters of Jones Creek located on the western boarder of the study area. The deposit allows for groundwater recharge within the study area, which is recognized as providing an important function for coldwater streams such as Jones Creek (as identified in MacVeigh et al., 2016), which in turn supports coldwater fisheries.



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Brantford Growth Plan

Study Area

Tertiary Study Area

Drainage Network

River Valley Slopes

Oversteep

Steep

Surficial Geology

Clay

Diamicton

Gravel

Sand

0 2 Kilometers

Figure 2-10

Watercourse Characterization

Surficial Geology and Valley Slopes

GM BluePlan

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2.5.3 Bedrock Geology

Two major bedrock units subcrop in the Brantford area: the Guelph Formation and the overlying Salina Formation (see Figure 2-11).

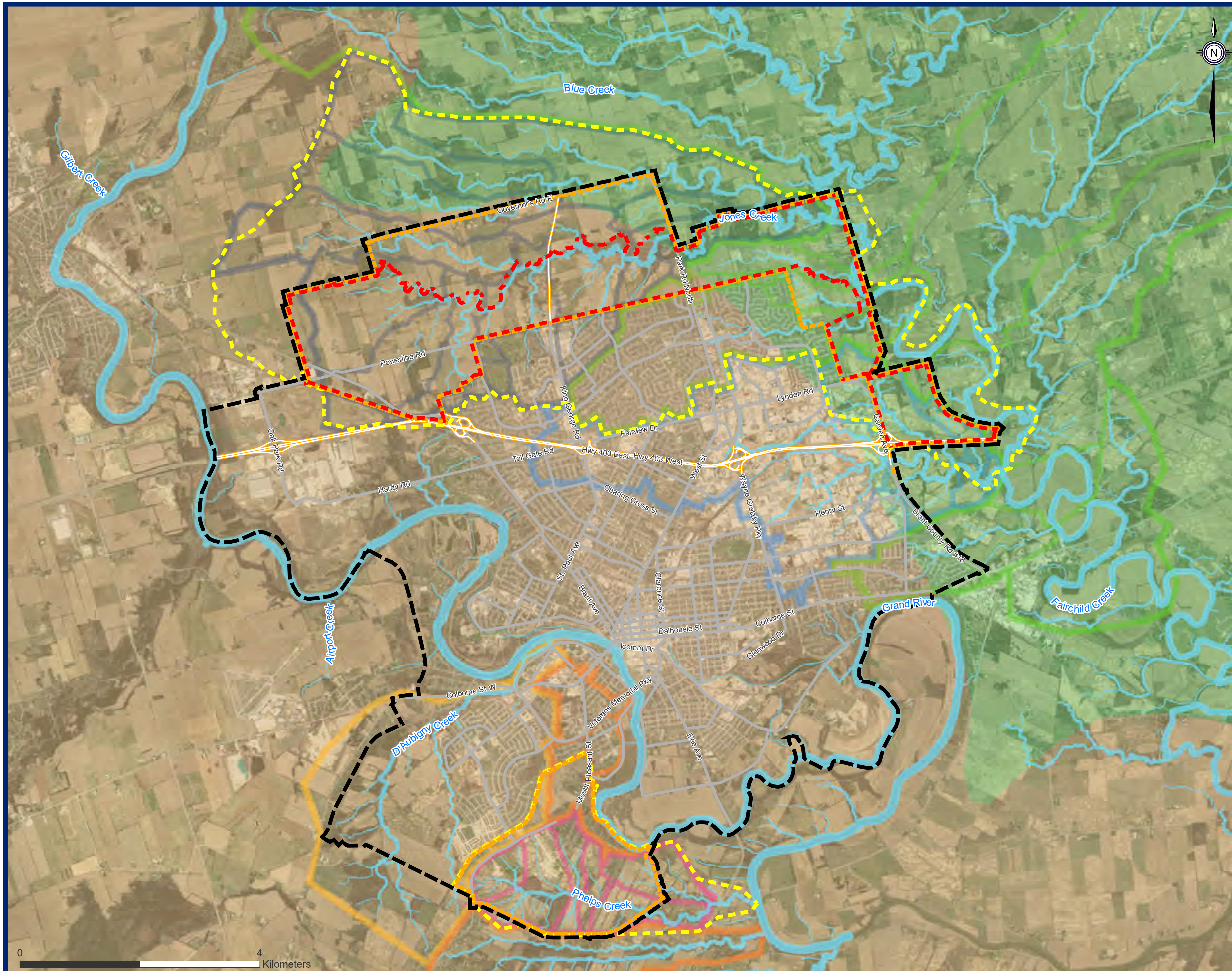
The Guelph Formation subcrops beneath the North Brantford expansion areas east of Golf Road and north of Powerline Road. The Guelph Formation is primarily made up of dolostone and shale.

The Salina Formation subcrops beneath the remainder of the North Brantford expansion areas and beneath the Tutela Heights area. The Salina Formation also contains carbonate rocks and shale but also contains a significant proportion of evaporite minerals. There is evidence that the Salina Formation is karstic, notably near Oak Park Road and the area south of Hardy Road (Plan B 2014, p. 12). Groundwater flows through the karst can be very rapid owing to the size of dissolution channels that may exist.

Both formations are characterized as being moderately productive aquifers, though the Salina Formation tends to produce water of poorer quality due to the prevalence of naturally-occurring evaporite minerals (e.g. anhydrite, gypsum; GRCA 2008, p 11). The Guelph Formation supports the municipal drinking water supply for numerous communities, including the City of Guelph (GRCA 2008, p 10).

In the Brantford Area, the potentiometric surface of bedrock wells indicates regional groundwater flow is generally southeastward, roughly toward the mouth of the Grand River at Lake Erie (GRCA 2008, p 59).

Recent study of bedrock valleys in the area west of Lake Ontario has indicated a bedrock valley structure running roughly west-by-southwest to east-by-northeast from the Tutela Heights area, along the extended point bar of the Grand River meander between County Road 18 and Mohawk Street, toward the intersection of County Roads 18 and 2 (Bajc *et al* 2018).



THE CORPORATION OF THE CITY OF BRANTFORD

Brantford Growth Plan

Environmental Features

- Watercourse
- Highway
- Arterial Road
- Collector Road
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary

Subwatershed

- D'Aubigny
- Fairchild
- Garden
- Grand
- Phelps
- Jones

Bedrock Geology

- Guelph Formation
- Salina Formation

Figure 2-11
Bedrock Geology

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May 2020
717003-G-007
NAD 1983 UTM Zone 17N
Source: GRCA, OGS, City of Brantford

2.6 Groundwater

2.6.1 Methodology

The high-level characterization of the groundwater system presented in this section was conducted using the following information sources:

- Incidental observations of seeps and groundwater discharge during stream investigations described in Section 2.8
- Tile drainage information described in Section 2.4
- Low flow analysis of flow monitoring data described in Section 2.7 and stream temperature monitoring described in Section 2.9.
- Relevant reports and investigations:
    - Wellhead Protection Area Delineation, Vulnerability Scoring and Threats Assessment for the St. George and Lynden Municipal Supply Wells (2018)
    - Studies to support development
- Geological information, particularly from OGS Brantford Woodstock Model, described in Section 3.3
- Ministry of the Environment and Parks Water Well database
- Topography analysis of local depressions
- Landowner anecdotal reports of springs, seasonal and historical variation in water table depth

In general, more detailed and more recent information was given higher confidence in the case of conflicts between sources.

2.6.2 Conceptual Hydrogeological System

Appendix E provides plan and section views of the Tertiary Study Areas showing the major hydro stratigraphic units. The surficial geology throughout is dominated by aquitards, mainly the Whittlesey Aquitard, which is a glaciolacustrine deposit of fine-textured (silty-clayey) material.

In the North Brantford expansion area, the headwaters of Jones and Blue Creeks lie within the hilly areas of the Paris-Galt Moraine in the western part of the Tertiary Study Area. The surficial soils of the moraine are made up by sandy-silty Wentworth Till which, by its silt content, generally functions as an aquitard. However, the closed depressions of the hummocky moraine topography permit significant recharge in this area.

In some locations in the western portion of the North Brantford expansion area, the Grand River Aquifer (an old alluvial deposit of coarse material) lies near the surface, usually below the Wentworth Till Aquitard, and appears to dip eastward where it pinches out beneath the Whittlesey Aquitard (see Section A-A', Appendix E).

The Whittlesey Aquitard and the associated overlying Whittlesey Regressive Aquifer are lacustrine/glaciolacustrine sediments formed by the historic glacial Lake Whittlesey. The Whittlesey Aquitard comprises a thick sequence of unconsolidated, fine-textured material that is predominantly silt and clay and some sand, with well records indicating a layered or laminated stratigraphy. The Whittlesey Regressive Aquifer is not continuous through the study area. In parts of the northern and western portions of the North Brantford Expansion Area, it lies adjacent to the Wentworth Till Aquitard and it also covers a small area in the central part of the North Brantford expansion area: these areas are separated by the Whittlesey Aquitard, which outcrops between them. The part of the Whittlesey Regressive Aquifer that extends into the central part of the North Brantford expansion area appears to be continuous with a much larger surficial aquifer that underlies much of the City of Brantford.

In the Tutela Heights / Phelps Creek area, the Whittlesey Aquitard dominates the surficial soils, with exception of a small area in the northeastern portion of the Tutela Heights Secondary Study Area which is covered by the Whittlesey Regressive Aquifer. The Whittlesey Aquitard also dominates the deeper stratigraphy, extending down to the bedrock subcrop which lies about 20 to 50 m below the ground surface.

Based on the stratigraphy, it is inferred that the general direction of groundwater flow depends on the unit, the depth and the proximity to a watercourse. In the bedrock, the groundwater flow is inferred to be toward the Grand River, or at greater depths toward the mouth of the Grand River at Lake Erie.

In aquifers (e.g. the Grand River Aquifer), groundwater flow is generally inferred to be primarily horizontally toward the nearest significant watercourse. Though intervening aquitards may limit flow to nearby watercourses or divert flows to larger regional streams (e.g. the Grand River itself), the dip of the Grand River Aquifer may result in hydraulic gradients favourable to support the formation of springs and upwellings in low-lying areas.

In aquitards (e.g. Whittlesey Aquitard), groundwater flow patterns tend to be more complicated. In the headwaters areas of the Paris-Galt Moraine, groundwater flow is inferred generally to be downward (i.e. a recharge function). In areas mid- to downstream in the catchments, groundwater flow is inferred to be generally upward in shallow locations near streams, and downward in areas more upland: at greater depths, the flow direction is more likely to be downward or horizontally toward a major local watercourse. Due to the glaciolacustrine origin of the Whittlesey Aquitard and the observation of “layered” materials in many local well records, there may be significant lateral flow in coarser sublayers within the bulk of the aquitard. Depending on the transmissivity and depth of these coarser sublayers, these may have the potential to generate springs or groundwater upwellings and contribute to coldwater baseflow in some streams (e.g. Jones Creek).

Groundwater-Surface Water Interaction

Stream data from the GRCA were available for two monitoring stations on both Blue Creek and Jones Creek. Catchments of these two creeks intersect portions of the North Brantford expansion area, and the Jones Creek catchment covers the better part of the Primary Study Area. This stream data was reviewed to determine the nature of general interaction between groundwater and surface water on those streams.

Springs identified during fieldwork conducted by Ecosystem Recovery will also be discussed as evidence of interaction between groundwater and surface water.

Jones Creek

For Jones Creek, the two monitoring stations are located at the Jones Creek crossings of Governor’s Road (upstream) and of Highway 24 (downstream). There is approximately 2.8 km distance (“as the crow flies”) between these two monitoring stations.

Plotting temperature versus time, it is noted that the range in fluctuation in stream temperature is much greater at Highway 24 (from 0°C in winter to about 23°C in summer) than at Governor’s Road (from 2°C in winter to about 17°C in summer). The narrower range in stream temperatures and the record of higher temperatures in winter and lower temperatures in summer at Governor’s Road indicates that the proportion of groundwater discharge to Jones Creek is greater above Governor’s Road than between Governor’s Road and Highway 24.

Though water level data was collected at both stations, no flow rates had been computed for the Governors station. As such, a mass balance comparing upstream and downstream flow rates to precipitation events could not be completed.

Blue Creek

For Blue Creek, the two monitoring stations are located at Highway 24 (upstream) and St. George (downstream). There is approximately 8.4 km distance (as the crow flies) between these two monitoring stations.

Reviewing the temperature data for these two stations, it appears that for a given time the water temperature at Highway 24 is slightly warmer than at St. George. It is inferred that the decrease in temperature with distance is due to the reservoir/pond structure immediately upstream of the Highway 24 station. Overflows from the reservoir may be subject to substantial warming due to sun exposure in the summer months and heat retention in the winter due to the heat capacity of the contained water, thus resulting in the elevated temperatures observed at the Highway 24 station. As the flow progresses toward St. George via the Blue Creek stream channel, the water would be expected to cool due to increased contact with the ground, hyporheic exchange, shade from vegetation, and potentially also due to the addition of groundwater discharge.

Flow rate data was computed for both the upstream and downstream stations on Blue Creek. In response to precipitation events, the increase in stream flow appeared to be significantly more intense (i.e. “flashy”) at St. George (downstream) than at Highway 24 (upstream). This may indicate a greater proportion of runoff to infiltration in the reach between St. George and Highway 24 as compared to the reach above Highway 24. This is likely due to the prevalence of surficial aquitards between St. George and Highway 24 versus the surficial aquifers upstream of Highway 24 but may also be exacerbated by the presence of tiled fields.

An attempt was made to compare baseflow rates between the two stations but, due to uncertainty in the accuracy of the ratings curves at low flow, no definitive conclusions could be made regarding stream gains or losses.

<u>Springs</u>

Field investigations conducted by Ecosystem Recovery identified two small springs in the North Brantford expansion area. Both were located within the Primary Study Area in Concession 1 of the Geographic Township of Brantford, one located in the central part of Lot 25 and the other in the southern portion of Lot 26. At the surface, the springs were both very well-defined open holes, each measuring about 10 cm in diameter. At the time they were identified (late April 2018), both springs were found to be seeping with clear water which flowed overland to nearby tributaries of Jones Creek.

The mechanism causing these springs is uncertain. They are located within a plain of fine-textured glaciolacustrine associated with the historic Lake Whittlesey. The minor artesian head in these deposits is likely the result of topographic and stratigraphic variation. It is possible that the springs were caused due to stratification within the glaciolacustrine deposit and that artesian head within a sufficiently permeable layer eventually caused groundwater to emerge at the surface, with the gentle flows creating the open hole morphology of the springs.

<u>Tutela Heights</u>

There were no observed groundwater-surface water interactions in the Tutela Heights area.

Recharge and Discharge Areas

The following discussion of recharge and discharge areas refers to subcatchments identified by GM BluePlan in preliminary assessment. The following figures provide plan views of these subcatchment areas as well estimated annual recharge values provided by the Grand River Conservation Authority through their hydrologic response unit (HRU) assessment:

- Figure 2-12: North Brantford expansion area – West of Park Road
- Figure 2-13: North Brantford expansion area – Eastern and Northeastern Portions
- Figure 2-14: Tutela Heights Expansion Area

The figures throughout Section 2.6 and Section 2.7 have assigned catchment IDs to each sub-area for discussion purposes. The catchment IDs have a prefix correlating to the outlet tributary, followed by a number that is unique to the outlet tributary prefix. The numbers ascend from one (1) onward for each outlet tributary. The following are the prefixes used, and their associated outlet tributaries:

- "D" – D'Aubigny
- "F" – Fairchild
- "GD" – Garden
- "GT" – Grand River
- "JT" – Jones
- "LJ" – Lower Jones
- "UJ" – Upper Jones
- "P" – Phelps
- "NO" – Internal Depression

North Brantford Expansion Area

The Paris-Galt Moraine areas, due to their hummocky topography, are well understood to be important local recharge areas. The GRCA GIS indicates recharge values more than 300 mm/yr within these areas, which occupy the uppermost reaches of the Jones Creek catchment area. The North Brantford expansion area intersects a small piece of the Paris-Galt Moraine (parts of subcatchments NO-1, UJ-1).

Most of the land of the North Brantford expansion area is underlain by fine-textured glaciolacustrine material which inhibits recharge due to its low hydraulic conductivity. Some parts of the upper reaches of the Jones Creek tributary catchments (e.g. UJ-1 through UJ-5, JT-1 through JT-3) intersect coarser sandy glaciolacustrine material: GRCA GIS indicates higher annual recharge (around 300 mm/yr) in these areas.

Portions of the North Brantford expansion area (mainly in catchments UJ-5 and LJ-1) are denoted by the GRCA GIS to be in a discharge condition. It is expected that this assignment is an artefact of the analysis method (which simply subtracts water table elevation from potentiometric surface elevation) and that most of the indicated area does not exhibit significant groundwater discharge, though the low-lying ravine bottoms and wetland areas would be the most-likely candidates if discharge areas do exist in these catchments.

Jones Creek is a known cold-water stream and so it is expected to feature some significant groundwater discharge along its banks. However, the finite element regional flow model completed for the Grand River *Integrated Water Budget Report* does not corroborate this established knowledge. Further investigation may be required to characterize the interaction between groundwater and surface water at Jones Creek. It may be that a greater amount of recharge is accepted by the glaciolacustrine surface along Jones Creek and the lower reaches of its tributaries. Potential monitoring activities could include detailed streamflow monitoring in Jones Creek and key tributaries as well as collection of local rainfall and piezometric data.

The Eastern Portion is generally identified by the GRCA GIS as exhibiting recharge conditions with minor recharge rates typically around 25 mm/yr owing to the prevalence of fine-textured glaciolacustrine soils. However, some parts of the upper reaches of subcatchment GD-1 (belonging to a tributary of the Grand River) are denoted as being discharge areas. Due to the location of these apparent discharge areas at the upper reaches of a subcatchment, it is likely that these are seasonal and likely dominated by interflow rather than deep groundwater flows.

The Northeastern Portion is like the Eastern Portion in terms of its annual recharge rates, which are generally less than 25 mm/yr except in certain locations along Jones Creek where it appears to be higher (up to 125 mm/yr in parts of LJ-3). Most of the area in the Fairchild catchments (F-1 through F-4) of the Northeastern Portion is identified as exhibiting discharge conditions, though it is unclear what would drive such prevalence of discharge conditions in these areas. They may be an artefact of the analysis used to identify discharge versus recharge areas: though there may be an apparent upward gradient between deep strata and the surface, there may be minimal discharge due to the presence of fine-textured soils and/or the topography. However, viewing aerial photographs of this area (GRCA 2015), the ground surface does appear to have a dark patchiness which may be associated with elevated moisture and potentially discharge. If selected as a candidate area for development, these areas should be investigated to determine seasonal water table and piezometric levels, as well as stream baseflow, to verify and quantify the discharge condition.

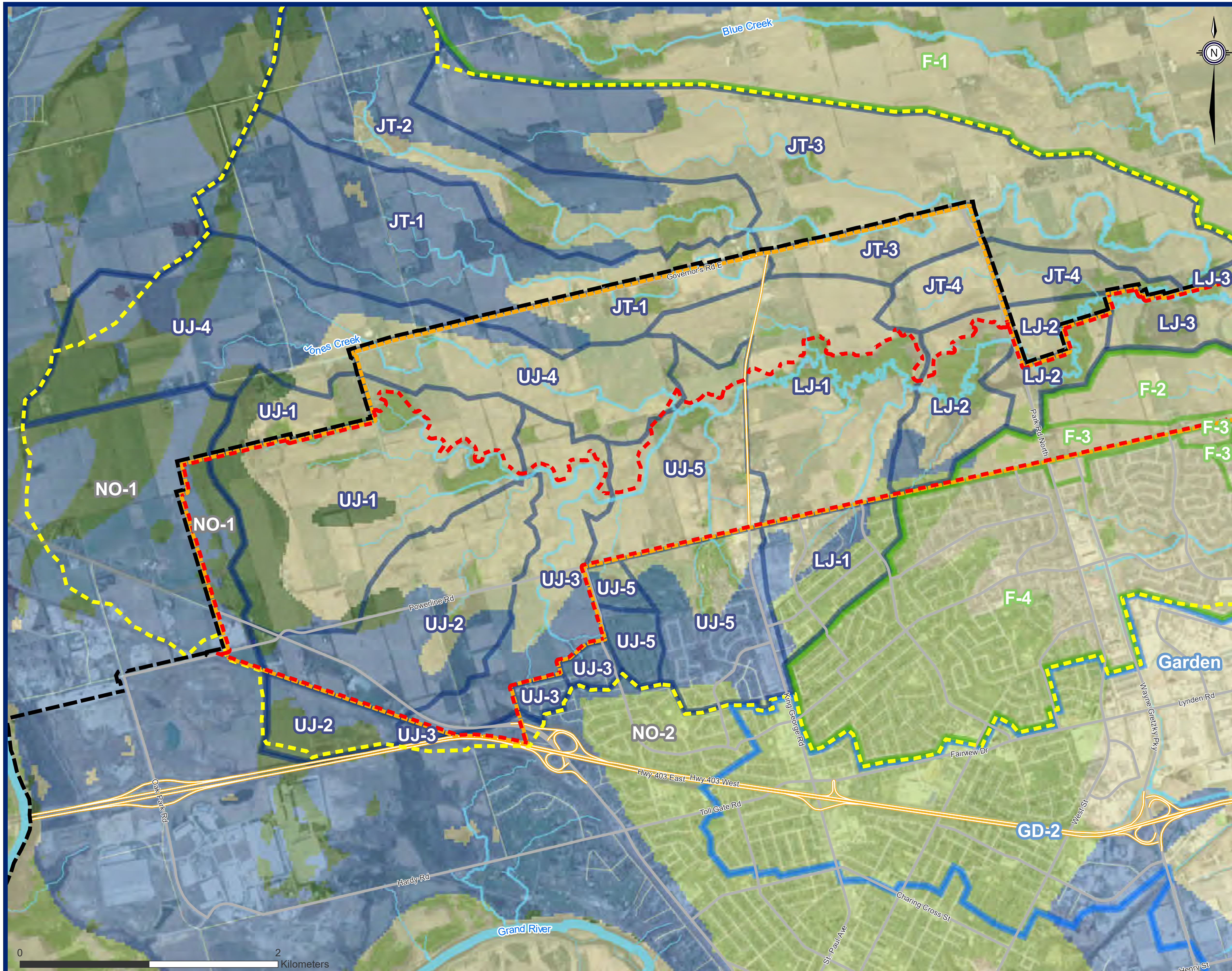
Tutela Heights

The GRCA GIS indicates this area is primarily underlain by fine-textured glaciolacustrine material and recharge is generally limited by the low hydraulic conductivity of the surficial soils. There are, however, some areas of more permeable soils, including a band of sandy glaciolacustrine along Tutela Heights Road (upper reaches of catchments GT-4, and P-3 through P-5). There is also a small area of coarse glaciodeltaic at the intersection of Phelps Road and Mt. Pleasant Road.

Much of this area features average annual recharge of less than 50 mm/yr though the narrow band of sandy soils along Tutela Heights Road and the area local to the intersection of Phelps Road and Mt. Pleasant Road have estimated recharge more than 300 mm/year (GRCA GIS).

Phelps Creek, a tributary of the Grand River, has its headwaters in the Tutela Heights area and portions of the low-lying areas in the ravine and some hummocky surfaces in the intervening hills (e.g. southeastern P-2, western P-2) have elevated recharge values (150 mm/yr). Atlas Canada topographic maps indicate Phelps Creek, downstream of Davern Road, to be an ephemeral or intermittent stream. This is evidence that the lower reaches of Phelps Creek may foster greater levels of recharge compared to the upper reaches, which is corroborated by the GRCA GIS hydrologic response mapping (150 mm/yr near the creek as it passes through catchment P-6).

Within the Tutela Heights area there do not appear to be any significant discharge areas south of Phelps Creek. However, there may be some discharge areas within the Grand River valley and some minor discharge into the upper reaches of the northern Phelps Creek tributaries. The former may be associated with regional discharge as identified by Plan B (2014) due to artesian conditions being common in the Grand River valley in Brantford. The latter are perhaps an artefact of the analysis used to identify discharge versus recharge areas: groundwater may not actually discharge here due to separation of flows of the “local basin” from the “regional basin” by aquitards and/or topography. Whether actual or apparent, much of these discharge areas have already been developed (i.e. estate homes along Tutela Heights Road and its collectors).



THE CORPORATION OF THE CITY OF BRANTFORD

Brantford Growth Plan

Environmental Features

- Watercourse
- Highway
- Arterial Road
- Collector Road
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary

Subwatershed

- D'Aubigny
- Fairchild
- Garden
- Grand
- Phelps
- Jones

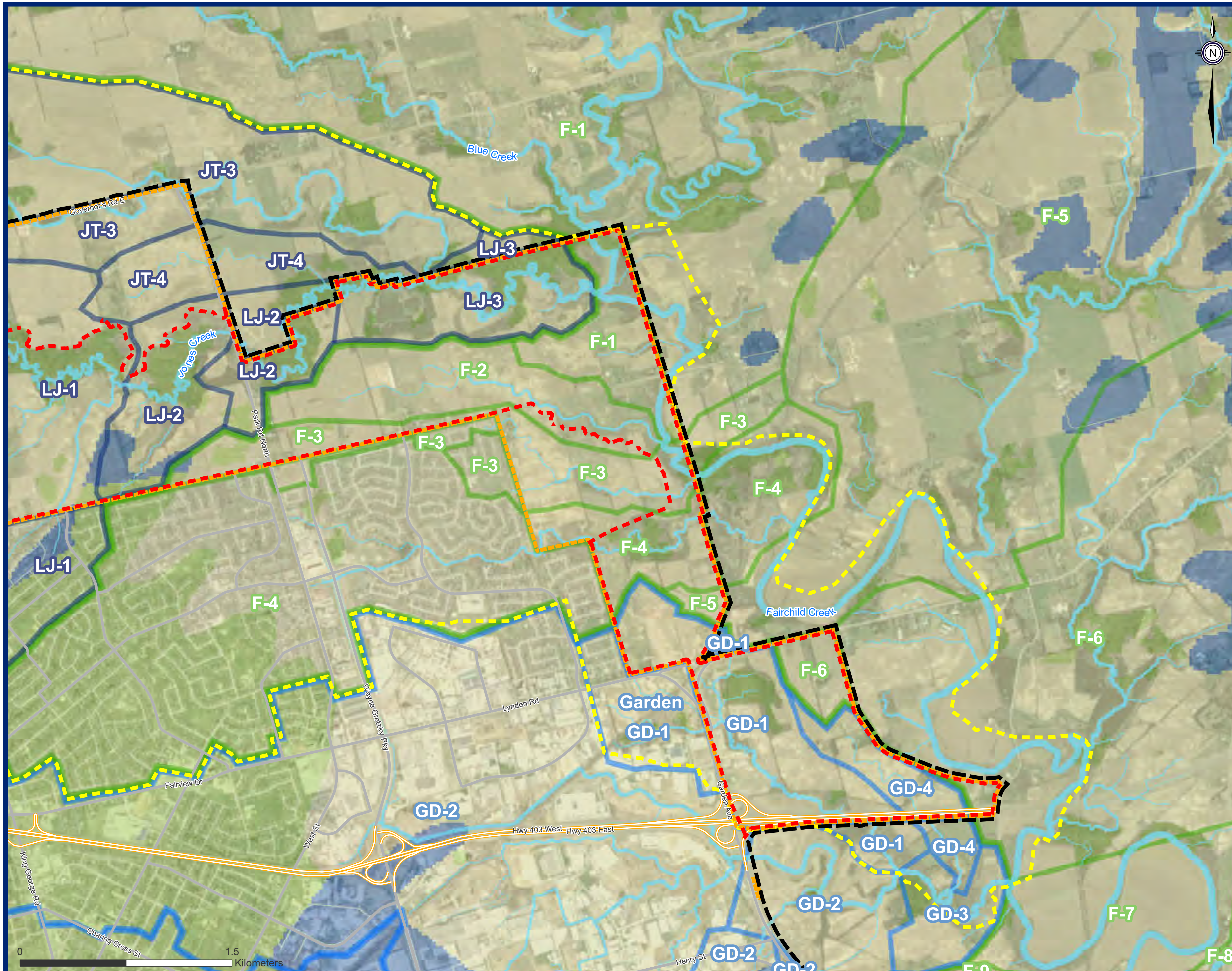
Average Annual Groundwater Recharge Rate

- < 100 mm/year
- 100 - 200 mm/year
- 200 - 300 mm/year
- 300 - 400 mm/year
- 400 - 500 mm/year

Figure 2-12
Distribution of Recharge
Northern Expansion Area West of Park Road

GM BluePlan

May 2020
717003-G-008
NAD 1983 UTM Zone 17N
Source: GRCA, OGS, City of Brantford



BRANTFORD
THE CORPORATION OF THE CITY OF

Brantford Growth Plan

Environmental Features

- Watercourse
- Highway
- Arterial Road
- Collector Road
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary

Subwatershed

- D'Aubigny
- Fairchild
- Garden
- Grand
- Phelps
- Jones

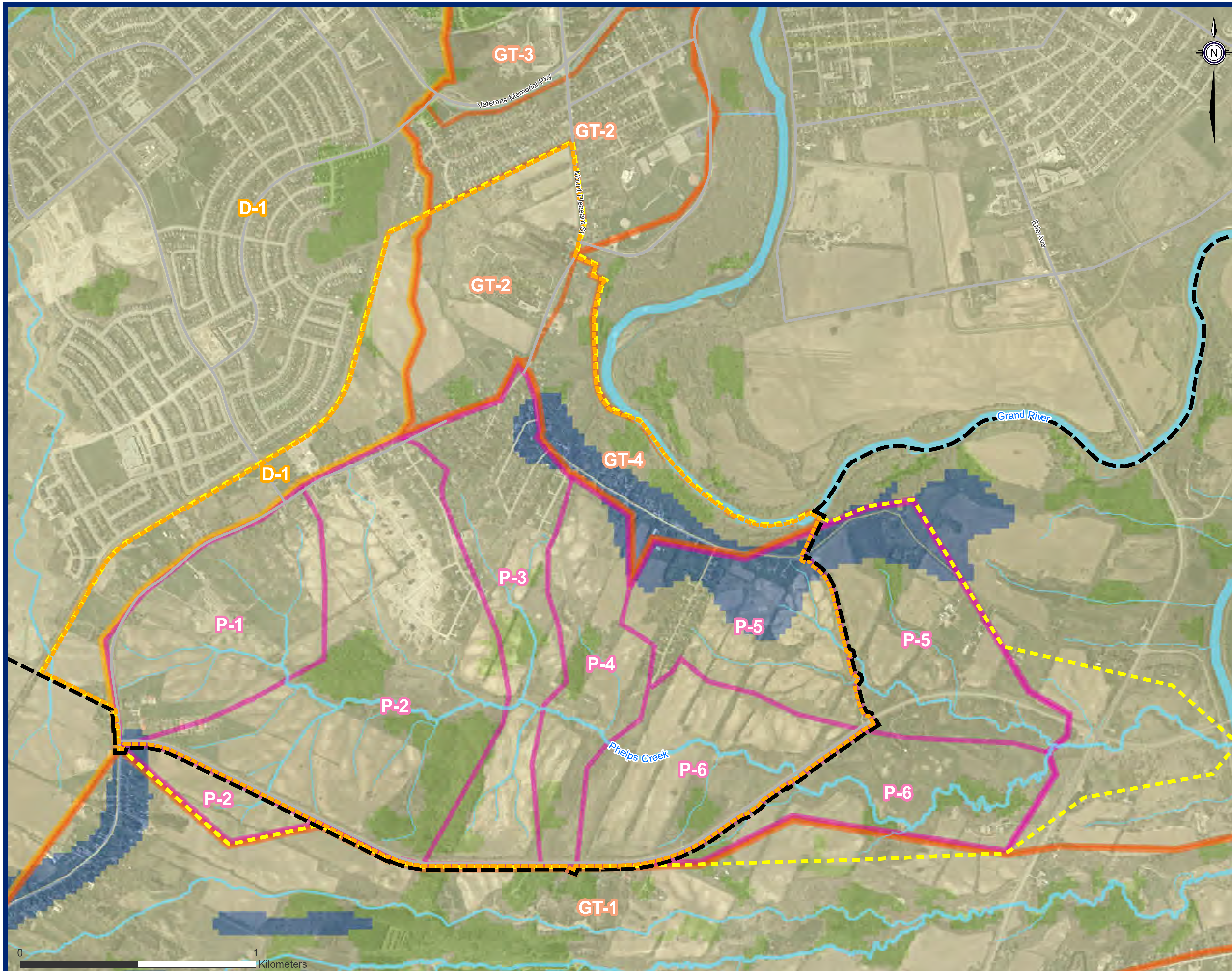
Average Annual Groundwater Recharge Rate

- < 100 mm/year
- 100 - 200 mm/year
- 200 - 300 mm/year
- 300 - 400 mm/year
- 400 - 500 mm/year

Figure 2-13
Distribution of Recharge
Northern Expansion Area East of Park Road

GM BluePlan ENGINEERING

May 2020
717003-G-009
NAD 1983 UTM Zone 17N
Source: GRCA, OGS, City of Brantford



Brantford Growth Plan

Environmental Features

- Watercourse
- Highway
- Arterial Road
- Collector Road
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary

Subwatershed

- D'Aubigny
- Fairchild
- Garden
- Grand
- Phelps
- Jones

Average Annual Groundwater Recharge Rate

- < 100 mm/year
- 100 - 200 mm/year
- 200 - 300 mm/year
- 300 - 400 mm/year
- 400 - 500 mm/year

Figure 2-14
Distribution of Recharge
Tutela Heights

BluePlan

June 2020
717003-G-010
NAD 1983 UTM Zone 17N
Source: GRCA, OGS, City of Brantford

Depth to Water Table

Planning exercises can benefit from identifying the depth to the water table because in some circumstances high water levels may be associated with areas of ecological importance (e.g. wetlands) or they may signal potential difficulties in development such as special requirements for waterproofing, grading, servicing, and stormwater management.

Available information does not provide a high-resolution distribution of depth to groundwater, but the depth to groundwater can often be qualitatively determined based on land use, aerial photos, topography and soil types.

North Brantford Expansion Area

Groundwater levels tend to mimic the topography of the ground surface. This phenomenon is more noticeable in fine-textured soils and more subdued in coarse-textured, well drained soils. Generally, it is expected that the depth to groundwater would be greater at local high points (i.e. hilltops) and lesser at local low points (i.e. ravine bottoms, low-lying wetland areas).

Seasonal variation of the water table would vary with respect to soil texture: in fine-textured soils (e.g. Whittlesey Aquitard) groundwater table elevations are often related to topography, with large seasonal fluctuations often being observed at topographic high points (i.e. hilltops, uplands) and minimal fluctuations being observed at low points (e.g. near streams, wetlands); coarse soils usually exhibit very minor fluctuations due to the capability to drain excess water readily.

Areas within the Paris-Galt Moraine may exhibit significant variation due to the hummocky terrain and the steep, irregular slopes: all these features affect the distribution of groundwater recharge and therefore groundwater table elevations. Areas with soils of low permeability and sufficiently level topography may exhibit seasonal high groundwater levels near surface due to poor drainage, despite being located at relatively high elevation.

Tutela Heights

Presence of some wetlands along Phelps Creek and some of its tributaries (northern parts of P3 and P4) indicate shallow depth to groundwater in the lowlands and ravine areas of Tutela Heights.

Groundwater levels in the rolling hills and uplands of Tutela Heights may reach relatively shallow depths as well, owing to the fine-textured soils there. However, groundwater levels in the hills would be expected to fluctuate significantly through the year, reaching lows in late summer and fall and rising again through the winter and spring.

2.6.3 **Groundwater Resources**

Existing Use of Groundwater

Well Record Search

A review of well records was conducted to acquire information on existing and/or historic wells located within the subwatershed study area in north Brantford and Tutela Heights. The data from the review was gathered from the MECP well records database and was tabulated, as seen in Appendix E. The search revealed 131 well records within the North Brantford and Tutela Heights study area and provided information such as the reported well use, source formation type (i.e. overburden/bedrock), and static water level. Figure 2-15 and Figure 2-16 show the locations of these wells and categorizes them by their characteristics (i.e. bedrock/overburden and well use).

For the North Brantford study area, the predominant well use was reported as domestic (65 records). A break down of all well uses attributed to records within the primary study area is provided here:

- Domestic: 65 records (19 in bedrock, 46 in overburden)
- Commercial: 10 records (4 in bedrock, 6 in overburden)
- Livestock: 6 records
- Public: 1 record
- Irrigation: 1 record
- Monitoring: 3 records
- Not Used/Abandoned: 6 records
- Unknown Use: 2 records

The commercial wells are predominantly located within the UJ-1 and UJ-2 catchment areas.

The average well depth was 28.4 mbgs (metres below ground surface). The deepest well identified extends to a depth of 63.4 mbgs (commercial well) and the shallowest to a depth of 4.5 mbgs (monitoring well).

For the Tutela Heights study area, the predominant well use was reported as domestic (13 records). A break down of all well uses attributed to records within the primary study area is provided here:

- Domestic: 13 records (4 in bedrock, 9 in overburden)
- Irrigation: 3 records
- Monitoring: 7 records
- Not Used/Abandoned: 5 records
- Unknown Use: 9 records

There are no records of commercial, livestock, or public wells in the Tutela Heights area.

The average well depth was 35.3 mbgs. The deepest well is recorded at a depth of 100.9 mbgs, which is a domestic well, and the shallowest well is recorded at 4.6 mbgs (monitoring well).

In terms of water balance, overburden domestic wells tend to have only a minor effect on the larger hydrogeological system: water taken from a near surface source is usually returned to the shallow groundwater system by discharge to an on-site sewage system. However, where there is significant hydraulic separation between the aquifer and surface (e.g. a bedrock aquifer below a clay aquitard) the operation of many domestic wells may result in a net addition of flow to minor streams which do not otherwise receive by groundwater discharge from deeper strata. The provision of municipal water sources and decommissioning of private domestic wells would be expected to negate this effect.

The effect of commercial wells is more difficult to predict because usage rates and purposes vary widely. For example, a commercial well that provides water that is incorporated into a product and shipped off-site (e.g. concrete batch plants, bottling facilities) may result in a significant net loss of water from the catchment, while a commercial well that supplies a restaurant that discharges its sewage to septic may have a much lesser effect for the rate of water use. It is recommended that existing businesses in the Primary Study Area be surveyed for their water usage and sewage disposal practices to provide catchment-level water balance information.

Permits to Take Water

A review was conducted for records of current and/or historic Permits to Take Water (PTTW) issued within the North Brantford and Tutela Heights subwatershed study areas. The search revealed 16 PTTW records within the North Brantford area – 7 of which were issued for agricultural purposes, 5 for construction site dewatering, 3 for commercial use, and 1 for a pumping test. No PTTW records were found within the immediate Tutela Heights study, but three in the peripheral area.

Only two of the North Brantford PTTW records that were found are for active permits (1 agricultural, 1 commercial). Figure 2-17 shows the relative location of the PTTW records, with the two active permits being labelled with their respective permit numbers.

The active agricultural PTTW (Permit #7511-A4SPUR) was issued for an agricultural operation in catchment LJ-3 (Brantwood Farms, located at 251 Powerline Road) for withdrawal of surface water from Jones Creek (which runs along this property to the north) and used for irrigation. Information provided by the MECP PTTW database states that a maximum limit of 328,000 litres per day can be withdrawn from Jones Creek as a condition of this permit.

The active commercial PTTW (Permit #0545-ABDQJF) is registered to the City of Brantford for the purposes of irrigating the Northridge Public Golf Course. This PTTW applies to groundwater taking via a bedrock supply well. The MECP PTTW database states that a maximum pumping of 1,278,000 L/day is permitted.

THE CORPORATION OF THE CITY OF BRANTFORD

Brantford Growth Plan

Environmental Features

- Watercourse
- Highway
- Arterial Road
- Collector Road
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary

Subwatershed

- D'Aubigny
- Fairchild
- Garden
- Grand
- Phelps
- Jones

MECP Water Wells

- Bedrock, Commercial
- Bedrock, Domestic
- Bedrock, Irrigation
- Bedrock, Livestock
- Bedrock, Public
- Overburden, Commercial
- Overburden, Domestic
- Overburden, Industrial
- Overburden, Livestock
- Overburden, Monitoring
- Overburden, Not used
- Overburden, Unknown

Figure 2-15
MECP Water Well Records Within the Primary Study Area
Northern Expansion Area

GM BluePlan

May 2020
717003-G-018
NAD 1983 UTM Zone 17N
Source: GRCA, OGS, MECP, City of Brantford

THE CORPORATION OF THE CITY OF BRANTFORD

Brantford Growth Plan

Environmental Features

- Watercourse
- Highway
- Arterial Road
- Collector Road
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary

Subwatershed

- D'Aubigny
- Fairchild
- Garden
- Grand
- Phelps
- Jones

MECP Water Wells

- Bedrock, Domestic
- Bedrock, Irrigation
- Bedrock, Monitoring
- Bedrock, Not used
- Bedrock, Unknown
- Overburden, Domestic
- Overburden, Irrigation
- Overburden, Monitoring
- Overburden, Not used
- Overburden, Unknown

Figure 2-16
MECP Water Well Records Within the Tutela Heights Area

GM BluePlan

June 2020
717003-G-010
NAD 1983 UTM Zone 17N
Source: GRCA, OGS, City of Brantford

BRANTFORD

Brantford Growth Plan

Environmental Features

- Watercourse
- Highway
- Arterial Road
- Collector Road
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary

Subwatershed

- D'Aubigny
- Fairchild
- Garden
- Grand
- Phelps
- Jones

Permit to Take Water

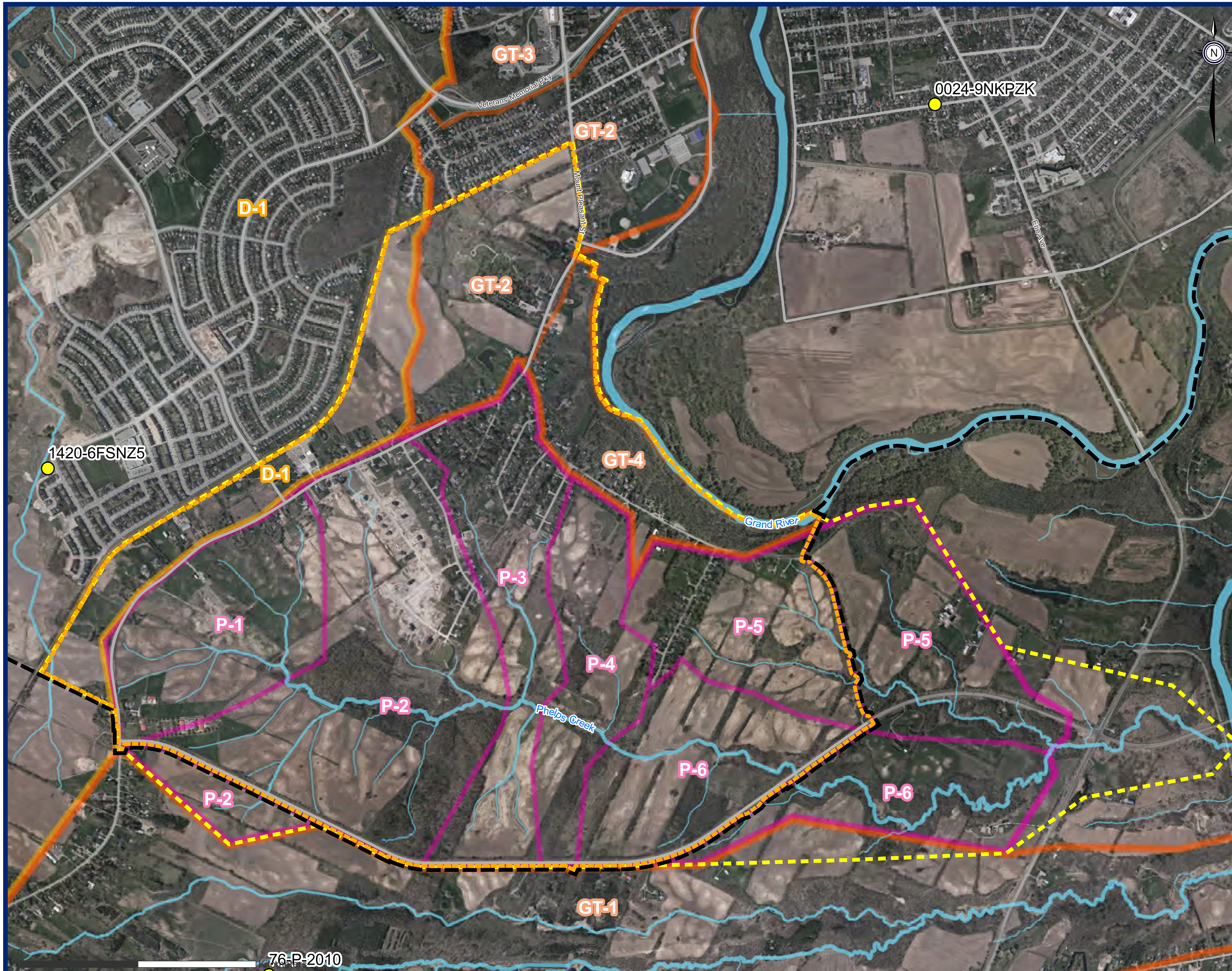
- Ground Water, Commercial
- Ground Water, Miscellaneous
- Ground Water, Water Supply
- Surface Water, Agricultural
- Surface Water, Dewatering Construction
- Surface and Ground Water, Agricultural
- Surface and Ground Water, Dewatering Construction

Figure 2-17

MECP Permit to Take Water Records Within the Northern Expansion Area

BluePlan

June 2020
717003-G-019
NAD 1983 UTM Zone 17N
Source: GRCA, OGS, MECP, City of Brantford



THE CORPORATION OF THE CITY OF BRANTFORD

Brantford Growth Plan

Environmental Features

- Watercourse
- Highway
- Arterial Road
- Collector Road
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary

Subwatershed

- D'Aubigny
- Fairchild
- Garden
- Grand
- Phelps
- Jones
- MECP PTTWs

Figure 2-18

MECP Permit To Take Water Records Within the Tutela Heights Area

BluePlan ENGINEERING

May 2020
717003-G-010
NAD 1983 UTM Zone 17N
Source: GRCA, OGS, City of Brantford

Drinking Water Source Protection Policy

Highly Vulnerable Aquifers

Within the study area, the local Source Protection Assessment Report assigns Intrinsic Vulnerability scores to the land area and from that identifies Highly Vulnerable Aquifers (HVAs). These qualities pertain to, and assist in evaluating potential risks to, groundwater resources.

Intrinsic Vulnerability is a measure of how susceptible an aquifer is to receiving contamination from the surface. It is based on a physical assessment of the hydrogeological characteristics of the overlying materials (e.g. topography, hydraulic conductivity, thickness, vertical gradient), which dictate the ease with which contaminants may migrate to the aquifer. Areas are assigned an Intrinsic Vulnerability score of "Low", "Moderate" or "High", depending on the physical characteristics of the system at that location.

Where the Intrinsic Vulnerability of an area is "High", that area is deemed a Highly Vulnerable Aquifer (or HVA).

North Brantford Expansion Areas

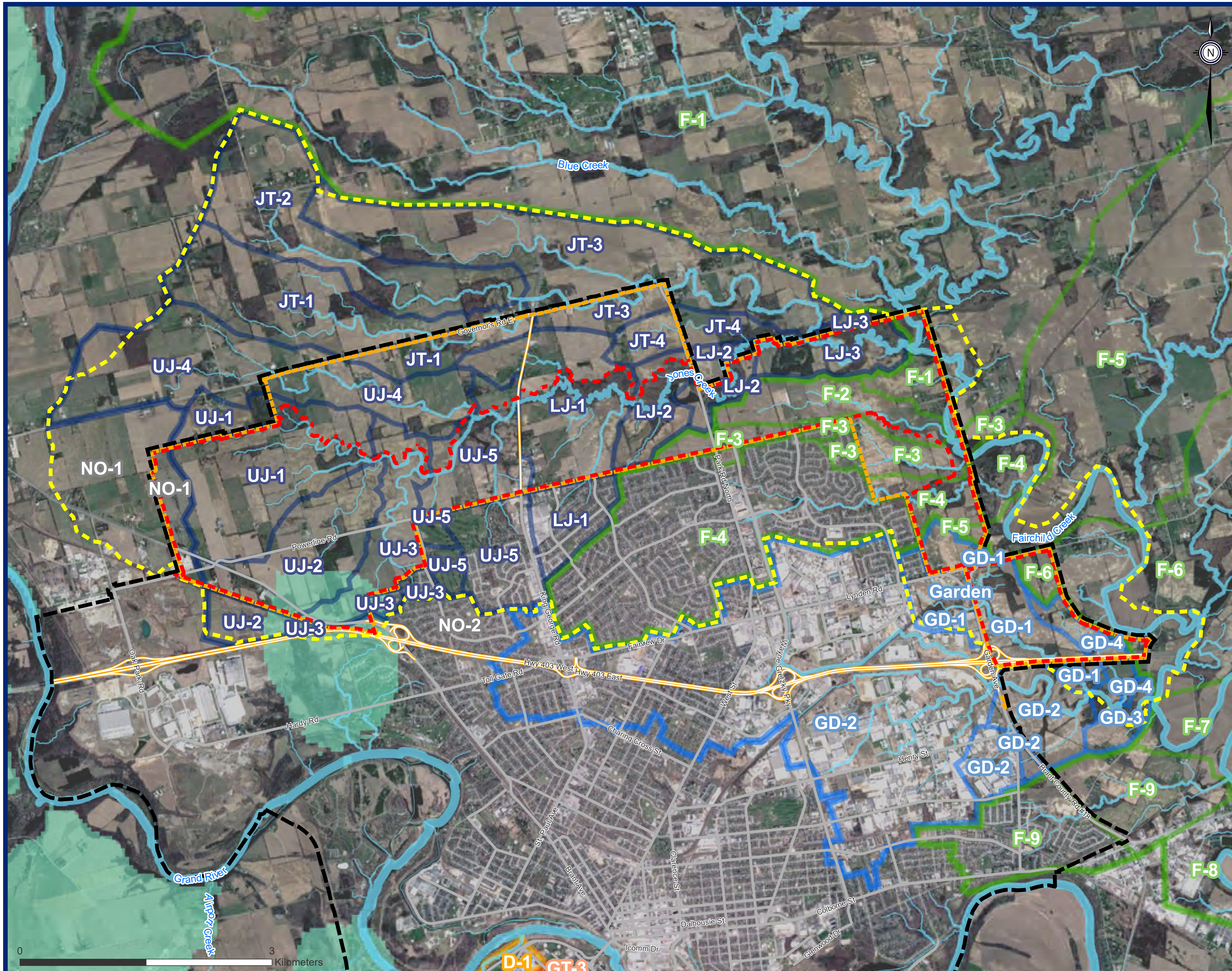
Intrinsic Vulnerability in this area ranges from "Low" (1-4) in the eastern portion to "Moderate" (5-7) in the western portion, save for a roughly circular region of "High" (8-10) vulnerability approximately 700 m radius centered on the intersection of Highway 403 and the CN Rail line (see Figure 2-19). This "High" vulnerability area coincides with a deposit of coarse-textured glaciolacustrine material. MECP well records in this area indicate bedrock at approximately 36 mbgs with intervening clay layers between the sand and the subcrop: this vulnerability level may be assigned for the protection of the overburden aquifer. If not preserved from development, enhanced recharge facilities and best management practices are likely to be required here to maintain recharge levels post-development. It may also be of interest to restrict or preclude certain land uses in this area, such as industrial processes utilizing organic solvents or fuel storage facilities.

Significant Groundwater Recharge Area (SGRA) classification is given to locations with a recharge rate more than 15% above the Grand River watershed average. Figure 2-20 shows these SGRA zones within the North Brantford expansion area. The area coinciding with the zone of "High" Intrinsic Vulnerability (described above) is identified as an SGRA with vulnerability score 6 while other areas south of Powerline Road and toward the western extent of the expansion area carry vulnerability scores of 4.

Tutela Heights

Intrinsic Vulnerability in this area is predominantly "Low" except for the portion extending approximately 700 m north and 1 km east from the intersection of Phelps Road and Mt. Pleasant Road (see Figure 2-21).

A very small area at that intersection is designated as an SGRA carrying a vulnerability score of 4 (moderate), as shown in Figure 2-22.



THE CORPORATION OF THE CITY OF BRANTFORD

Brantford Growth Plan

Environmental Features

- Watercourse
- Highway
- Arterial Road
- Collector Road
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary

Subwatershed

- D'Aubigny
- Fairchild
- Garden
- Grand
- Phelps
- Jones
- Highly Vulnerable Aquifer

Figure 2-19

Highly Vulnerable Aquifers

Northern Expansion Area

GM BluePlan ENGINEERING

May 2020
717003-G-014
NAD 1983 UTM Zone 17N
Source: GRCA, OGS, City of Brantford

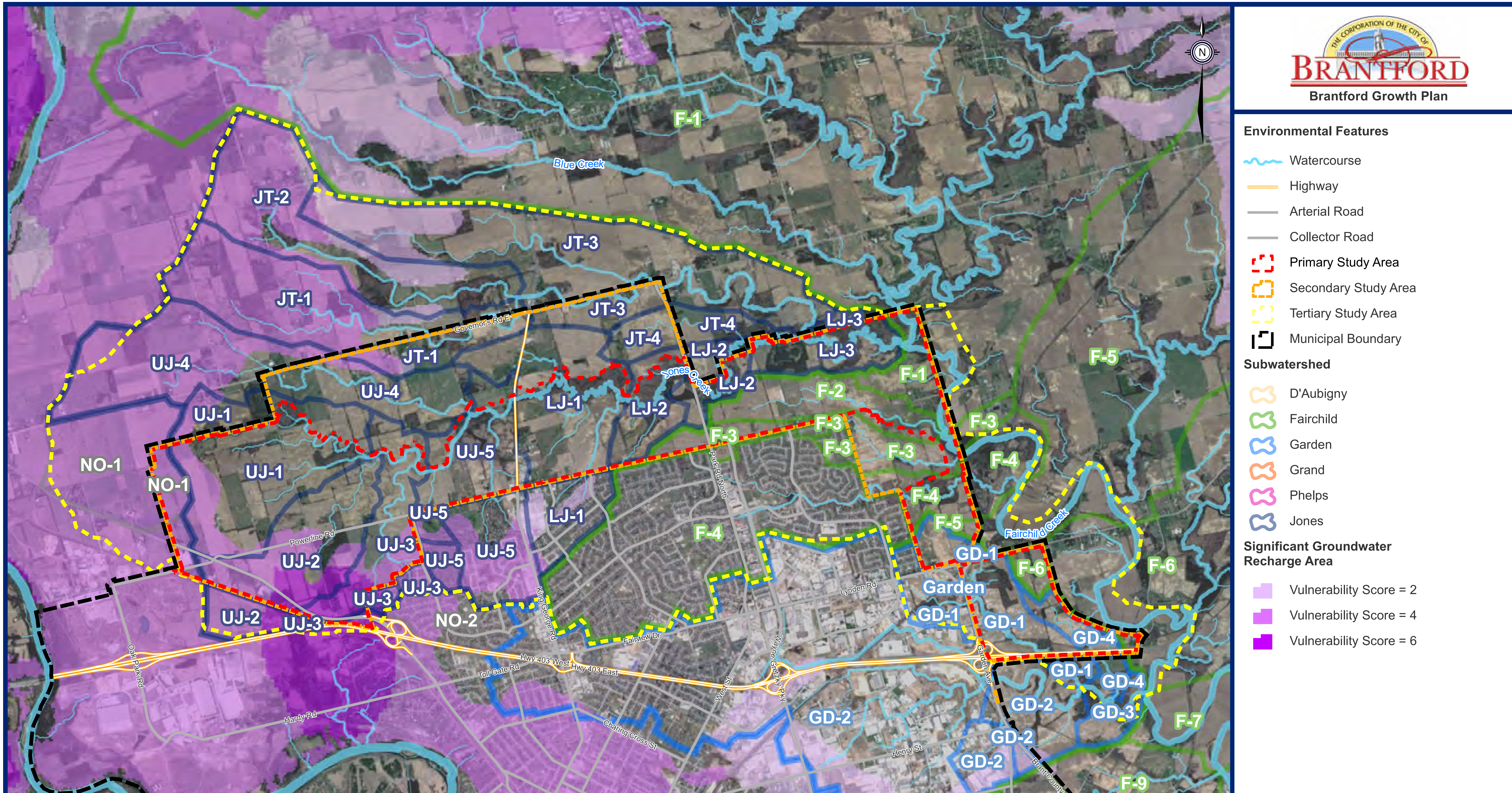
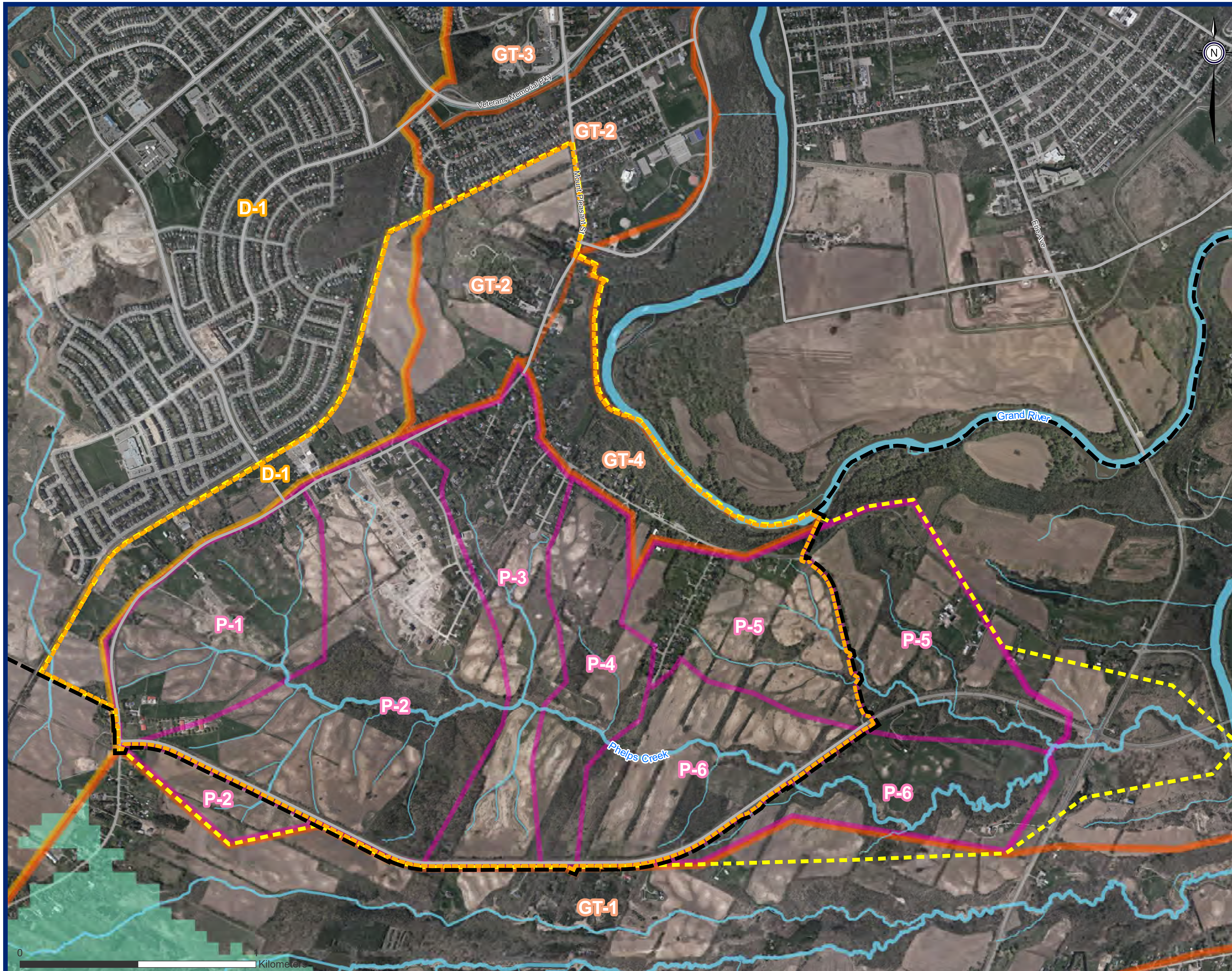


Figure 2-20
Significant Groundwater Recharge Areas
Northern Expansion Area

BluePlan

May 2020
717003-G-015
NAD 1983 UTM Zone 17N
Source: GRCA, OGS, City of Brantford



THE CORPORATION OF THE CITY OF BRANTFORD

Brantford Growth Plan

Environmental Features

- Watercourse
- Highway
- Arterial Road
- Collector Road
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary

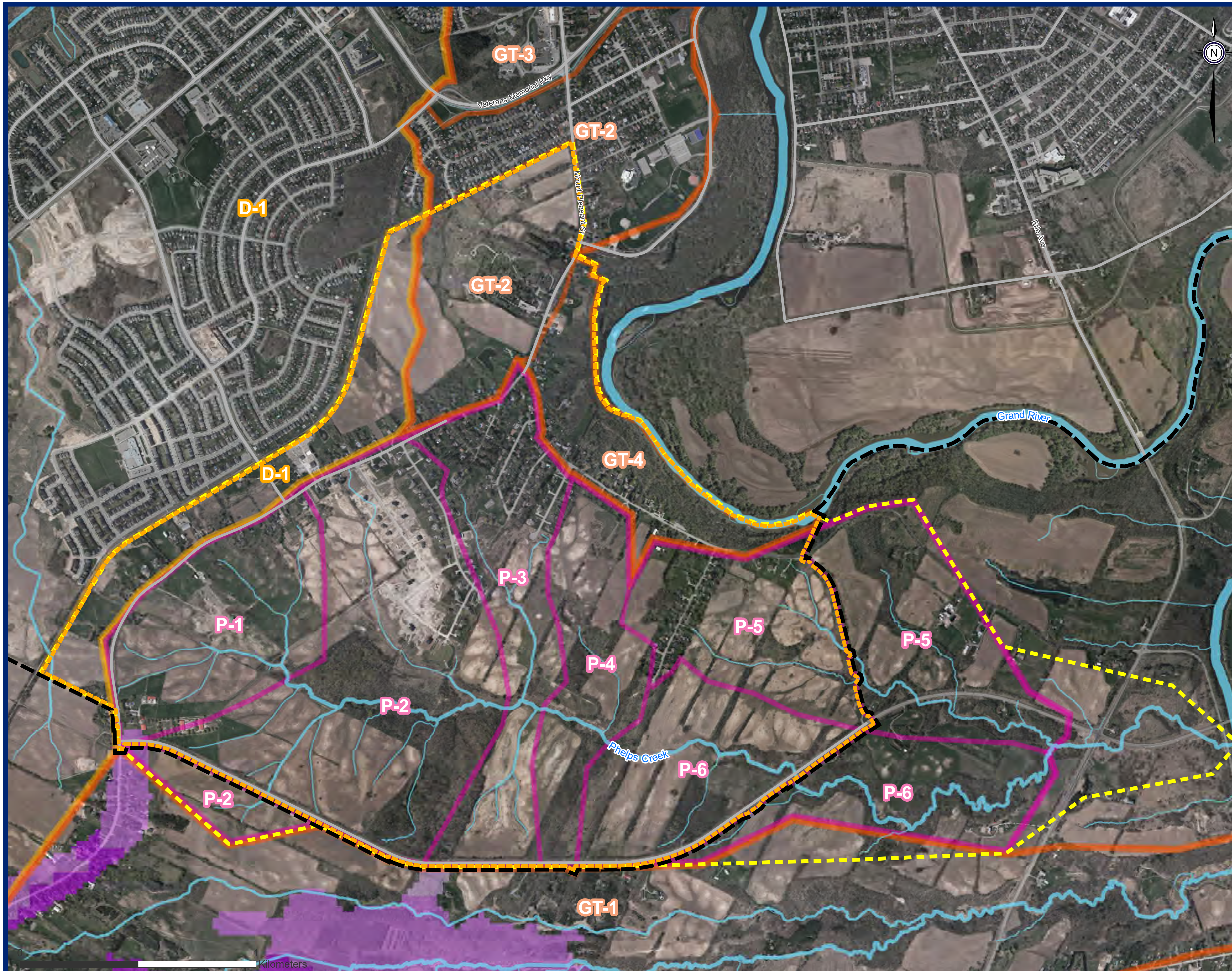
Subwatershed

- D'Aubigny
- Fairchild
- Garden
- Grand
- Phelps
- Jones
- Highly Vulnerable Aquifer

Figure 2-21
Highly Vulnerable Aquifers
Tutela Heights

GM BluePlan

June 2020
717003-G-016
NAD 1983 UTM Zone 17N
Source: GRCA, OGS, City of Brantford



THE CORPORATION OF THE CITY OF BRANTFORD

Brantford Growth Plan

Environmental Features

- Watercourse
- Highway
- Arterial Road
- Collector Road
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary

Subwatershed

- D'Aubigny
- Fairchild
- Garden
- Grand
- Phelps
- Jones

Significant Groundwater Recharge Area

- Vulnerability Score = 2
- Vulnerability Score = 4
- Vulnerability Score = 6

Figure 2-22
Significant Groundwater Recharge Areas
Tutela Heights

GM BluePlan

May 2020
717003-G-017
NAD 1983 UTM Zone 17N
Source: GRCA, OGS, City of Brantford

2.7 Drainage and Hydrology

2.7.1 Methodology

The high-level characterization of the surface water system presented in this section was conducted using the following info.

GIS data from City of Brantford and GRCA, including:

- Existing infrastructure: gravity main pipes, inlets, manholes, discharge points, culverts, detention ponds, ditches, watercourses, roads, buildings, land use, etc.
- Aerial imagery
- Topographical information (GRCA)
- Modelled stream groundwater discharge per length (GRCA)
- Design drawings, design reports, condition assessment reports, bathymetric survey files, etc. for detention ponds as available
- Field data collected by Ecosystem Recovery Inc. as part of the Master Plan update and Subwatershed Study
- Field data collected by GMBP staff as part of a separate Ditch Survey project

The City of Brantford's storm sewer model was comprehensively updated to include the study area. Details can be found in the City of Brantford Stormwater Master Plan provided separately.

2.7.2 Drainage Network and Catchment Areas

The study area was delineated and divided into major subwatershed catchments based on visual interpretation of topographical data (1 m contour lines) and existing infrastructure data provided by the City of Brantford.

The North Brantford study area comprises the drainage catchments of the following watercourses:

- Jones Creek and its tributaries
- Unnamed western tributaries to Lower Fairchild Creek
- Garden Avenue Municipal Drain and its tributaries

A small region to the extreme west of the northern boundary expansion lands does not appear to drain to Jones Creek. One portion drains west toward the Grand River, while another portion appears to drain to a local depression with no surface outlet. The catchment of this internal depression has been included in the study area.

The Tutela Heights area contains three major catchments. Most of the area drains to an unnamed tributary to the Grand River which crosses Phelps Road, hereafter known as Phelps Creek. Smaller regions along the west and north borders of the area drain to D'Aubigny Creek or the Grand River via existing stormwater infrastructure.

Major subwatershed characteristics are summarized in the table below:

Table 2-1: Major Subwatershed Catchment Characteristics

Catchment ID	Catchment Area (ha)	Larger Catchment Area	Associated ERI Reach ID's
D-1	1355	D'Aubigny	Not assessed
F-1	28394	Fairchild	LF-A, LF-B
F-2	122	Fairchild	KN-A
F-3	163	Fairchild	LF-A

F-4	716	Fairchild	JC-A, JC-B
F-5	2316	Fairchild	Not assessed
F-6	1264	Fairchild	Not assessed
F-7	156	Fairchild	Not assessed
F-8	629	Fairchild	Not assessed
F-9	353	Fairchild	Not assessed
Garden	462	Garden	Not assessed
GD-1	215	Garden	Not assessed
GD-2	1335	Garden	Not assessed
GD-3	51	Garden	Not assessed
GD-4	53	Garden	Not assessed
GT-1	524	Grand	Not assessed
GT-2	127	Grand	Not assessed
GT-3	114	Grand	Not assessed
GT-4	44	Grand	Not assessed
JT-1	343	Jones	TRIB B
JT-2	315	Jones	TRIB B
JT-3	529	Jones	TRIB B
JT-4	83	Jones	TRIB D
LJ-1	325	Jones	JC-I, JC-J, JC-K, JC-L, JC-M, JC-N, JC-O, JC-P, TRIB K, TRIB M, TRIB N
LJ-2	149	Jones	JC-F, JC-G, JC-H, TRIB F, TRIB H-C, TRIB J
LJ-3	105	Jones	JC-A, JC-B, JC-C, JC-D, JC-E, JC-F, TRIB A, TRIB-C
UJ-1	327	Jones	Not assessed
UJ-2	244	Jones	Not assessed
UJ-3	171	Jones	Not assessed
UJ-4	392	Jones	JC-T
UJ-5	297	Jones	JC-Q, JC-R, JC-S, JC-T, TRIB O
P-1	64	Phelps	Not assessed
P-2	147	Phelps	Not assessed
P-3	69	Phelps	Not assessed
P-4	47	Phelps	Not assessed
P-5	118	Phelps	Not assessed
P-6	103	Phelps	Not assessed
NO-1	198	Internal Depression	N/A
NO-2	80	Internal Depression	N/A

2.7.3 Stream Gauging Data

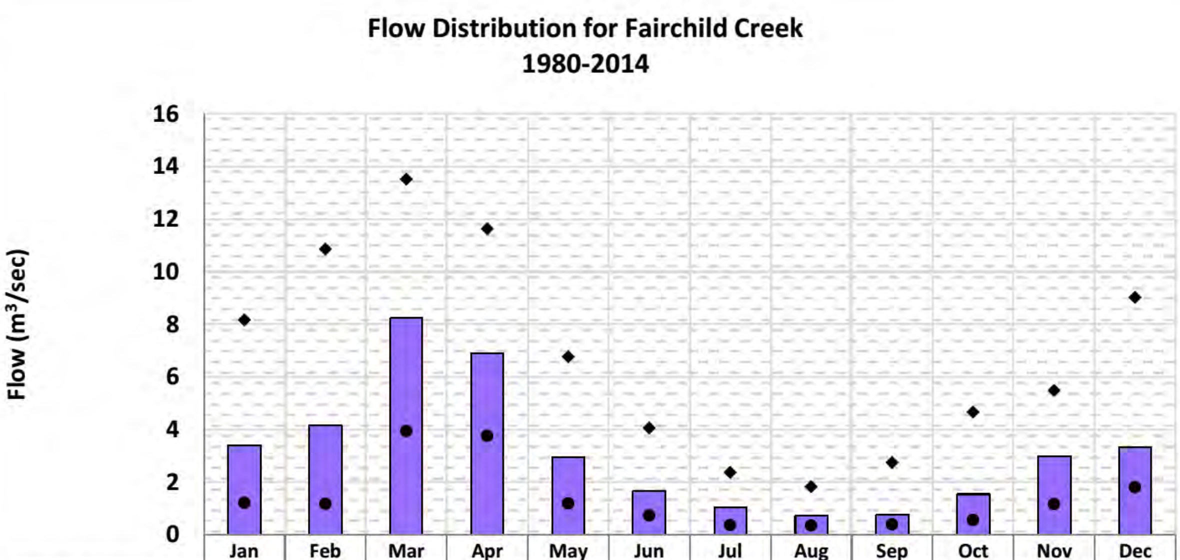
The GRCA provided stream gauging data that was used in support of the Boundary Expansion Lands PCSWMM model. Presented in Figure 2-24 are the catchment areas within the Study Area, as well as the GRCA stream gauges.

These stream gauges were in the following locations within and around the study area:

- Jones Creek @ Governors Road (later removed and relocated due to poor quality data)
- Jones Creek @ Highway 24
- Jones Creek @ Park Road
- Blue Creek @ Highway 24 (not used for validation)
- Blue Creek @ St. George (not used for validation)

A continuous recording water level gauge owned and operated by the Water Survey of Canada (WSC), is stationed within the Tertiary Study Area. This stream device is located outside of Cainsville at the end of West Harris Road and measures stream flow and level for a 390 km^2 drainage area. A summary of flow data from the 1980-2014-time period presented in GRCA's Fairchild Creek Characterization (2017) has been reproduced in Figure 2-23. By analyzing the flow distribution chart in Figure 2-23, it is evident that this is a runoff dominated system with low baseflow occurring throughout the summer months. Rain data from the rain gauge at the Brantford Visitor and Tourism Centre on Wayne Gretzky Parkway was used in validating the PCSWMM model,

No stream gauging data is available in the Tutela Heights area from the GRCA or the WSC.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Flow	3.4	4.15	8.24	6.89	2.94	1.65	1.04	0.73	0.759	1.55	3	3.33
10th Percentile Flow	1.212	1.182	3.946	3.762	1.194	0.7286	0.3678	0.3598	0.3942	0.5602	1.168	1.81
90th Percentile Flow	8.176	10.86	13.52	11.64	6.766	4.058	2.372	1.828	2.744	4.662	5.494	9.03

Figure 2-23: Flow Distribution for Fairchild Creek Stream Gauge

2.7.4 Design Flows

Using the stream gauge data and the catchment areas noted above, GM BluePlan developed an existing condition model of the stormwater management system (see Appendix F: Tech Memo 1- Stormwater Model Development). This model was validated based on the best information available. The model was run for 2, 5, 10, 25, 50, and 100-year design storms. Based on the Environment and Climate Change Canada data, the 3-hour Chicago design storm distribution was used for the model.

As part of the preliminary modelling process, design flows at the following junctions have been developed, for 2, 5, 10, 25, 50, and 100-year Chicago storms. These junctions are illustrated on Figure 2-24. It is noted that the modeled flows taken from the flow junctions at Jones Creek had actual stream flow data available to support validation of the model. Since there was no available stream flow information for Phelps Creek, the modeled peak flow for the flow junction on Phelps Creek Rd has not been validated.

Table 2-2: Modeled Peak Flows (L/s) at Flow Junctions

Flow Junctions	Modeled Peak Flows (L/s) for Design Storms					
	2	**5**	**10**	**25**	**50**	**100**
Jones @ Governor's	504.2	773.4	1229.0	2036.1	2949.4	4163.5
Jones @ Hwy 24	494.1	2921.2	4770.2	8744.8	12523.9	16562.9
Jones @ Park	517.1	2773.2	4708.5	10206.1	13637.4	16998.8
Phelps @ Phelps Rd	982.6	3842.4	7013.4	8223.7	10310.3	12411.1

The following table identifies the upstream catchments of each of the flow junctions.

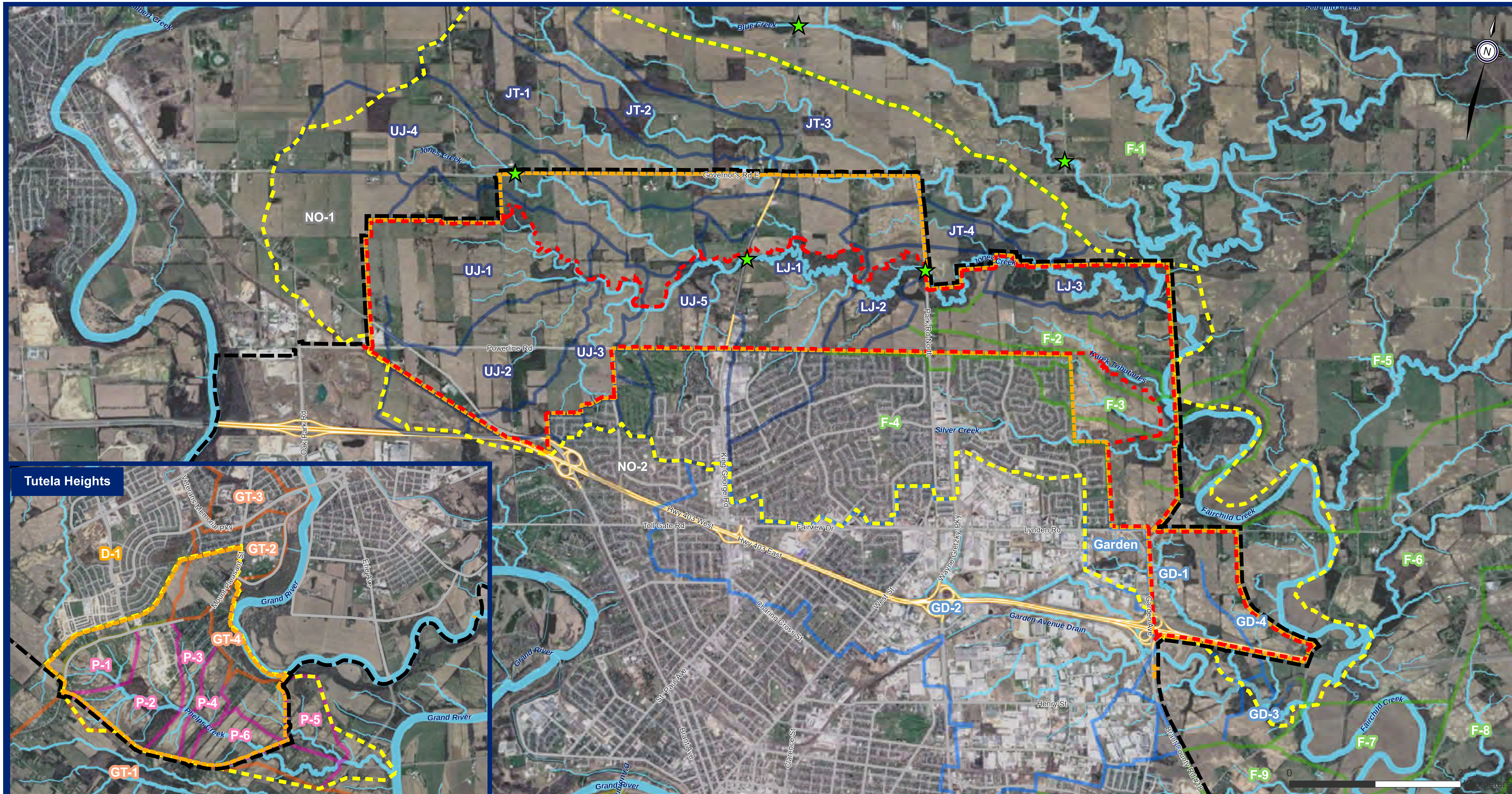
Table 2-3: Upstream Catchments of Flow Junctions

Flow Junction	Upstream Catchments
Jones @ Governor's	UJ-4
Jones @ Hwy 24	UJ-1 through UJ-5
Jones @ Park	UJ-1 through UJ-5, LJ-1, LJ-2
Phelps @ Phelps Rd	P-1, P-2, P-3, P-4, and P-6

2.7.5 Floodplain

Figure 2-25 shows the approximate extent of the floodplain within the secondary study areas based on GRCA mapping. The floodplain of Jones Creek and its tributaries, unnamed western tributaries to Lower Fairchild Creek, tributaries to the Garden Avenue Drain, and Phelps Creek are all considered "estimated" as they have not been verified by an engineering study.

Other natural hazards mapped by GRCA are also presented in Figure 2-25.



Brantford Growth Plan

Environmental Features

- Watercourse
- Highway
- Arterial Road
- Collector Road
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary

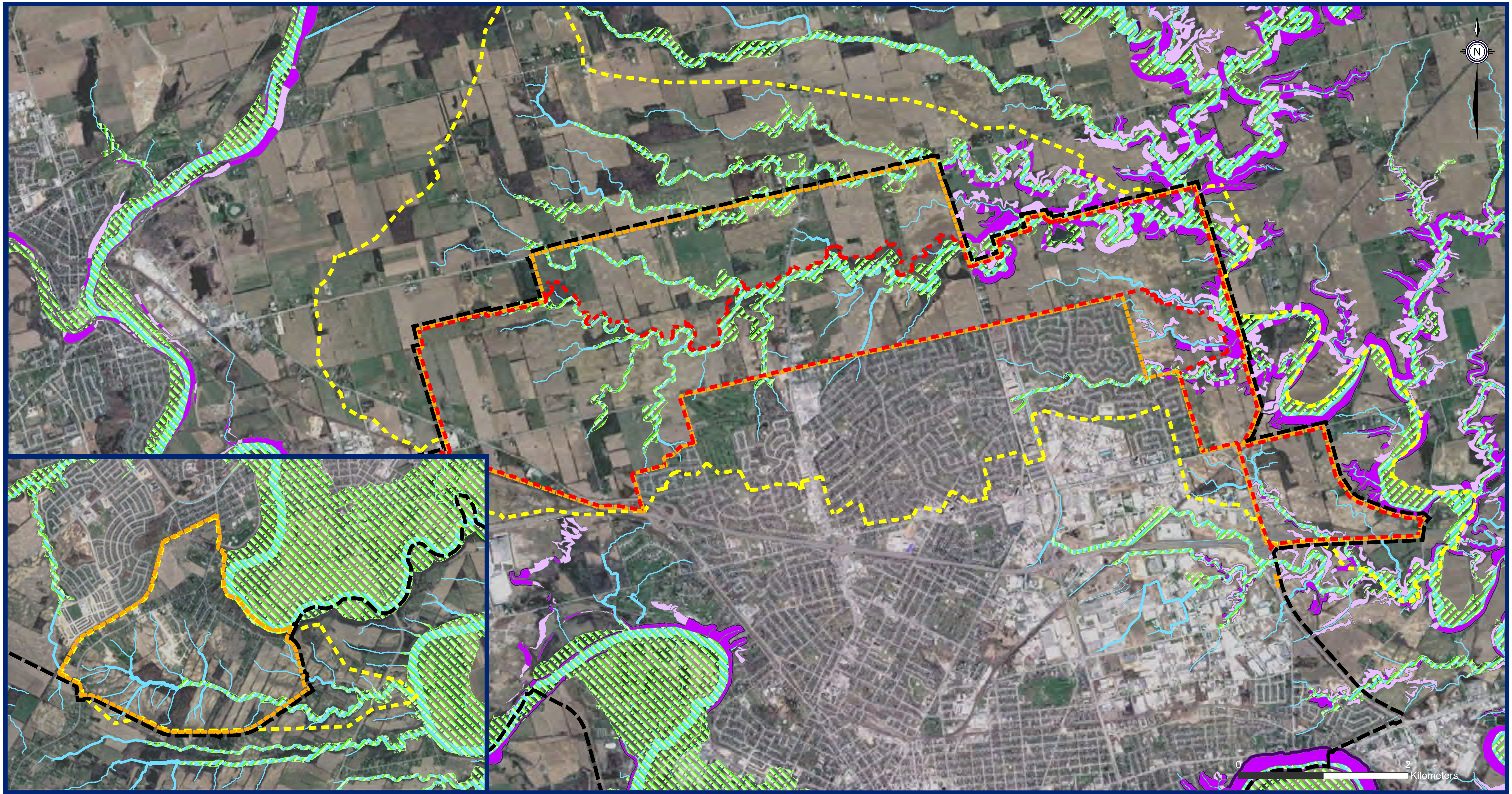
Subwatershed

- D'Aubigny
- Fairchild
- Garden
- Grand
- Phelps
- Jones
- GRCA Gauge Stations

Figure 2-24
Catchment Areas and Stream Reaches

BluePlan
ecosystem recovery
PROFESSIONAL ENGINEERS

May 2020
717003-G-022
NAD 1983 UTM Zone 17N



Brantford Growth Plan

General Features

- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Municipal Boundary
- Watercourse

River Slope Erosion Hazard Area

- Steep
- Oversteep
- Toe

Regulatory Floodplain

- Engineered
- Estimated
- Approximate

Figure 2-25
Regulatory Floodplain

May 2020
717003-G-004
NAD 1983 UTM Zone 17N

2.7.6 Drinking Water Source Protection Policy (Surface Water)

Brantford and other downstream municipalities (e.g. Oshweken, Dunnville) largely obtain their municipal drinking water supply from surface intakes. As such, the primary policy areas of concern in the Brantford area are Intake Protection Zones (IPZ). Intake Protection Zones are areas where runoff and surface drainage are likely to pass by a municipal surface water intake used for a municipal supply. As such, spills and other contaminant releases in these areas may result in impacts to the quality of surface water utilized by the municipality for drinking water.

The primary source of water for Brantford is the Holmedale Canal intake but the Intake Protection Zones for the Holmedale source do not overlap with the catchment areas of concern to this study. As such, the Holmedale Canal will not be discussed.

North Brantford Expansion Area

Parts of the Jones Creek (e.g. LJ-1, UJ-3, UJ-5) and Fairchild Creek (e.g. F-3, F-4, GD-2) catchments that extend into the developed area of Brantford have been designated as IPZ-3 (Vulnerability 8). It is reasonable to expect that the areas downgradient (i.e. in the expansion area) would also be assigned the same designation (see Figure 2-26). Because all the natural drainage features correspond to IPZ-3 (Vulnerability 8) areas, “significant” drinking water threats that may be applicable in these areas include: untreated discharge from stormwater management facilities serving predominantly commercial/ industrial areas over 100 hectares, discharge from areas where Agricultural Source Material is stored, and the discharge of industrial effluent from the National Pollutant Release Inventory NPRI-reporting facilities.

Tutela Heights

An IPZ-2 (Vulnerability 8) associated with Phelps Creek stretches from just west of Davern Street downstream to the Grand River in the east (see Figure 2-27).
An additional IPZ-3 (Vulnerability 8) is associated with the various residential properties along Davern Road, Tutela Heights Road, and Mt. Pleasant Road (see Figure 2-27): these are likely areas that have been graded to drain stormwater northward to the Grand River. As many of the properties appear to be estate residential, on-site sewage systems may also be present in these areas. However, on-site sewage systems are not specifically mentioned as a “significant” drinking water threat for IPZ-3 (Vulnerability 8) areas.

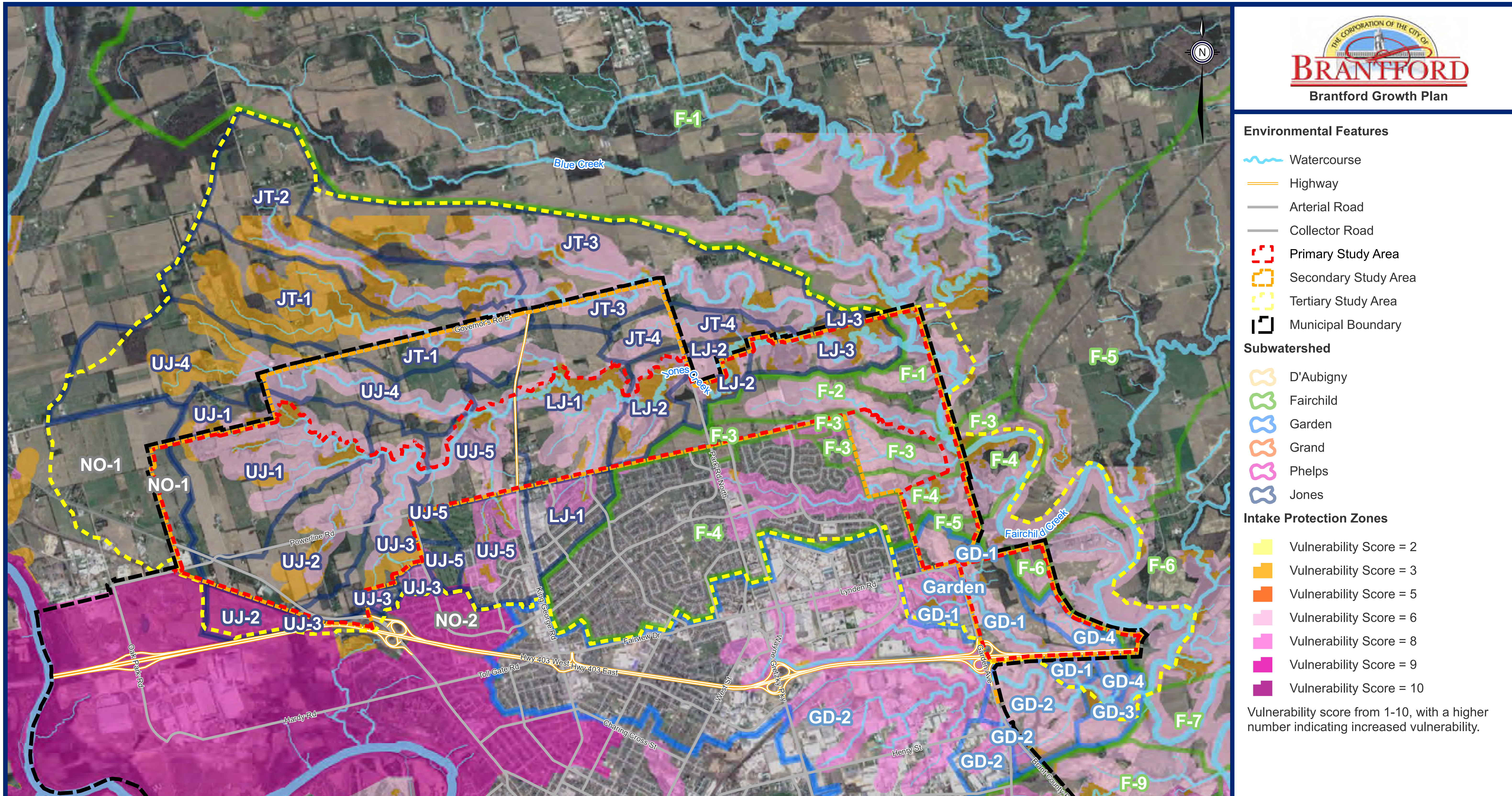


Figure 2-26
Intake Protection Zones
Northern Expansion Area

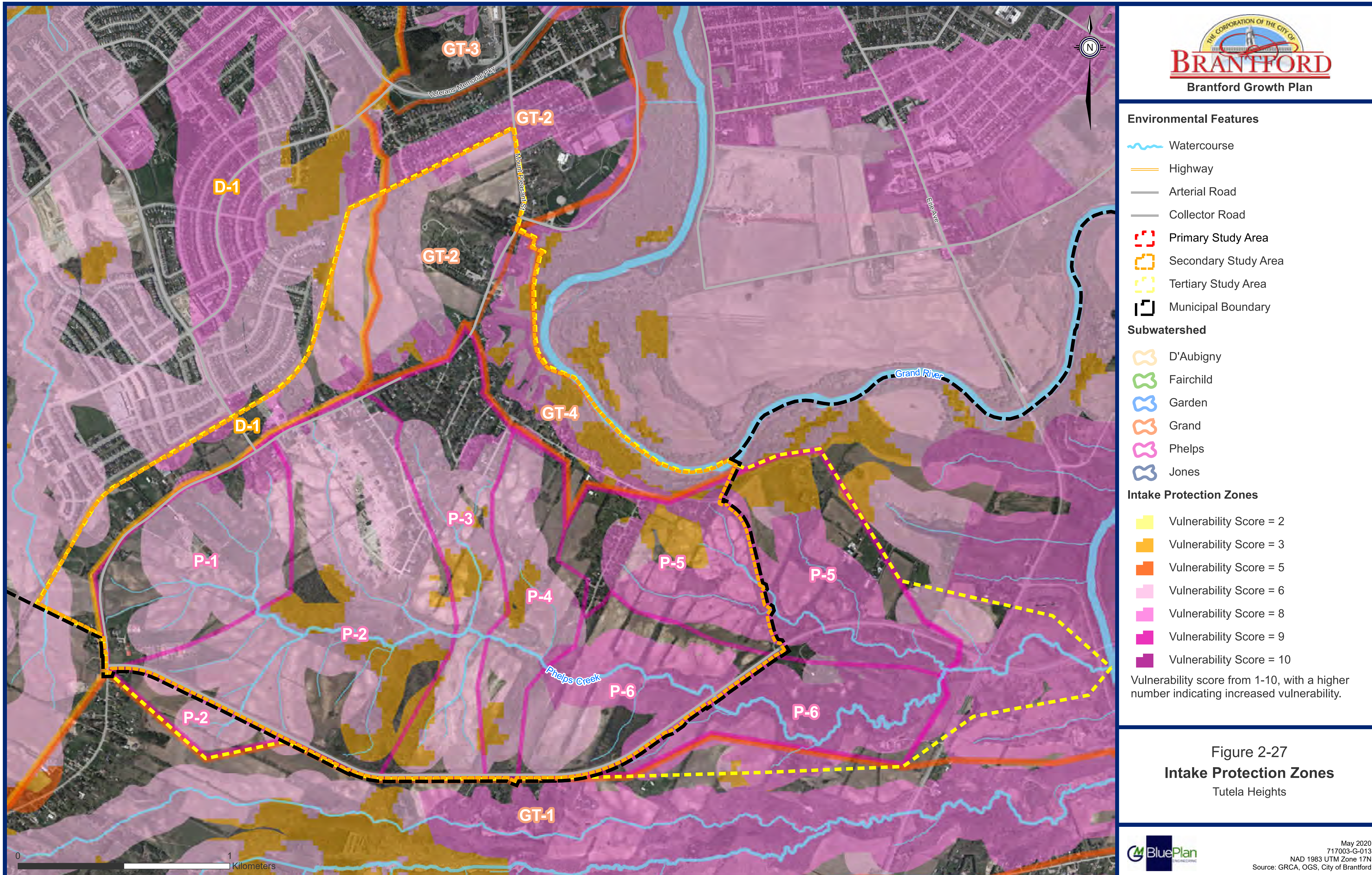


Figure 2-27
Intake Protection Zones
Tutela Heights

2.8 Fluvial Geomorphology

The origin, form, structure, and development of the drainage network and watercourses within the landscape are primarily due to the interaction between geology (physiography, floodplain material characteristics) and hydrology (magnitude and frequency of flow events). Watercourses receive water and sediment from adjacent and upstream watershed areas and convey these downstream through their drainage network. The interaction between geology and hydrology determines the aquatic habitat that develops and is available to support aquatic communities. To develop a holistic understanding of the conditions and functions of a watershed, and the watercourses within them, assessments should be completed at a range of spatial scales. A geomorphic assessment was completed for those watercourses that flow through the Brantford Boundary Expansion Area and included Jones Creek, Silver Creek, Phelps Creek, and its tributaries.

The geomorphic assessment included both desktop and field assessments to document existing conditions and contribute to an understanding of the form and function of the drainage network. Characterization of existing conditions forms the basis for identifying linkages within the study area and establishing goals and targets for future management to protect or enhance channel functions. Findings from the geomorphic assessment are presented in the following sub-sections.

2.8.1 **Background Review**

Documentation of existing conditions along Jones Creek and the Fairchild Creek Tributaries that flow through the study area is limited and restricted primarily to the written description included in the Fairchild Creek Subwatershed Characterization Report (MacVeigh et al., 2016). From that report, the following existing conditions information was gleaned:

- There are significant slope erosion issues throughout the lower Fairchild Creek subwatershed on the clay plain (this may also refer to Jones Creek).
- Areas of slope erosion have been identified along lower Jones Creek, along the valley walls.
- One of the key sources of sediment for Fairchild Creek is the subcatchment receiving flow from Jones Creek, a tributary originating near Lynden, and urban tributaries draining northwest Brantford.
- Characterization of key areas facing development pressure (e.g., Brantford/Brant Boundary Adjustment Area – Jones and Blue Creeks) is strongly limited by lack of data and outdated information.
- "Fairchild Creek and its tributaries are in many places highly meandering, narrow, and incised with sand or silt substrates, and may be referred to as "E5" and "E6" type channels in accordance with the classification system developed by Rosgen and Silvey (1996) (OMNR and GRCA, 1998)"
- Riparian wetlands were identified as an important control on channel flows; "where riparian wetlands exist, "high flows are sharp but prolonged whereas baseflows are low but somewhat stable. Where riparian wetlands are absent, tributaries exhibit highly variable flows with rapid, short, and intense high flows and extreme low baseflows"
- The "Galt Moraine system …. is an area of higher infiltration and reduced surface runoff due to coarser materials present."
- Jones Creek and urban tributaries draining northwest Brantford were identified as a key source area for suspended sediment loading to Fairchild Creek (Stone, 2004). The author postulated that vegetation (riparian and in-channel) provides in-channel storage (trapping sediment and acting as a sink for inputs), and stabilizes sediments, thus decreasing the potential for export of phosphorus and sediment from stream banks, beds and floodplain deposits through erosion (Stone, 2004).
- A review of Best Management Practices within the Fairchild Creek watershed reveals that livestock restriction, tree planting, and nutrient management plans have been implemented in select locations within the Jones Creek watershed (Stone, 2004).

Based on the background review, it is evident that a substantial gap exists in knowledge regarding the drainage network and existing creek conditions of the Jones Creek and Silver Creek watershed; both are tributaries of Fairchild Creek. Likewise, no background information has yet been located for Phelps Creek which drains the Tutela Heights portion of the study area and is a tributary of the Grand River. This study is intended to begin addressing this gap.

2.8.2 Controls and Modifiers of Channel Form

Boundary Materials

The boundary materials (bed and banks) of a watercourse are determined by the local surficial geology and upstream sediment contributions. The physiography of a region is intrinsically linked to the topography of the landscape and the geomorphic influences acting upon it. Together, the surficial geology and physiography of a region will exert a dominant influence on channel form, function and processes (See Section 2.5).

Characteristics of the boundary materials (size, cohesion) along a watercourse affects the configuration of the watercourse, the available sediment supply for downstream channel sections, and the rate and mode of channel erosion. Non-cohesive and unconsolidated sediment are more prone to erosion from hydraulic stresses than cohesive and consolidated sediment. The predominant mode of channel adjustment (i.e., channel response to change) tends to occur along the weaker boundary materials; this can lead to predominant widening, migration or deepening tendencies. The strength of bank materials can be enhanced by the rooting network of riparian vegetation.

The surficial geology along the Jones Creek, Silver Creek, and Garden Avenue Tributaries in the North Brantford area is mapped as a sand deposit that is surrounded by clay materials (See Figure 2-10**)**. Field observations suggest that the boundary materials (bed and bank) of Jones Creek and the Garden Avenue Tributaries consist entirely of silty-clay cohesive materials. Silver Creek and a tributary of Jones Creek (Tributary K; Figure 2-9) have incised into a firm till unit. Upper banks may consist of sandy materials. The cohesive boundaries have implications for channel adjustment processes and suggest a limited supply of coarse sediment for riffle development (See Section 2.8.8 for further discussion).

The boundary materials along Phelps Creek in the Tutela Heights area were not field assessed as permission to access the properties was not provided during the field investigations.

Physiography

Landscape characteristics exert an important influence on channel form and functions. The topography of the area will determine the gradient of the channel. This influences the energy regime of a watercourse. The energy of a watercourse will determine the rate of change that will occur in a channel as it adjusts to changes in sediment loading or hydrology. Variations in energy along the channel profile will determine areas of sediment transport and deposition.

Land Cover and Land Use

The land use and land cover of an area influence the form and function of watercourses. When these change, then the hydrology of the drainage networks may be altered, and a change in sediment loading to the watercourses may occur. When these changes are beyond the ability of a watercourse to absorb, then the equilibrium channel form that previously existed may become unbalanced. Awareness of the land use and changes that have occurred within both the North Brantford and Tutela Heights subwatershed areas provides a context for observed channel conditions.

Vegetation

Riparian vegetation exerts an important influence on channel form and on water quality. The rooting network of bankside vegetation enhances the structural strength of bank materials through the rooting network of the vegetation. The presence of a vegetated buffer provides shade to a watercourse and overhanging vegetation that supports aquatic habitat. Buffers also provide a filtering function, reducing the volume of sediment that flows into the watercourse through surface runoff.

The main branches of Jones Creek and Phelps Creek are generally situated within the Natural Heritage System. The tributaries and headwater drainage feature typically lack a riparian corridor or buffer; when a vegetated buffer is present, then this tends to be narrow (i.e., less than 5 m).

Agricultural Land Use

Review of aerial photographs and Figure 2-2 and Figure 2-3 clearly demonstrates that most of the land use within the North Brantford and Tutela Heights area is agricultural; a practice which can have significant impacts on a watercourse. Potential effects of agricultural activity on watercourses include increased amounts of sediment through eroded soils, pollution from nutrients and pesticides, reduction of the natural riparian canopy, disruption of the hydrological regime, and physical disturbance through ploughing activity, livestock grazing and tramping, and dredging (Fraser and Fleming, 2001). When machinery is operated near the channel banks, then the mechanical impact and vibration from the machinery can destabilize banks. Cattle access to watercourses contribute to erosion, loss of morphological form, and a deterioration in water quality.

The predominant agricultural land use observed during 2018 included row crops (corn) and soy bean. The land in North Brantford was used locally for sod mats and for cattle and equestrian operations. The establishment of agricultural practices within the area during European settlement would have resulted in deforestation, likely causing increased sediment inputs and greater runoff volumes to the drainage network.

In conjunction with agricultural land use, drainage features have often been altered (i.e., straightened, dredged) to support field drainage and/or water storage. An extensive network of tile drains occurs within the North Brantford area (Figure 2-8). It is evident that the occurrence of tile drainage varies within the study area; while tile drains appear to be absent between 317 and 505 Powerline Road (i.e., immediately west of King George Road to Park Road), tile drains appear to generally occur to the east and west limits of the study area.

The majority of tile drainage systems present within the study area occur in the clay-based plains (i.e., where infiltration rates are lessened due to the fine, cohesive substrate materials). The tile drains outlet to tributaries, or the main branch, of Jones Creek and/or Fairchild Creek within the North Brantford area. Based on field observations, it is likely that there are additional, unmapped tile drains.

Tile drains reduce the amount of surface runoff by allowing for greater temporary subsurface storage through greater infiltration into the soil profile (Fraser and Fleming, 2001). With the reduction in surface runoff through tile drainage, the amount of sediment produced through hillslope and headwater feature erosion is lessened.

The tile drains and underground pipe system (i.e., Hickenbottom structures capture surface water) have diverted surface water underground. This has eliminated some of the headwater drainage features from the landscape and altered hydrograph characteristics. The water that is captured and conveyed through the subsurface tile drain system is typically discharged into a ditch or defined watercourse feature; this alters the shape of the flow hydrograph of the receiving watercourse (i.e., more rapid time to peak flow, and increase in flow magnitude) and can exacerbate erosion within that watercourse. When there is a substantial loss of headwater drainage features (HDF), then the benefits of HDF along the drainage network (see Section 2.8.5 and Appendix D-2) are not realized. The actual impacts of tile drains are dependent on several site-specific factors, including drain size and depth, soil type and permeability, topography, and water budget conditions (Fraser and Fleming, 2001).

Urban Development

The northern limit of existing urban development occurs to Powerline Road (i.e., southern boundary of the North Brantford study area); the eastern limit is to the east of Brantwood Park Road. This urban development occurs within the Jones Creek, Silver Creek and Fairchild Creek tributary subwatersheds in North Brantford, and within the Phelps Creek subwatershed in Tutela Heights. Review of the construction of watermains in proximity to the North Brantford area (See Figure 2-5) suggests that urbanization began in the late 1950's and continued through to the 1980s, with a general trend of development moving east to west across the landscape.

The establishment of urban land use within the landscape is associated with various impacts to watercourses and other drainage features. Historically, small headwater drainage features are removed from the landscape and replaced with an extensive system of stormwater and drainage infrastructure (See Section 2.3.2). The increase in impervious surfaces alters the flow regime within a catchment, increasing both the frequency of flow events and volume and peak flow rates of those flows into the receiving watercourses.

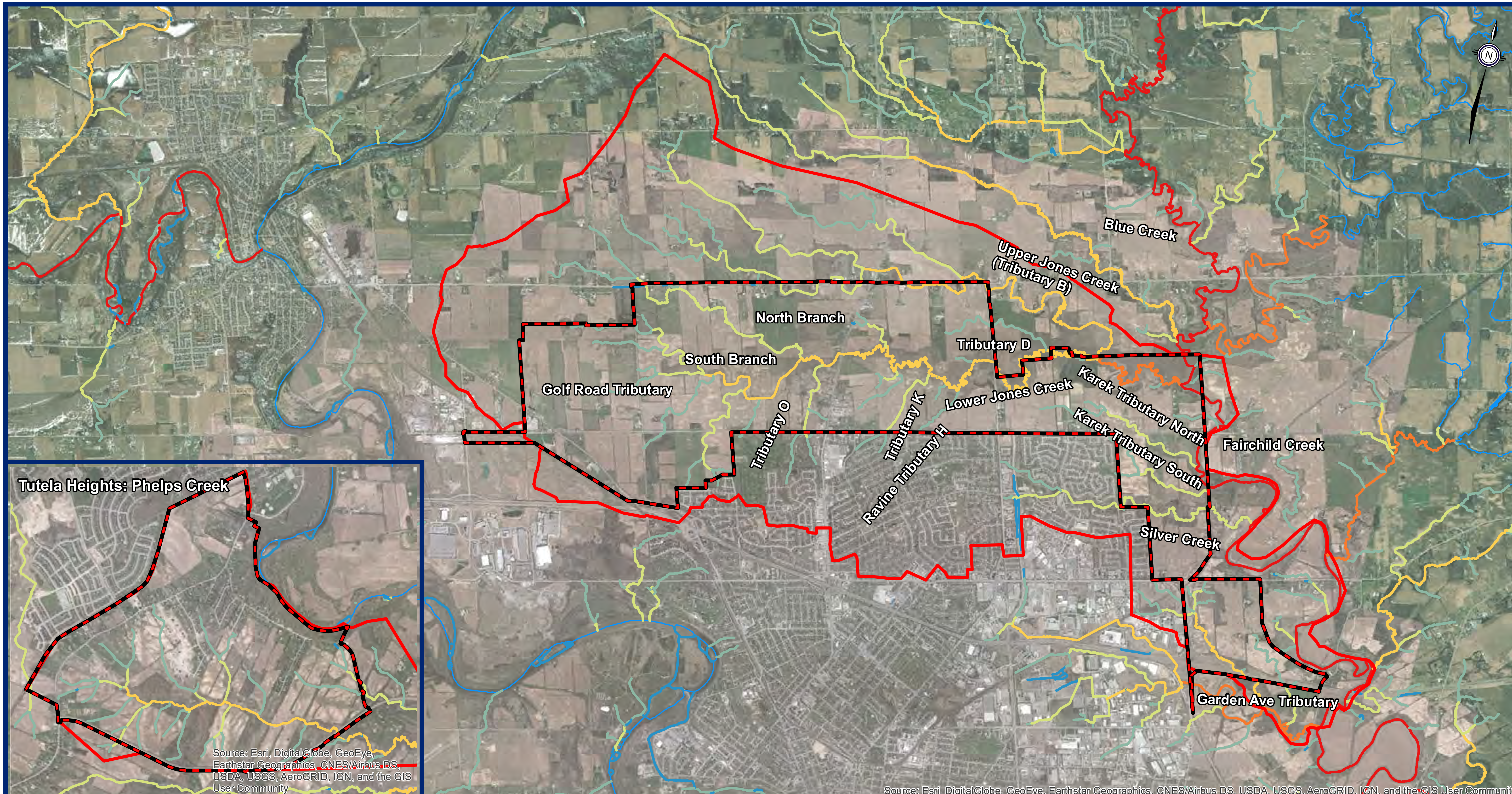
In Southern Ontario, management of stormwater runoff was not prevalent until after the 1980s. As noted in Section 2.8.2 and shown on Figure 2-7, uncontrolled discharge is conveyed into the North Brantford drainage network (i.e., Jones Creek tributaries, Silver Creek, and Fairchild Creek tributaries).

2.8.3 **Drainage Network and Morphometric Characteristics**

The drainage network that develops on a landscape is determined by general precipitation patterns (i.e., how much precipitation falls on the ground), and characteristics of the ground surface that affect how the precipitation is distributed with respect to evaporation, infiltration, or runoff (e.g., geology, soils, vegetation, topography) (Knighton, 1998). The permeability of the surficial geology determines the drainage density; the topography (often influenced by geological processes) influences drainage pattern.

In addition to the mapped surface water features available from the GRCA, a review of aerial photography was undertaken to supplement the drainage network mapping with respect to potential headwater drainage features. The potential headwater drainage features (HDF) observed on the study area aerial photos were digitized and used to augment the surface water drainage feature mapping received from the GRCA. The HDF features were field verified and used to update the mapping as shown in Figure 2-28 for both the North Brantford and the Tutela Heights boundary expansion areas.

The position of watercourses along a drainage network generally coincide with specific roles and functions as part of the larger spatial continuum; upstream sections of a watercourses are typically erosional and sources of sediment whereas downstream sections tend to be depositional. Examination of drainage network characteristics involves both planform and profile analyses. Quantitative analyses of drainage network characteristics are referred to as drainage basin morphometry.



Brantford Growth Plan

Study Area
Tertiary Study Area
Drainage Network

Strahler Stream Order

0
1
2
3
4
5

0 3.5 Kilometers

This drawing has been prepared for the use of Ecosystem Recovery Inc.'s client and may not be used, reproduced or relied upon by third parties, except as agreed by Ecosystem Recovery Inc. and its client, as required by law or for use by governmental reviewing agencies. Ecosystem Recovery Inc. accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without Ecosystem Recovery Inc.'s express written consent.

Figure 2-28
Watercourse Characterization
Strahler Stream Order

May, 2020
NAD 1983 UTM Zone 17N

Drainage Density

Drainage density refers to the length of watercourse per unit area and provides an indication of how well an area is drained by the surface water drainage network. The density of channels within a landscape is a result of two primary factors: the volume of water received at the surface (i.e., precipitation), and the distribution of water on the land surface (e.g., geology soils, vegetation, topography) (Knighton, 1998). In natural watercourses, a low drainage density (i.e., fewer watercourses) typically indicates more infiltration (more permeable materials) and less runoff, resulting in longer lag times and lower peak flows. A higher drainage density indicates a proportionally larger number of watercourses that convey water over a less pervious landscape, resulting in a flashier hydrograph.

The active drainage network (i.e., that which conveys flows) will expand and contract through time, in response to fluctuations and magnitude in precipitation patterns and antecedent soil moisture conditions (Gregory and Walling, 1968). Thus, during precipitation events, ephemeral zero-order channels (i.e., headwater features such as swales etc.), become an active part of the drainage network. Seasonally, intermittent watercourses are part of the active drainage network.

Drainage density can be modified by human alterations of the drainage network resulting in an alteration of the drainage patterns that might naturally exist within any given area. Drainage network alterations that have occurred in the study area are related to agriculture (e.g., tile drains, dredging and channelization, etc.) and development (e.g., piping watercourses, topographic regrading, etc.). Sections 2.3 and 2.4 of this report discuss the anthropogenic (stormwater management and tile drainage, respectively) modifications of the drainage network that have occurred within the North Brantford and Tutela Heights Subwatershed areas.

The drainage densities of the subwatersheds situated within the North Brantford and Tutela Heights areas were calculated (Table 2-4**).** The calculations were repeated at different scales to support various planning scales within the current study, including the entire subwatershed (tertiary area), the portion of the subwatershed situated within the Boundary Expansion Area (secondary area), and those situated within the Settlement Area (i.e., a subset of the Boundary Expansion Area, referred to as the primary area).

Review of Table 2-4 shows that the drainage density for the Jones Creek subwatershed (1.94 km/km^2) is like that of the Garden Ave. (2.05 km/km^2) and Fairchild Creek tributaries (2.04 - 2.09 km/km^2) except for Silver Creek; the similarities reflect surficial geology and land use/cover. The tributaries that flow through the Karek property have drainage densities that are both higher and lower than Jones Creek and the other Fairchild Creek tributaries; this may reflect the headwater drainage classification assigned to these features, after completing the field reconnaissance. The lower drainage density of Silver Creek (1.19 km/km^2) likely reflects historical alterations to the drainage network due to urbanization (i.e., removal of low order tributaries from the surface drainage network and diversion into the subsurface stormwater network). Implications of reduction in drainage density is reflected in altered storm hydrograph characteristics.

The drainage density of the Phelps Creek subwatershed (2.90 km/km^2), which originates in the Tutela Heights Area, is substantially higher than that of the North Brantford subwatersheds. This reflects the high density of headwater features within the Phelps Creek subwatershed and the relatively impermeable silty clay surficial geology of the area.

The drainage density of the Fairchild Creek watershed is “extremely high in comparison to other areas of the Grand River watershed, indicative of high runoff rates and low groundwater recharge (ARI, 2009); … high runoff rates can be attributed to the relative impermeability of the clay plains” (MacVeigh et al., 2016). No quantitative drainage density values were found in background documents to enable comparison to the values presented in Table 2-4. Drainage densities for several Credit River tributaries were reported in Credit Valley Conservation (CVC, 2009) and ranged from 1.33 km/km^2 (Caledon Creek) to 1.92 km/km² (East Credit); values provided in Table 2-4 are generally similar or higher than those from the Credit River subwatersheds.

Table 2-4: Drainage Density Characteristics

	Subwatershed (Tertiary Area)			Boundary Expansion Area (Secondary Area)			Settlement Area (Primary Area)		
Watercourse / drainage network	Drainage area (km^2)	Total stream length	Drainage density (km/km^2)	Drainage area (km^2)	Total stream length	Drainage density (km/km^2)	Drainage area (km^2)	Total stream length	Drainage density (km/km^2)
North Brantford: Jones Creek									
Jones Creek	35.07	70.88	2.02						
Lower Jones Creek	22.13	46.19	1.94	14.32	41.89	2.93	11.22	36.49	3.25
Upper Jones Creek	12.61	24.60	1.95	1.28	2.62	2.05	0.52	0.73	1.40
North Brantford: Fairchild Creek Tributaries									
Karek Tributary North	1.03	2.81	2.72	1.03	3.26	3.17	1.01	3.26	3.22
Karek Tributary South	1.53	2.61	1.71	0.88	1.46	1.66	0.83	1.46	1.76
Silver Creek	6.52	7.73	1.19	0.67	1.84	2.75	0.65	1.84	2.83
Garden Ave. Tributary	14.13	29.02	2.05	1.84	2.48	1.35	0.73	1.02	1.40
Grand River Tributary (Tutela Heights)									
Phelps Creek	7.42	21.53	2.90	5.78	8.03	1.39	0.10	0.35	3.5
Note: Denotation of 'Not Applicable' (N/A) indicates that the watercourse does not occur within the identified spatial area.									

Stream Order and Bifurcation Ratio

The drainage network of any watercourse consists of both external (i.e., beginning of streams, no other channel flows into them – headwater drainage feature) and internal links (i.e., water flows into and out of them). External links of the drainage network are defined as the first surface drainage features that collect water and enable a connected pathway towards the main channel. These features may include shallow topographic depressions that become connected as a continuous channel only during high runoff events.

Stream order is a measure of the relative size of watercourses along a drainage network. Ephemeral swales that are connected to the drainage network only during precipitation events are often referred to as zero-order channels. Otherwise, external links (i.e., headwater channels) are assigned an order of one (1) within the Horton-Strahler stream order scheme. When two first order channels join, then the channel downstream of the confluence is a 2nd order channel. Similarly, when two 2nd order channels join, then the resultant channel is a 3rd order. This pattern continues along the entire drainage network.

Fairchild Creek, the receiving watercourse for North Brantford area watercourses, is a 5th order stream and is comparable to other watercourses of similar size in the lower Grand River watershed. Typically, systems of similar size range from 5th to 6th order channels, with the Grand River classified as a 7th order system. The relatively high concentration of zero and first order channels in both the North Brantford and Tutela Heights areas reflect the rather high density of headwater features within these areas.

Figure 2-28 provides a visual representation of the stream orders of each watercourse in the study area. The stream order of each watercourse that drains the North Brantford and Tutela Heights areas is provided in Table 2-5. Review of these values demonstrates that Jones Creek is a substantial tributary and contributor of flow and sediment to Fairchild Creek in North Brantford.

Table 2-5: Stream Order of Study Area Drainage Networks

Watercourse	Stream Order	Highest Stream Order in Boundary Expansion Area
North Brantford		
Jones Creek	4	4
Karek Tributary North	2	2
Karek Tributary South	2	2
Silver Creek	2	2
Garden Tributary	3	3
Tutela Heights		
Phelps Creek	3	3

Bifurcation ratio is the ratio of the number of streams of one stream order divided by the total number of streams in the next highest order and is sometimes referred to as the law of stream numbers. The higher the ratios, the more stream branches there are coming into a watercourse. Characteristics of the drainage network, like the drainage density, are highly influenced by subwatershed geology and climate. Typical bifurcation ratios reported by Horton (1945) and Strahler (1957) range from 2-4 and are generally around 3. Chorley (1969) suggests that values between 3 and 5 are typical for areas in Southern and Eastern Ontario where glacial deposits (e.g., till) comprise the overburden materials (Chorley, 1969).

The bifurcation ratios for North Brantford and Tutela Heights subwatersheds are provided in Table 2-6. Review of the table shows that Jones Creek, the Garden Avenue tributary and Phelps Creek exhibit the highest bifurcation ratio values for all stream order class comparison; they also exceed the expected average value reported in the scientific literature (i.e., between 2 and 4). The high bifurcation ratios reflect the role of the clay-based surficial geology within the study area (i.e., larger number of surface drainage features) and dendritic pattern of the drainage network. It is clear, from Table 2-6, that headwater features (1st and 0 order watercourses) play an important role in flow conveyance from the landscape.

High bifurcation ratios suggest that flows may be quickly routed from low order streams to the main tributary (higher order), which generally indicates a relatively rapid response to precipitation events and contributes to a higher peakedness in storm hydrographs in comparison to watercourses with lower bifurcation ratios.

Table 2-6: Bifurcation Ratios of Study Area Drainage Networks

	Subwatershed Area							Boundary Expansion							Settlement Area					
	Ratios by Strahler (1957) Stream Order Classes																			
Subwatershed	**Avg**	**5:4**	**4:3**	**3:2**	**2:1**	**1:0**		**Avg**	**5:4**	**4:3**	**3:2**	**2:1**	**1:0**		**Avg**	**5:4**	**4:3**	**3:2**	**2:1**	**1:0**
North Brantford																				
Jones Creek	9.24	3.01	12.59	12.29	17.68	0.62		8.38	3.01	15.56	11.29	11.67	0.36		9.02	3.01	15.38	7.11	10.56	
Karek Tributary North	1.09			1.81	0.37			1.10			1.81	0.37			1.08			1.79	0.37	
Karek Tributary South	1.30			1.33	1.27			1.22			1.33	1.10			1.22			1.33	1.10	
Silver Creek	2.58			5.32	0.81	1.60		1.99			1.99				1.95			1.95		
Garden Tributary	5.80	3.53	6.81	7.52	9.21	1.95		1.62		1.68	0.61	2.56			1.02				1.02	
Tutela Heights																				
Phelps Creek	5.38		5.66	12.30	3.56	0.01		5.50		2.58	11.04	2.87			0.35				0.35	

Drainage Network Profile

In natural watercourses, the profile of the channel adjusts to a downstream control point (e.g., lake level or downstream receiving watercourse), resulting in a concave up configuration with steep headwaters, a range of slopes through the middle, and gently slopes towards the outlet. These three zones typically correlate with sediment erosion, transport and depositional zones. While this is the 'classic model', if other control points exist (e.g., geologic outcrop, structure), then the profile may repeat the concave up profile and corresponding processes. When knickpoints (pronounced drops in elevation) occur in the profile (i.e., either as a control point, or human action) and if it occurs in erodible geologic materials, then it may be expected that headward retreat of the knickpoint will occur through time. Such information is useful when anticipating future channel processes. A profile was created, from LiDAR data, for Jones Creek and its dominant tributaries (Figure 2-29), and also for the main branch of Phelps Creek (Figure 2-30).

The Jones Creek profile (Figure 2-29), shows a subtle concave up profile, with a steeper profile in the upstream end, and shallower profile towards the downstream end; the profile steepens again towards the confluence with Fairchild Creek. This steepening may be in response to a long term lowering of Fairchild Creek, which acts as a base level control point for the Jones Creek profile. Knickpoints in the profile are evident in the north branch, Upper Jones Creek, Tributary D and Tributary O (See Figure 2-28). The knickpoint in Tributary D reflects the transition from tablelands into the Jones creek valley; the other knickpoints may reflect geologic variation along the channel.

The profiles of the tributaries (e.g. Tributaries D, H, K, O) reflect the topography of the area and the transition from table-lands into valley bottom. The high slopes associated with the tributaries suggest that they are a likely source of sediment to Jones Creek. The relatively low gradient of the main branch of Jones Creek and of Lower Jones Creek suggests that it has a low energy and reduced sediment transport capacity.

The Phelps Creek profile, through the Tutela Heights area shows a subtle concave up profile. Downstream of the southern Tutela Heights area boundary (i.e., at Phelps Road), two knickpoints in the channel bed profile are evident. These may coincide with local variations in geology. In addition to serving as local base level control points, knickpoints often migrate in the upstream direction, over time (i.e., if they are an erodible material).

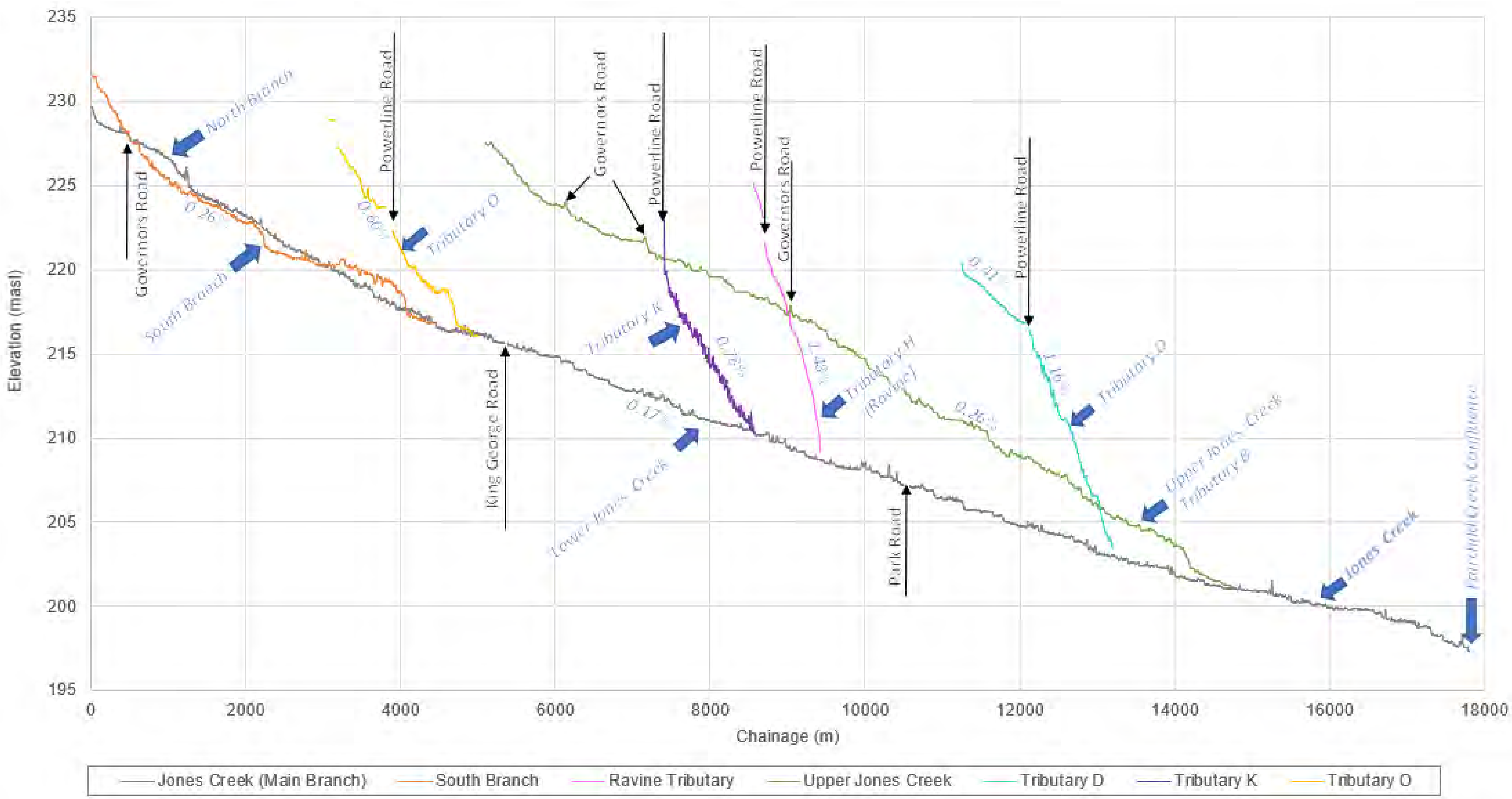


Figure 2-29: Profile of the Jones Creek Drainage Network in North Brantford

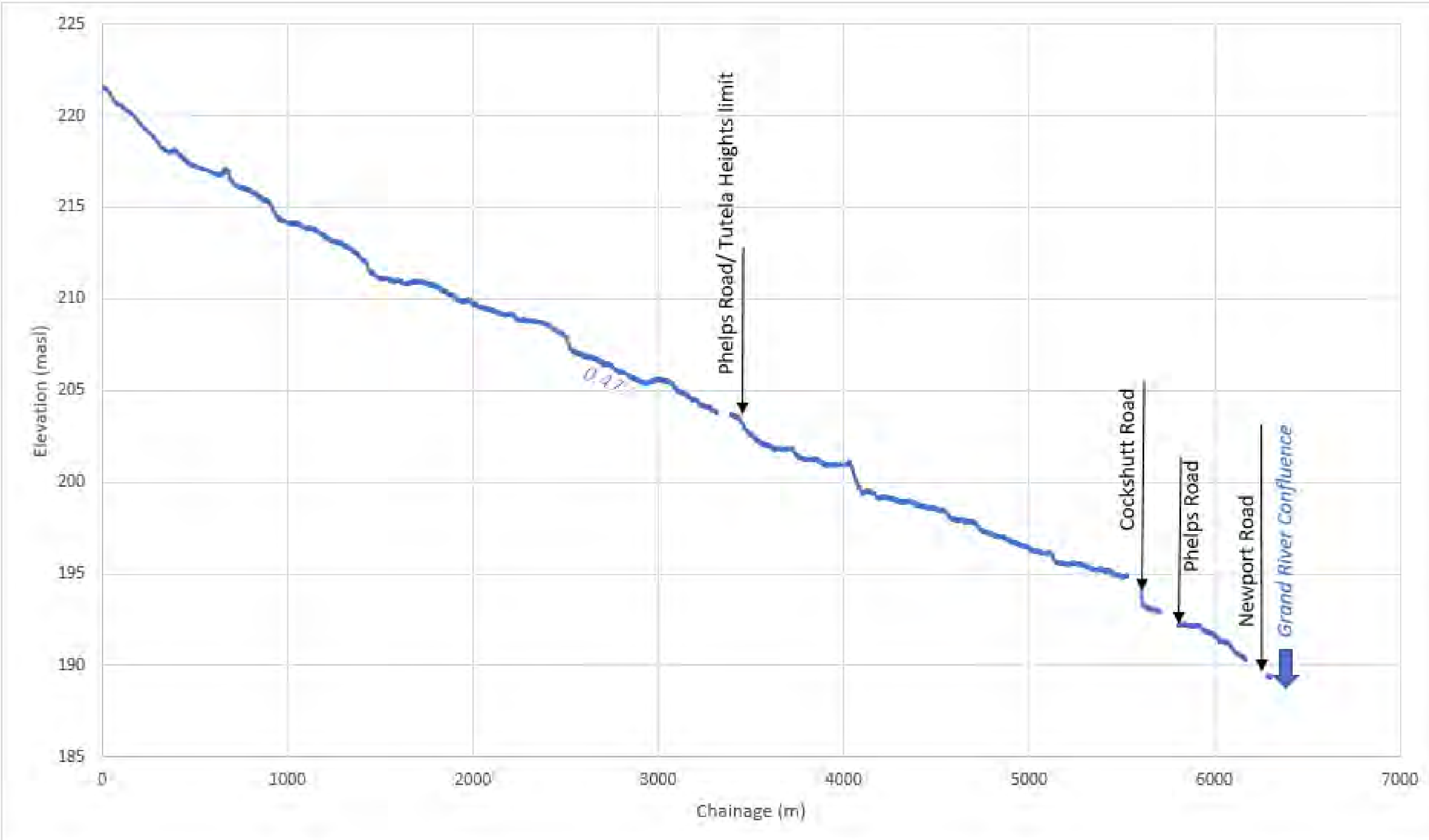


Figure 2-30: Profile of the Phelps Creek Drainage Network in, and Downstream of Tutela Heights

Stream Gradients

The gradient of a watercourse provides an indication of the overall setting in which the channel is situated. Steep watercourses are often indicative of incision into the landscape and may represent ravine forms that are sensitive to a change in hydrology. Low gradient watercourses are often indicative of flatter terrain in which a broader spatial footprint may be occupied by a watercourse.

As demonstrated in Figure 2-29, the profile of a watercourse and its tributaries vary along their length and do reflect the influence of topography. Variations in channel gradient influence hydraulic conditions within the channel (e.g., stream energy) and are linked to trends with respect to sediment transport. For example, when the channel gradient decreases abruptly (e.g., from tributary to main branch of Jones Creek as shown in Figure 2-29), then this could indicate a decrease in sediment transport competence or carrying capacity and a depositional environment.

The dominant gradients of Jones Creek and its tributaries are shown directly on Figure 2-29**;** the average grade of Phelps Creek is shown on Figure 2-30. GIS mapping of the gradients along the North Brantford and Tutela Heights watercourses is demonstrated in Figure 2-31. These gradients were used to support stream power calculations as discussed in the following section.

Stream Power

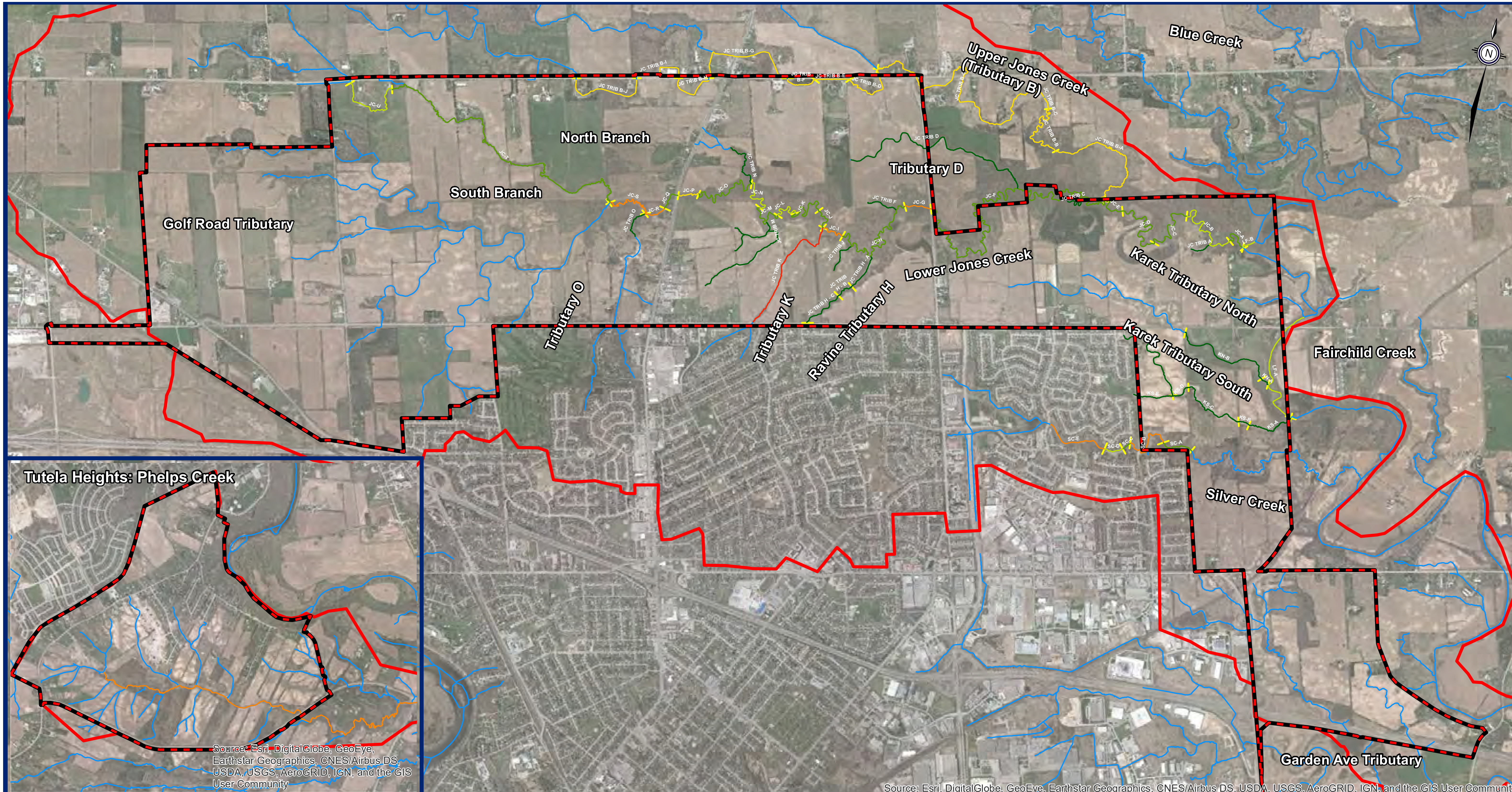
Stream power refers to the rate of energy dissipation against the bed and banks a watercourse per unit length of channel and provides indication of the potential for channel flows to perform geomorphic work. Geomorphic work refers to the transport or deposition of sediment and to overall processes of channel widening, incision or aggradation. Stream power is calculated as the product of the specific weight of water, discharge, and channel slope. Specific stream power refers to stream power per unit width of channel.

Various classification schemes exist that correlate stream type with stream power and are thus indicative of the processes occurring within the channel and the sediment load and supply characteristics necessary to sustain the stream type. The Nanson & Croke (1992) classification scheme has discretized channels into high, medium, and low energy systems. High values of stream power commonly correspond with steep, straight channels. Low stream power typically occurs in broad alluvial floodplains. When the stream power of flows is in proximity to a threshold number associated with a change in stream type, then adjustment in channel form from one type to another may occur. If the boundary materials and sediment supply are insufficient to sustain the new channel type, then instability will result. Such instability may occur when there are changes in discharge (e.g., from uncontrolled stormwater runoff) or changes in slope (e.g., channel straightening).

Specific stream power was calculated on a reach basis for the watercourses assessed during the geomorphic field reconnaissance, which include Jones Creek and its tributaries, and Silver Creek, both located in the northern study area. Input parameters to the specific stream power calculation included estimated 2-year flow along Jones Creek (See Section 2.7), average reach slopes, and measured channel widths. Flows for Silver Creek were estimated based on empirical relations. Stream power calculations completed for Phelps Creek were based on estimates of the 2-year flow developed by the study team (See Section 2.7). Stream power for study area watercourses are mapped on Figure 2-32**.**

Review of Figure 2-32 shows that the specific stream power along Jones Creek and its tributaries fall within a narrow range (i.e., < 10 W/ m^2). A value of 10 W/m^2 is defined by Nanson and Croke (1992) as a threshold for low energy systems and characteristics of cohesive floodplains in which channel development is largely governed by the vertical accretion of fine sediment deposits. This classification seems accurate for Jones Creek.

Review of Figure 2-32 further shows that the stream power of Tributary K (Figure 2-28) is high, reflecting the steep slope that is evident on the overall channel bed profile (Figure 2-29). Overall, the specific stream power through the Jones Creek and Silver Creek watersheds increases in the downstream direction. This trend is expected as it reflects the channel bed profile.



Study Area
Tertiary Study Area
Reach Break

Gradient (%)

0.00 - 0.03
0.04 - 0.18
0.19 - 0.27
0.28 - 0.36
0.37 - 0.64
0.65 - 1.09
Drainage Network

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Brantford Growth Plan

Figure 2-31
Watercourse Characterization
Watercourse Gradient

BluePlan
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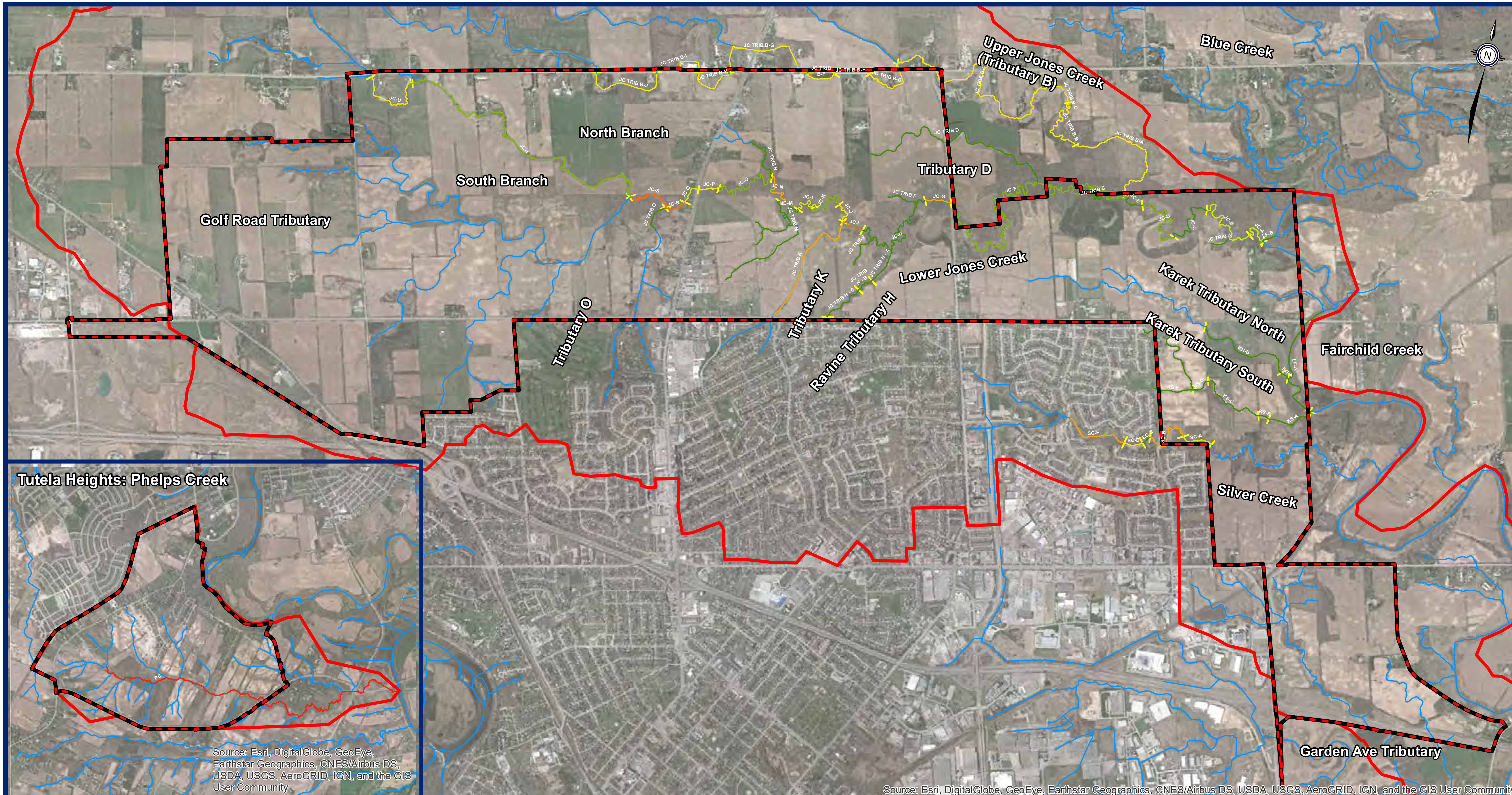


Brantford Growth Plan

Legend		Specific Stream Power (W/m²)	
Study Area		0.00 - 0.79	4.02 - 6.52
Tertiary Study Area		0.80 - 1.22	6.53 - 8.77
Reach Break		1.23 - 1.75	8.78 - 15.05
Drainage Network		1.76 - 4.01	

0 2 Kilometers

Figure 2-32
Watercourse Characterization
Specific Stream Power Mapping

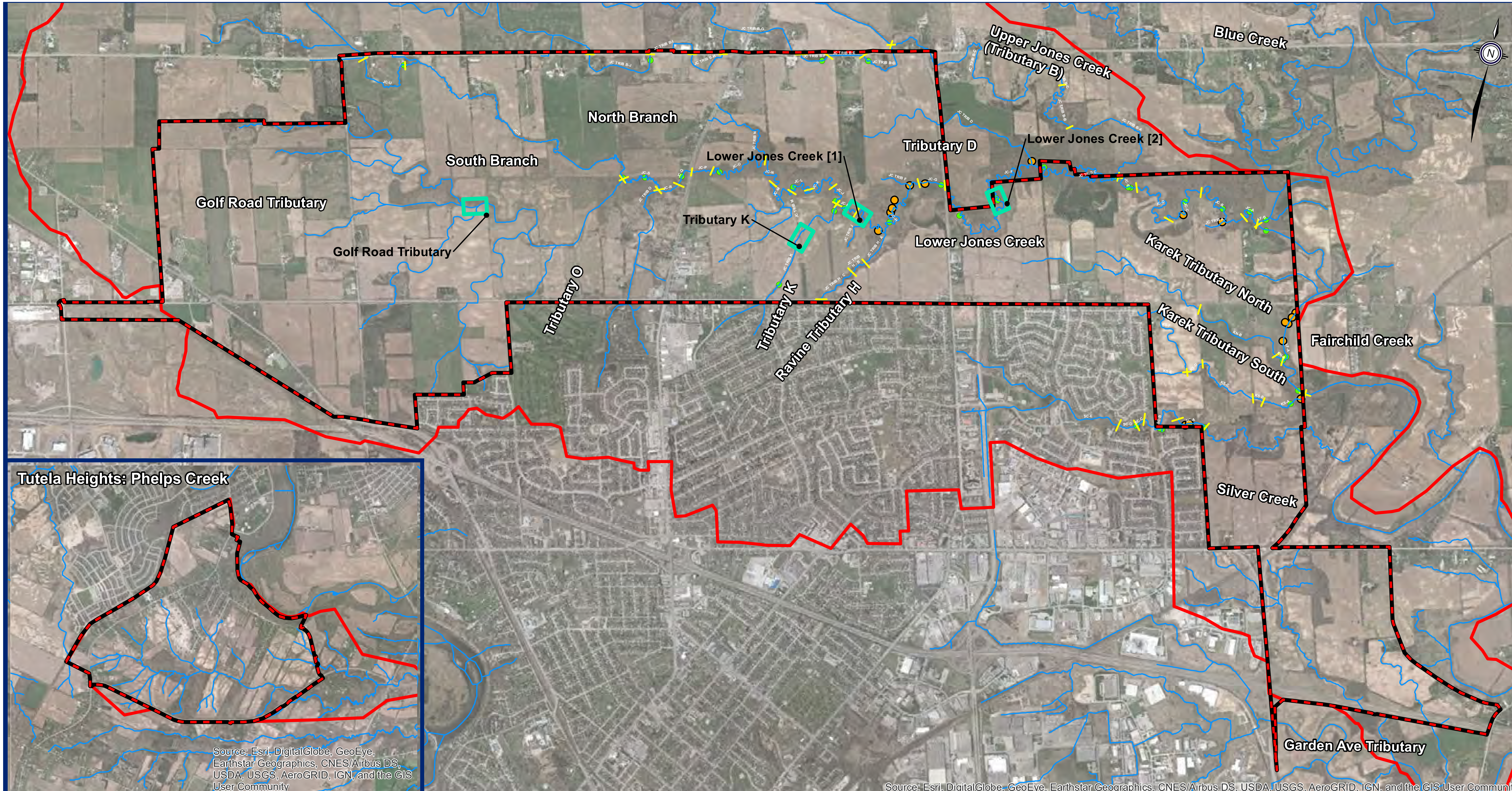
May, 2020
NAD 1983 UTM Zone 17N

2.8.4 Overview of Existing Channel Characteristics and Conditions

A reconnaissance level field investigation was completed for all watercourses within the subwatershed where access was granted by the landowner. The purpose of this field investigation was to gain general insight into the existing characteristics and conditions of the watercourses, and to identify the modifying and controlling influences acting within the systems.

Reaches were defined to facilitate the spatial documentation of watercourse conditions. Reaches are lengths of channel that are influenced by a relatively homogeneous set of controlling and modifying factors in such that the morphological form and processes occurring within the channel segment are similar. Thus, reach breaks typically occur where a change in channel setting (i.e., riparian vegetation, topography, geology) and/or channel form (i.e., planform and profile) occurs. Reach boundaries were first delineated through desktop analyses of aerial images and mapping; they were confirmed and refined during the reconnaissance level field walks. In total, 59 reaches were defined along the watercourses within the study area (Figure 2-33). All reaches were assigned a unique identifier reflecting their tributary and location along the system (e.g., JC – 1 = Jones Creek, Reach 1). Figure 2-34 provides an overview of the regulation status of the study area drainage networks.

During the reconnaissance field assessment, the length of each reach was walked and documentation of channel setting, channel geometry and substrate, observed seepage, and water quality (See Section 2.9.2) was completed. A photographic record of channel conditions was compiled and observations regarding channel functions and any controls or modifiers of channel form and connectivity to the floodplain were recorded. The overall channel stability and dominant channel processes (aggradation, degradation, widening, planform adjustment) were assessed through application of the Rapid Geomorphic Assessments (RGA) (MOE, 2003; See Appendix D-1 for detail regarding the RGA). Field observations and measurements were compiled into reach summaries and supplemented with desktop characterization of reach properties (length, grade, sinuosity); reach summaries are provided in Appendix D-1. An overview of channel conditions and observations is provided for each watercourse in the following sections. Results of the RGA results are mapped on Figure 2-35 and Figure 2-36.



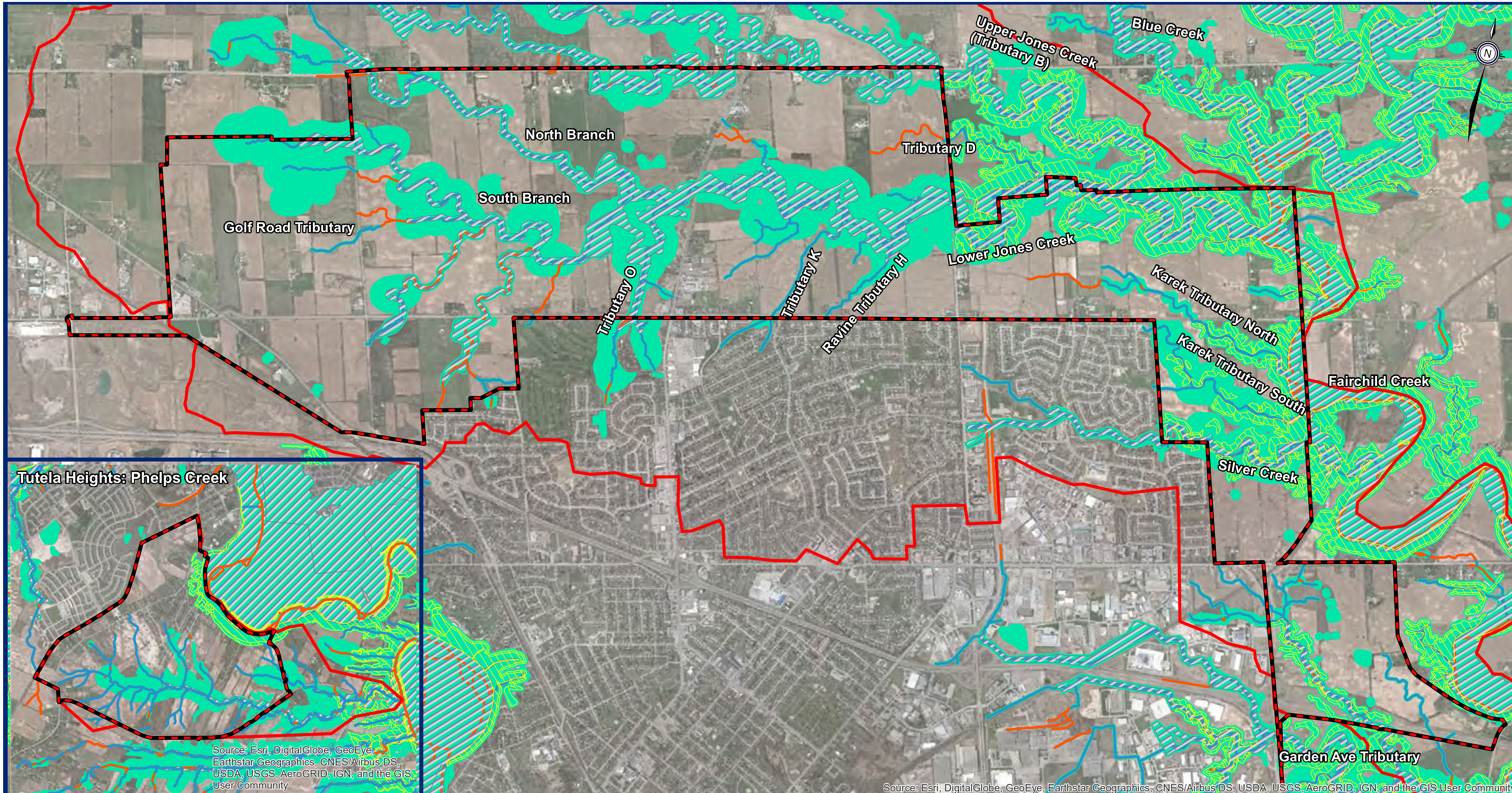
Brantford Growth Plan

- Study Area
- Tertiary Study Area
- Reach Break
- Seepage Observation
- Water Quality Sample
- Detailed Field Site Location

0 2 Kilometers

Figure 2-33
Watercourse Characterization
Reach Breaks and Detailed Field Sites

May, 2020
NAD 1983 UTM Zone 17N



Brantford Growth Plan

Study Area

Tertiary Study Area

Regulated Watercourse (Reg. 150/06)

Non-regulated

Regulated

Regulatory Floodplain (GRCA, 2018)

Regulation Limit (GRCA, 2018)

River Slopes and Erosion Allowance (GRCA, 2018)

0 2 Kilometers

Figure 2-34

Watercourse Characterization

Regulated Areas

May, 2020

NAD 1983 UTM Zone 17N

Fairchild Creek

Fairchild Creek is an intermediate sized (5th order) tributary of the Grand River watershed, draining an area of approximately 401 km^2 (MacVeigh et al., 2016). The creek generally flows from north to south, and flows into the Grand River downstream of Brantford, at Onondaga. Fairchild Creek is a low gradient, low energy channel which meanders through agricultural land use, with a riparian buffer dominantly comprised of forest and herbaceous vegetation

A short section of the middle portion of Fairchild Creek is located along the eastern limit of the North Brantford boundary expansion area. Two reaches were delineated during field investigations. A summary of the reach characteristics is listed in Table 2-7 with further details for each reach, including select photos, provided in Appendix D-1.

Table 2-7: Reach Characteristics of Fairchild Creek

Reach	Length (m)	Grade (%)	Geology	Riparian Vegetation	Substrate	Bed Morphology	Bankfull Width Range (m)	Bankfull Depth Range (m)
FC-A	1159	0.27	Modern alluvial deposits	Forest; herbaceous	Silty-Clay	Undulating	6.3 – 11.0	1.2 - 3
FC-B	128	0.25	Modern alluvial deposits	Forest; herbaceous	Silty-Clay	Undulating	5.0 – 11.0	1.8 – 2.6

In the North Brantford area, Fairchild Creek flows through a shallow valley with limited valley contacts. Evidence of terracing in the floodplain was considered indicative of long term downcutting and channel migration. Bank materials were consistently soft silty clay, representing a hydrated boundary condition in the lower banks. Channel banks were relatively steep and ranged from vegetated to unvegetated conditions. Slopes along the Fairchild Creek valley walls, in Reach FC-A, have been delineated as steep to over-steep (GRCA, 2018).

The channel cross-section throughout both reaches was generally symmetrical. The channel bed materials consisted of silty clay materials, like the banks. Benching along the toe of the banks was a common feature observed in Fairchild Creek. The bench, or shelf-like, features are typical of watercourses situated in cohesive boundary materials. The shelves were typically subaqueous and covered with a layer of ‘softer’ sediment (i.e., loose material into which a boot would ‘sink’) that appeared to have been deposited on these features. Firmer silty clay materials coincided with the thalweg alignment in the centre of the channel.

The bed morphology, which was submerged throughout the study area consisted of an undulating profile with limited variation in water depth; a deeper pool was observed along the outside of a meander bend. The water was turbid, reflecting the low energy of the reach and fine grained (silty clay) boundary materials.

Large woody debris (LWD) was observed in the channel, where water depth was relatively shallow. The LWD consisted of an accumulation of branches and smaller woody debris on the channel bed throughout both reaches. In Reach LF-A accumulation of gravel had begun to occur, locally, at some of the LWD.

Evidence of cattle access to the creek was observed along channel banks in Reach LF-A. A local area of concrete erosion control materials had been placed along private property in Reach LF-A, a short distance downstream of Powerline Road; some of this material appeared to be failing.

Jones Creek

Jones Creek, a tributary of Fairchild Creek, is a 4th order system which drains approximately 38.8 km^2. And is the predominant drainage network in the North Brantford area. The channel was delineated into 18 reaches along the main branch of the creek. The highly sinuous, low gradient channel flowed through a valley that was well vegetated with trees to approximately King George Road); agricultural or herbaceous-based riparian areas were dominant along upstream reaches of Jones Creek and along its tributaries. A large proportion of the valley slopes surrounding the main branch of Jones Creek, downstream of Park Road, have been delineated as steep to over-steep.

Tile drainage is common throughout the Jones Creek subwatershed (See Section 2.4**)**; most of the headwater drainage features are in tile drained agricultural fields. The main branch of Jones Creek is generally delineated as occurring within a regulated floodplain (Figure 2-34), with regulated wetlands along the channel; the main branch of Jones Creek is located within the Natural Heritage System.

The channel setting ranges with respect to valley confinement and floodplain connectivity. Variations in the channel which prompted reach breaks in Jones Creek were commonly due to changes in channel setting (confinement) and floodplain access, which was often manifested in variations in channel form and function. In total, 23 reaches were delineated along the main branch of Jones Creek and several tributaries (Figure 2-33). Reaches were not delineated along headwater drainage features; headwater features are discussed in Section 2.8.5. A summary of reach characteristics is provided in Table 2-8 with further details for each reach, including select photos, provided in Appendix D-1. Several reaches were excluded from the field assessment due to lack of landowner access permission (i.e., Reach JC-R, and portions of JC-F).

Table 2-8: Reach Characteristics of Jones Creek

Reach	Length (m)	Grade (%)	Sinuosity	Geology	Riparian Vegetation	Substrate	Bed Morphology	Bankfull Width Range (m)	Bankfull Depth Range (m)	RGA Stability	Dominant Adjustment Process
JC-A	290	0.18	2.17	Modern alluvial deposits	Trees; herbaceous	Silty-clay	Undulating	4.5 – 6	1.2 – 1.5	in adjustment	Degradation/ Widening
JC-B	844	0.23	2.06	Modern alluvial deposits	Trees; herbaceous	Silty-clay	Undulating	5.5 – 8	1.3 – 1.5	in adjustment	Degradation/ Widening
JC-C	664	0.04	1.61	Modern alluvial deposits	Trees; herbaceous	Silty-clay	Undulating	6.5 – 9	0.8 – 1.3	in adjustment	Aggradation/ Widening
JC-D	919	0.11	1.60	Modern alluvial deposits	Trees; herbaceous; grasses	Silty-clay	Undulating	5.0 – 6.0	1.0 – 1.5	stressed/ transitional	Aggradation/ Widening
JC-E	281	0.08	1.60	Modern alluvial deposits	Trees; herbaceous	Silty-clay	Undulating	9	1.5	in adjustment	Aggradation/ Widening
JC-F	4241	0.15	2.06	Modern alluvial deposits	Trees; herbaceous; grasses	Silty-clay	Undulating	7 – 8	1.1 – 1.25	stressed/ transitional	Aggradation
JC -G	209	0.57	0.96	Modern alluvial deposits	Herbaceous	Silty-clay	Undulating	5	1.5	stressed/ transitional	Aggradation
JC-H	1515	0.05	1.96	Modern alluvial deposits	Trees; herbaceous	Silty-clay	Undulating	4.5 – 9.0	0.8 – 1.4	stressed/ transitional	Aggradation/ Widening
JC-I	229	0.60	1.30	Modern alluvial deposits	Trees; herbaceous	Silty-clay	Undulating	3.5	1.1	stressed/ transitional	Degradation/ Widening

Reach	Length (m)	Grade (%)	Sinuosity	Geology	Riparian Vegetation	Substrate	Bed Morphology	Bankfull Width Range (m)	Bankfull Depth Range (m)	RGA Stability	Dominant Adjustment Process
JC-J	222	0.16	1.67	Modern alluvial deposits	Herbaceous	Silty-clay	Undulating	1.9 – 2.4	0.7	stressed/ transitional	Aggradation
JC-K	620	0.16	2.61	Modern alluvial deposits	Trees; herbaceous	Silty-clay; some cobble	Undulating	8.0	0.9	stressed/ transitional	Degradation
JC-L	339	0.24	1.89	Modern alluvial deposits	Trees; herbaceous	Silty-clay; gravel; cobble	Riffle-pool	6.0 – 8.0	0.8 – 1.1	stressed/ transitional	Degradation
JC-M	451	0.07	2.65	Modern alluvial deposits	Herbaceous	Silty-clay	Undulating	4.0 – 5.0	0.6 – 1.0	stressed/ transitional	Degradation/ Widening
JC-N	443	0.19	1.88	Modern alluvial deposits	Trees	Silty-clay; cobble (angular)	Riffle-pool	6.0	0.5	stressed/ transitional	Degradation/ Widening
JC-O	613	0.17	1.38	Modern alluvial deposits	Trees	Silty-clay; gravel; cobble	Riffle-pool	5.0 – 9.0	0.6 – 0.9	stressed/ transitional	Degradation/ Planform
JC-P	249	0.36	1.06	Modern alluvial deposits	Trees; herbaceous	Silty-clay; fine gravel; sand	Undulating	4.3	0.6	Stable/ in-regime	Degradation/ Widening
JC-Q	348	0.12	1.46	Modern alluvial deposits	Manicured lawn	Silty-clay; fine gravel	Undulating	3.4 – 3.5	0.4 – 1.1	N/A	N/A
JC - R	601	0.56	1.82	Modern alluvial deposits	Trees; herbaceous			Permission to complete assessment of surface water features was not received			

Reach	Length (m)	Grade (%)	Sinuosity	Geology	Riparian Vegetation	Substrate	Bed Morphology	Bankfull Width Range (m)	Bankfull Depth Range (m)	RGA Stability	Dominant Adjustment Process
JC-S	192	0.64	1.10	Modern alluvial deposits	Grasses; herbaceous	Silty-clay	Riffle-pool	3.2 – 4.0	0.5 – 0.6	Stressed/ transitional	Degradation/ Widening
JC-T	164	0.09	1.07	Modern alluvial deposits	Herbaceous; cropped land	Silty-clay; till (firm)	Undulating	2.4 – 4.5	0.7 – 1.1	Stable/ in-regime	Degradation
Ravine Trib.	852	1.52	1.10	Silt / Clay	Trees; herbaceous	Silty-clay; soil	Dry	Dry	Dry	N/A	N/A
Trib. K	1163	1.09	1.14	Silt / Clay	Herbaceous; cropped land	Silty-clay; till (firm)	Sculpted clay	1.8 – 2.8	1.5 – 2.5	Stressed/ transitional	Degradation/ Widening

Beginning at the confluence of Fairchild Creek, Jones Creek Reaches JC-A and JC-B appeared to have incised into the floodplain as demonstrated by the high banks and disconnected floodplain setting; this is supported by the channel profile slope shown in Figure 2-29. The general floodplain connectivity improved in the upstream direction and it became evident that characteristics of reaches JC-C and JC-D recurred alternately along Jones Creek.

Reach JC-C demonstrated evidence of floodplain scour, included relic channel features (e.g., meander scars), and chute formation (i.e., scour channel formed during overbank flows), suggesting a relatively dynamic/active planform development. Meander scars are evident on LIDAR mapping of the channel corridor. The floodplain occupation and scarring are expected when a reach is characterized by lower channel banks and greater floodplain access. The processes are supported by the stream type classification as discussed in Section 2.8.3 Stream Power. Similar channel conditions and evidence of active planform adjustment and channel floodplain setting was observed in other upstream reaches along Jones Creek and was therefore considered to be a representative reach type along the main branch of Jones Creek.

Reaches that were similar in characteristics to Reach JC-C alternated with reaches that were like Jones Creek Reach JC-D. Reach JC-D exhibited higher channel banks, and therefore, reduced floodplain access and displayed indicators of channel incision. Floodplains along this reach included less evidence of floodplain scour and dynamic planform activity. Accumulation of LWD was observed in the channel and the rooting network of vegetation exerted a stabilizing influence on bank materials.

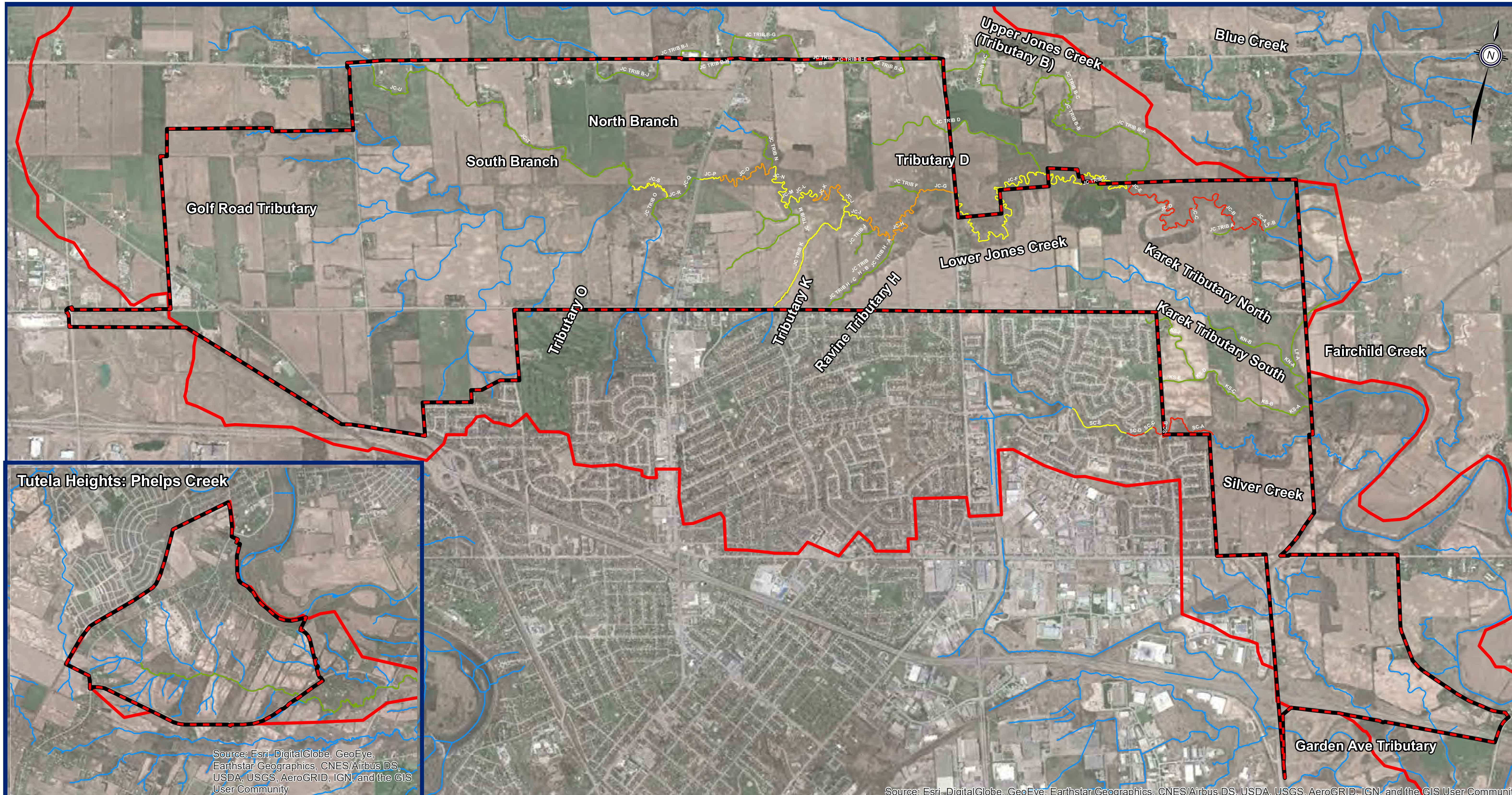
Overall, Jones Creek exhibited a relatively low width: depth ratio and a submerged undulating bed morphology. The boundary materials (bank and bed) were consistent with those observed in Fairchild Creek, and were comprised primarily of silty clay. Well defined gravel riffles were rare along Jones Creek; the first gravel emergent riffle, occurred in Reach JC-L (i.e., first riffle recorded when walking upstream from the outlet at Fairchild Creek). Sources of gravel and cobble materials within banks was limited and observed locally in Reaches JC – L, JC-N, JC – O. Hydraulic roughness within Jones Creek was often due to LWD in the channel.

Bench-like features were observed along the toe of banks throughout much of the channel; an accumulation of loose or ‘softer’ fine grained material was deposited on these benches; firmer substrate occurred along the thalweg alignment.

Two locations within the Jones Creek subwatershed (Reach O and Tributary K) exhibited exposed firm glacial till (diamicton) that underlay the silty clay materials that was observed throughout the rest of the Jones Creek drainage network. Exposure of the till in Reach O was localized; in Tributary K, the till exposure extended along the entire length of channel. Where exposed, the till was ‘sculpted’ and very stiff/firm. A similar exposure of till was observed along Silver Creek. Tributary K was deeply (e.g., 3 m) incised into the floodplain and was steep, confirming the gradient trend observed on Figure 2-29. Erosion and slumping of the channel banks/valley walls were prevalent. Tile drains outlet into the channel. A narrow vegetative buffer extended along the top of the bank that separated the channel corridor from agricultural land use; proximity of land use to the top of bank could affect bank stability. A culvert and stone embankment occurred across the creek, enabling machinery access between fields on both sides of the incised channel.

The field assessment confirmed that many of the headwater drainage features that discharged into Jones Creek were dry; several tributaries appeared to be indirectly linked to the main branch of Jones Creek (e.g., ravine tributary lost definition along its downstream length and was not well defined at the confluence to Jones Creek). The ravine tributary included areas of standing water and may be more properly classified as a headwater drainage feature.

Results of the Rapid Geomorphic Assessment (RGA) assessment for Jones Creek are summarized in Table 2-8 and illustrated in Figure 2-35 and Figure 2-36**.** Results show that Jones Creek is generally ‘stressed’ (See Appendix D-1 for further explanation) and that areas of higher stress occur downstream of tributary confluences; these tributaries convey stormwater discharge from the urban Brantford area. Degradation of channel conditions occurs downstream of the Upper Jones tributary confluence and coincides with the lower reaches that have incised into the landscape. The dominant adjustment process observed along Jones Creek was long term degradation and channel widening. Observations of aggradation reflect more contemporary processes.



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Brantford Growth Plan

Study Area

Tertiary Study Area

Drainage Network

Rapid Geomorphic Assessment - Channel Stability

0.000000 - 0.210000

0.210001 - 0.310000

0.310001 - 0.400000

0.400001 - 0.600000

0 2 Kilometers

Figure 2-35

Watercourse Characterization

Rapid Geomorphic Assessment

GM BluePlan

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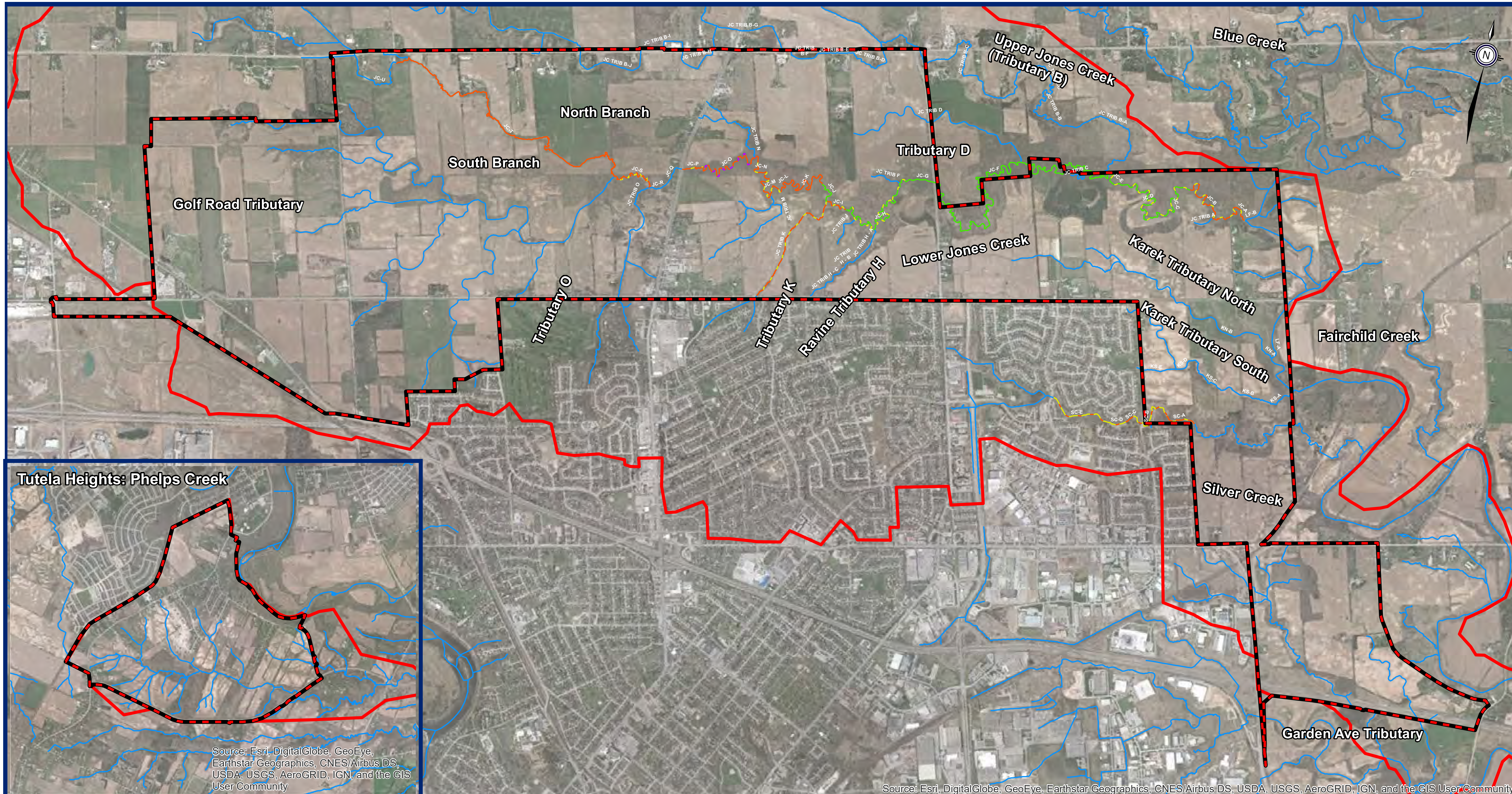
May, 2020

NAD 1983 UTM Zone 17N



Study Area

Tertiary Study Area

Drainage Network

Dominant Reach Scale Channel Processes

Aggradation

Aggradation / Widening

Degradation

Degradation / Planform

Degradation / Widening

Widening / Degradation

0 2 Kilometers

Brantford Growth Plan

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Figure 2-36

Watercourse Characterization

Dominant Reach Processes

May, 2020
NAD 1983 UTM Zone 17N

Silver Creek

Silver Creek is a tributary of Fairchild Creek and is in the southeastern portion of the North Brantford area. The channel is a 2^{nd} order stream which originates from roadside ditches along Wayne Gretzky Parkway in Brantford. Field investigations of the channel extended from upstream to downstream of the urban development, where property access was granted.

Silver Creek was delineated into five (5) reaches (Table 2-9**;** Figure 2-33); Reaches SC-A and B were situated downstream of the urban limit and Reaches SC-C, D and E were within the urban channel corridor. Within the urban channel corridor, the creek appeared to have been straightened; downstream of the urban limit, the planform configuration appeared to have been minimally altered and the channel had a highly sinuous, meandering planform that flowed through forested and herbaceous vegetated floodplain.

Table 2-9: Reach Characteristics of Silver Creek

Reach	Length	Grade (%)	Sinuosity	Geology	Riparian Vegetation	Substrate	Bed Morphology	Bankfull Width Range (m)	Bankfull Depth Range (m)	RGA Stability	Dominant Adjustment Process
SC-A	281	0.14	1.10	Modern alluvial deposits	Trees	Till/clay; fine gravel; sand	Riffle-pool	5.2 – 6.1	1.3 – 1.7	In adjustment	Degradation/ Widening
SC-B	533	0.58	1.21	Modern alluvial deposits	Trees; herbaceous	Till/clay; sand	Riffle-pool	5.2	1.4	In adjustment	Widening/ Degradation
SC-C	79	0.08	1.00	Modern alluvial deposits	Trees; herbaceous	Till/clay; sand	Riffle-pool	6.6	1.5	Stressed/ transitional	Degradation/ Widening
SC-D	163	0.25	1.01	Modern alluvial deposits	Trees; herbaceous	Till/clay	Riffle-pool	5.2	1.4	In adjustment	Widening/ Degradation
SC-E	569	0.49	1.14	Modern alluvial deposits	Trees; herbaceous	Till/clay; sand	Riffle-pool	5.2	1.2	Stressed/ transitional	Widening/ Degradation

Along Reaches SC-A and B, Silver Creek was situated in a ravine-like setting, with steep valley walls and evidence of incision. Boundary materials consisted of three stratigraphic layers: sculpted firm grey till (basal unit; diamicton), brownish relatively firm silty clay, and a mixture of dark soil with silt and clay (top unit). This stratigraphy was like that observed in portions of Jones Creek (Reach O and Tributary K), perhaps suggesting that the underlying till layer is more common throughout the study area than previously identified in surficial geology mapping. Discolouration of the stratigraphy was observed between the till and clay units which may indicate groundwater seepage between the different geologies. Downstream of the pedestrian bridge crossing (from Ludlow Crescent to Hackney Ridge) the riverine slopes surrounding Silver Creek have been identified as steep; this was confirmed during field investigations. The channel is located within the Natural Heritage System.

The watercourse exhibited evidence of active incision and widening, with slumped blocks of vegetated bank commonly deposited throughout the channel, considered to be cantilever-like failures from the top of the banks. Trash lines from high flows were identified along the channel banks, occurring approximately 1.5 m above the channel bed. In the most downstream section assessed (Reach SC - A), multiple channels have been carved into the firm underlying till layer. Here, the channel slope was relatively steep, with a cascade-pool-like profile. Upstream, the active flow channel occupied the bottom of the ravine more consistently. Throughout the channel, deposits of sand and fine gravels were observed, commonly occurring in crevasses or depressions within the sculpted till channel bed; most of the deposits were “soft”. Riffle-pool features have been developed through the erosion of underlying till, with finer sediment deposited in riffle features.

Upstream of the pedestrian bridge crossing (Reach SC - C), the channel banks become more stable and vegetated, and there was less evidence of channel bed and bank scour. More extensive deposition of fine sediment was observed on the channel bed as lobate and medial bars. The channel was connected to a shrub vegetated floodplain. Evidence of water taking from the creek was observed.

Results of the RGA assessment for Jones Creek are summarized in Table 2-9 and illustrated in Figure 2-35 and Figure 2-36**.** Results show that Silver Creek is generally ‘in adjustment’ or ‘stressed’ (See Appendix D-1 for further explanation). This condition is likely attributable to the effect of urban hydromodification within the watershed. The dominant adjustment processes observed along Silver Creek were long-term degradation and channel widening.

Garden Tributary

The Garden Tributary (Figure 2-33) is a relatively small watercourse located in the southeastern portion of the Boundary Expansion Area (BEA). The tributary is likely ephemeral, demonstrating little to no flow conditions during field assessments in the headwaters of the system. The feature outlets to Fairchild Creek south of Highway 403. Due to insufficient existing data and lack of property access, the Garden Tributary and its drainage features were not assessed during field investigations.

Phelps Creek

Phelps Creek (Figure 2-33) is a relatively small 3rd order channel located in the Tutela Heights boundary expansion area. The watercourse extends from the confluence with the Grand River westward to Tutela Heights. The drainage system is comprised of several first and second order features which make up the dendritic drainage network of Phelps Creek. Following the assessment of Phelps Creek headwater drainage features, it appears that the riparian vegetation through the area is primarily that of herbaceous plans, and some areas of wetlands along the drainage features. Due to insufficient existing data and lack of property access, the main branch of Phelps Creek was not assessed during field investigations.

2.8.5 **Headwater Drainage Features and Assessment**

Headwater drainage features (HDF) differ from downstream reaches by their close coupling to hillslope processes and greater temporal and spatial variation (Gomi et al., 2002). Although small, HDF can provide important functions within the surface water network and can account for 70-80 % of total drainage network length (Meyer et al, 2003). Variability among HDF is demonstrated through a diversity of feature definition, dimensions, and physical characteristics, and a diversity of processes and responses that occur within headwater features. Headwater drainage features are often ephemeral or intermittent.

Specific roles attributed to headwater features include (Dunne and Leopold, 1978; Schollen et al., 2006; TRCA, 2007; Stanfield and Jackson, 2011; OHI, 2016) (See Appendix D-2 for further discussion):

- Hydrograph moderation through flow attenuation and storage;
- Production zone of sediment and flow (Schumm, 1977);
- Excess sediment storage;
- Groundwater recharge potential;
- Contribution of organic energy inputs that sustain aquatic biota and contribute to the productivity of the downstream watercourse (Wallace et al. 1997);
- Nutrient retention and uptake (Alexander et al. 2000, Peterson et al. 2001);
- Strongest association between terrestrial and aquatic environments (Schlosser, 1991);
- Temperature moderation;
- Habitat for terrestrial and aquatic species and biota (Morse et al, 1993); and
- Seasonal contribution to biota habitat (CVC and TRCA, 2014).

Identification of HDF was based on a review of available surface drainage mapping from GRCA, aerial photography, and field identification. Within the Settlement Area boundary expansion lands, there are approximately 48 km of headwater drainage features (HDF); approximately 36 km in the North Brantford area, and 12 km in the Tutela Heights area. HDF represent approximately 63% of the overall drainage density in North Brantford area and 75% in the Tutela Heights area. These percentages fit within the range identified by Meyer et al. (2003).

The Toronto and Region Conservation Authority (TRCA) and Credit Valley Conservation (CVC) (2014) Headwater Drainage Feature Guideline document was used to evaluate, classify, and develop management recommendations for all HDF that were included in the Settlement Area field program. Inclusion in the field program was based on landowner permission to access properties for completing surface water feature assessments. The details of the headwater drainage feature assessment, including methodology and management recommendations, are provided in detail in Appendix D-2**.** An overview of the HDF is provided in this section of the report.

The HDF assessment followed the ‘Rapid Method’ of evaluation (TRCA and CVC, 2014) which was considered appropriate for a secondary plan scale of study. This evaluation method requires that each feature be assessed with respect to feature type, hydrologic function, and riparian vegetation conditions during prescribed field observation events based on anticipated soil moisture content associated with snowmelt, early spring, and summer conditions (see Table 2-10).

Three field sample events were completed to examine the condition of each identified HDF feature (Table 2-10. The timing of the assessments is generally prescribed in the Ontario Stream Assessment Protocol (OSAP S4. M10; 2017). Photos were collected and features documented and georeferenced in the field, using digital data collection software (Epicollect 5).

Table 2-10: HDF Sampling Events

Sample Event	Time	Requirements (OSAP S4. M10)
1	April 23, 24, 27, 2018	Assessment following an extended warm period that enables frost to leave the ground; surface flows from recent rain or melt conditions are sufficient to generate bankfull flows; vegetation has yet to establish in riparian areas. Typically, this occurs in late winter and spring; weather patterns in 2018 extended these conditions into late April; this was confirmed by GRCA.
2	June 4 & 11, 2018	Preferably prior to leaf out, with at least three days of no precipitation. Note: weather conditions in early spring delayed leaf out condition into late May – early June.
3	August 13, 2018	Following at least three days without a significant (i.e., flow generating) precipitation event.

While all features should be assessed in the first sampling event, inclusion in subsequent events depends on observed field conditions. In total, 24 km of headwater drainage features situated within the North Settlement Area, and 3 km within the Tutela Heights Settlement Area were identified and assessed at least once in 2018; the timing of landowner permission determined the completeness of the HDF assessment (i.e., not all features were assessed in the first sampling event, and some were not assessed at all, within the Settlement Area).

Based on observations made during the field assessment, the HDF were evaluated and classified based on feature type (Table 2-11), hydrologic function, and riparian vegetation conditions as required under the Rapid Method of HDF assessment (CVC and TRCA, 2014) (See Appendix D-2 for classification and results). Due to a lack of property access for all sample events, the HDF assessment is considered incomplete for some features as discussed further in Section 4**.** Preliminary management recommendations have been developed and are included in Appendix D-2; as noted, these are preliminary and incomplete at this time.

The aquatic and terrestrial habitat classification processes of the headwater drainage feature assessment were not completed since no specific alterations are yet proposed for the study area. Further investigation of the headwater features is required to confirm the aquatic and terrestrial habitat conditions of the study area.

Table 2-11: HDF Classification Categories for Rapid Method of Assessment

HDF Classification Categories	Description
Feature Type	• Defined natural channel; • Channelized or constrained; • Multi-thread; • No defined feature; • Tiled; • Wetland; • Rills; • Swale; and • Roadside ditch
Hydrologic Classification	This is determined by the relative importance of biotic feature function which considers the flow condition and feature type of a headwater drainage feature. The classification considers the highest or most significant feature function observed during the three sampling events. Appendix D-2 provides details regarding the hydrological classification process and the results pertaining to the headwater drainage features within the study area.
Riparian Vegetation Classification	The riparian vegetation conditions associated with headwater drainage features also influences the management decisions for a feature. Like the hydrologic assessment, the highest or most significant function provided by the vegetation type is considered. Appendix D-2 provides details regarding the riparian classification process and the results pertaining to the headwater drainage features within the study area.

At the outset of this study, the two unnamed tributaries of Fairchild Creek that occur in the southeastern portion of the northern boundary expansion area were included in the reach assessment, based on watercourse mapping. These tributaries were delineated as the North and South Tributaries; these flowed through the Karek family property prior to discharging into Fairchild Creek (Figure 2-33). When site inspection was undertaken, the tributaries were identified as headwater drainage features. As more substantial HDF features within the study area, a description is provided below.

Karek Tributary South

The south unnamed tributary is a poorly defined channel system that was dry during the field assessment. The feature, delineated as a 2nd order system based on watercourse mapping, is predominantly a wetland feature that is situated within the Natural Heritage System. At the downstream end of this tributary, an ill-defined channel meandered through dense shrubs and grasses; the outlet to Fairchild Creek was elevated above the channel bed of Fairchild Creek. The feature was delineated into six reaches. A large knickpoint in the landscape is located at the boundary between Reach B and Reach C. Upstream of the knickpoint, the feature is largely a broad depression with wetland type vegetation including cattails and grasses which grow throughout the feature. At the upstream limits, the two branches of the feature originate at uncontrolled stormwater outfalls. The landowner situated along this tributary indicated that, since upstream development, a portion of the land has become undevelopable for agriculture due to prolonged moist conditions along the channel.

Karek Tributary North

The unnamed tributary of Fairchild Creek is a 2nd order feature that was delineated into two reaches. A relatively defined channel setting exists at the downstream limit of the feature (Reach A). Here, exposed roots and bank scour indicated concentration of flows and erosional processes. Moving upstream into Reach B, the channel definition ended, and the feature becomes a broad meadow-like feature. Located in a grazing pasture, the feature is trampled, with grass vegetation throughout the reach.

2.8.6 Detailed Field Site Inventory

Detailed field investigations were completed at four (4) sites within the study area in October and November 2018 (See field site locations on Figure 2-33**)**. Results from the detailed field site investigation will provide context as to ongoing channel processes and functions and will offer insight as to impacts from future development. Furthermore, the inventory will provide baseline conditions for future monitoring of the tributaries assessed. Field sites were selected with consideration of diversity of channel form, previous impact, and on the perceived sensitivity of the reach to future land use changes. The field assessments included channel bed profile surveys, cross-sections, substrate and bank material characterization, and instantaneous flow measurements. A summary of results is provided in Table 2-12; detailed field summaries are provided in Appendix D-3**.**

Through review of the field data, insight into existing conditions within the Jones Creek drainage networks, in the North Brantford study area was gained. A brief overview of key findings is provided below. No field sites were established in the Tutela Heights area.

Table 2-12: Summary of Channel Dimensions and Substrate at Detailed Field Sites

	Lower Jones Creek (Golf Road Tributary) (upstream)	Lower Jones Creek (Golf Road Tributary) (downstream)	Tributary K	Jones 1	Jones 2
Reach	HDF	HDF	-	JC-H	JC-F
Sample Date	Oct 11, 2018		Oct 10, 2018	Nov 15, 2018	Nov. 19, 2018
Survey length	158		114	215	130
Number of cross-sections	7		9	8	9
Cross-section					
Bankfull Width (m)	6.02	3.10	1.82	6.01	5.84
Max. Bankfull Depth (m)	0.39	0.52	0.48	1.21	1.34
Avg. Bankfull Depth (m)	0.25	0.37	0.31	0.72	0.84
Width: Depth (m/m)	24.14	8.33	6.49	8.44	7.05
Bankfull Area (m^2)	1.51	1.16	0.56	4.38	4.89
Hydraulic Radius (m)	0.24	0.33	0.22	0.62	0.73
Wetted Width (m)	3.49	2.06	0.89	3.36	3.40
Max. Water Depth (m)	0.14	0.15	0.15	0.57	0.59
Avg. Water Depth (m)	0.14	0.15	0.10	0.37	0.59
Wetted Width: Depth	51.00	25.90	14.88	9.13	10.68

(m/m)					
Wetted Perimeter (m)	3.48	2.21	1.06	3.95	4.06
Substrate (mm) **D5** **D50** **D90**	Soft fine sediment	Soft fine sediment	5 20 50	Soft fine sediment	Soft fine sediment
Low flow measurements					
Discharge (m^3/s^{-1})	-	-	-	0.06	0.12
Avg. Flow Velocity (m/s)	-	-	-	0.11	0.09
Hydraulic Calculations					
Bankfull Gradient (%)	0.26	0.56	0.60	0.03	0.10
Bankfull Discharge (m^3/s^{-1})	0.85	0.97	0.54	2.25	4.00
Est. Bankfull Velocity (m/s)	0.98	1.07	1.01	0.87	1.39
Total Stream Power (W/m^2)	21.66	53.39	32.90	6.63	39.26
Unit Stream Power (W/m)	3.60	17.25	18.11	1.10	6.72
Shear Stress (N/m^2) **Maximum** **Average**	9.94 6.38	28.56 20.45	29.39 19.05	3.57 2.13	13.18 8.23

Lower Jones Creek – Golf Road Tributary

A field site was placed along this watercourse since it was considered a dominant headwater feature during the HDF assessment (Section 2.8.5). Active flow was observed to be flowing into the feature during the first HDF assessment for this site (April 2018). Given the volume of water in the channel, and the large channel dimensions, the watercourse first appeared to be a perennially flowing feature. Through subsequent field assessments, it became apparent that Lower Jones is an HDF and that the dimensions likely reflect agricultural management practices to enable drainage from the adjacent fields. The feature serves as a sink for fine sediment that is washed from the agricultural fields; establishment of vegetation within the channel further traps sediment and may also provide a water quality enhancement function (e.g., limited shade, nutrient uptake). The channel lacked diversity with respect to cross-sectional and profile configurations.

The field site was separated into an upstream and downstream section, straddled around the confluence of a well-defined HDF tributary. Evident in Table 2-12 is a notable difference in channel grade and channel dimensions. Analysis of bankfull flow capacity may reflect the input of water from the HDF feature; the flow estimate is larger than provided by GMBP based on their Storm Water Management Model (SWMM) for the study area (See Section 2.7); the flow estimate would reflect the human modifications made to the drainage feature, resulting in a higher than bankfull flow capacity.

Tributary K

Tributary K is situated downstream of the existing northern limit of development and receives uncontrolled stormwater flow. The downstream Powerline Road culvert is perched above the channel bed. From the culvert outlet to its confluence with Jones Creek, the channel has incised into stiff/firm till materials. A field site was placed along this watercourse to enable monitoring and further future assessment to inform erosion control management and better understand the effect of urban discharge into the Jones Creek drainage network.

From the desktop analyses, it was apparent that the stream power of Tributary K is the highest of all active watercourse estimated stream power within the Jones Creek Drainage network (Figure 2-32); the RGA assessment findings of a stressed watercourse with dominant degradation (bed lowering) and channel widening processes is consistent with all field findings. Indeed, review of the channel bed profile in Appendix D-2 clearly shows that the Tributary K channel bed is approximately 3 m lower than the table lands. Tributary K could therefore be more properly classified as being situated in a ravine. The configuration and characteristics of the tributary reflect the development history of the area.

During bankfull flows, the shear stress exerted within the channel cross-section is sufficient to enable entrainment of ~ 0.04 m sized sediment. It is likely that this grain size is moved during bankfull flows due to the generally smooth channel bed underneath the accumulations of gravel (i.e., less resistance to movement). Since the channel is situated in a ravine like setting, the energy associated with larger than bankfull flows generally remains within the cross-section; this will exacerbate any existing channel processes. This, in conjunction with the limited source of gravel sized sediment in the channel banks supports the continuous degradation process of the channel and limits the channel's ability to self-repair and establish a stable configuration.

Lower Jones Creek Site 1 (Reach JC - H)

This field site is situated downstream of Tributary K and occurs along a meandering portion of channel. Through the RGA assessment, the reach along which the field site is situated was classified as stressed with the dominant adjustment process of aggradation identified. The depositional or aggradational tendency of this reach may reflect the sediment input from Tributary K. That is, the gradient of this reach and the estimated stream power are much less than in Tributary K; this suggests a reduction in sediment transport conveyance potential. The sediment aggradation tendency may also reflect sediment transport processes typical of cohesive boundary channels (See Section 2.8.8)

Defining a bankfull stage was difficult for the field site, given the relatively smooth banks. Measurements of cross-section geometry suggest that the creek may be oversized for the flow predicted to be conveyed through the study area (See Section 2.7). The relatively large cross-sectional area, for the predicted flows (Section 2.7) may reflect a water storage function along Lower Jones Creek. That is, due to the low gradient, a larger cross-section is needed to convey the flows.

The channel bed profile was defined by undulations resembling a sequence of submerged riffles and pools (See Profile in Appendix D-3); no emergent riffles were observed. Both the bank and bed boundary materials consisted of silty clay. No source of gravel was observed in the field site. The entire field site seemed to have very slow-moving flow that resembled a backwater condition – no weirs or obstructions were situated within Lower Jones Creek, based on the reach level reconnaissance walks.

Lower Jones Creek Site 2 (Reach JC - F)

Lower Jones Creek Site 2 is situated downstream of Park Road and is a sinuous meandering watercourse. Through the RGA assessment, the reach along which the field site is situated was classified as stressed with the dominant adjustment process of aggradation identified. While no specific source of sediment was identified for Site 2, the aggradational tendency of this reach likely reflects the reflect sediment transport processes typical of cohesive boundary channels (Section 2.8.8) The low grade and correspondingly low energy conditions will also contribute to the aggradational tendency of this channel and the sediment transport processes.

The entire field site seemed to have very slow-moving flow that resembled a backwater condition – no weirs or obstructions were situated within Lower Jones Creek, based on the reach level reconnaissance walks. The low bankfull gradient estimated for this reach, based on estimated bankfull elevations, is low, confirming the low water surface grade observed.

The cross-sectional area was only slightly larger for Site 2 than Site 1. Like Site 1, defining a bankfull stage was difficult for the field site, given the relatively smooth banks. Measurements of cross-section geometry suggest that the creek may be oversized for the flow predicted to be conveyed through the study area (See Section 2.7). The relatively large cross-sectional area, for the predicted flows (Section 2.7) may reflect a water storage function along Lower Jones Creek. That is, due to the low gradient, a larger cross-section is needed to convey the flows.

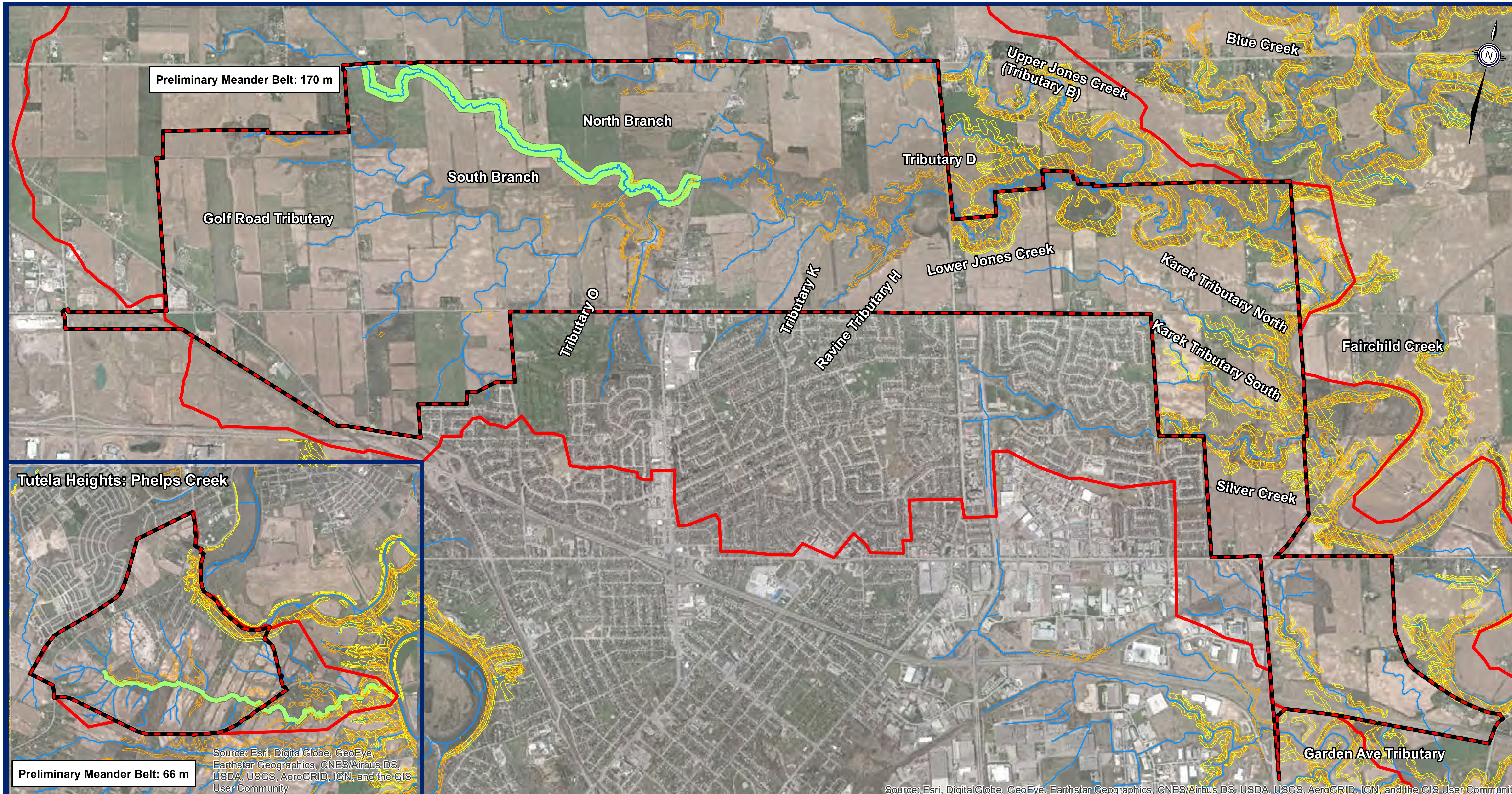
The relatively large cross-section may also reflect a long-term downcutting tendency. Given the cohesive boundary materials, and different channel processes, compared to alluvial channels, replacement of material that has been removed from the channel bed is complex. Along the study area, and this reach, few, or no, sources of gravel material were observed along channel banks. The cohesive boundary condition has enabled an undulating bed morphology to develop; no emergent coarse-grained riffles were observed.

2.8.7 **Erosion Hazards (Confined and Unconfined Settings) and Thresholds**

Channel Corridor Delineation - Confined / Altered Systems

When a watercourse is situated in a valley setting, then the lateral movement of a watercourse may be restricted by the valley walls. MNR (2002) defines a confined system as a watercourse which is located within a valley corridor, where valley slopes are discernable. For such systems, MNR (2002) requires a toe erosion allowance, stable slope allowance, and an erosion access allowance to be delineated for the system. GRCA (2018) has identified areas with steep slopes which fall under the erosion hazard requirements of a confined channel system. Review of the available geodata created by GRCA demonstrates that Jones Creek and its tributaries to the east of Park Road, in the North Brantford Area have been delineated with a “River Slope Erosion Allowance” (Figure 2-37). From review of topographic data, extension of the river slope erosion allowance should be extended west of Park Road.

The delineation of these hazards would have been based on high level analyses and stable slope assumptions. In support of any future land development planning initiative, delineation of the River Slope Erosion Allowance hazard should follow accepted protocols such as those outlined in MNRF (2002) and as required by GRCA. Typically, the delineation requires geotechnical assessments to determine a stable slope line. A toe erosion access allowance may need to be determined, and a 15 m setback from the stable top of slope line applied.



Brantford Growth Plan

Study Area
Tertiary Study Area
Drainage Network
River Valley Slopes (GRCA, 2018)
River Slopes and Erosion Allowance (GRCA, 2018)
Preliminary Meander Belt

0 2 Kilometers

Figure 2-37
Watercourse Characterization
Meander Belt Width and River Slopes

May, 2020
NAD 1983 UTM Zone 17N

Meander Belt

Erosion is a natural process that occurs along all natural watercourses. When the erosion, through planform migration, interacts with the anthropogenic landscape, then the erosion may become a hazard. The meander belt of a watercourse refers to the spatial extent which a channel currently occupies or may occupy in the future as it develops its planform configuration and migrates freely across its floodplain. The meander belt area is considered to envelop all channel functions and processes (i.e., erosion and deposition) which interact with the surrounding landscape. The meander belt is typically used to define the spatial limit of erosion hazards; development is not permitted within the meander belt. The meander belt is determined for unconfined or partially confined well-established watercourses (e.g., valley wall on one side of the creek corridor that limits lateral migration) and is not directly used for confined watercourses (see Channel Corridor Delineation – Confined/Altered Systems).

For the purposes of this subwatershed study, the meander belt for all unconfined reaches defined along Lower Jones Creek, in the North Brantford area, was estimated, based on high level planform analyses (Figure 2-36). Meander belts were delineated for unconfined watercourses which exhibited defined channel bed and banks, and perennial or intermittent flows with downstream connectivity. The meander belt was not estimated for Tributary K, given its deeply incised condition and its 'ravine' or valley like setting. A meander belt was also not estimated for HDF; defining a corridor for HDF should consider whether the position of the watercourse is driven by erosion forces or determined based on other site factors. Verification/refinement of the meander belt is typically undertaken at a secondary or site plan level of study followed accepted methods of analysis.

The meander belt has not been defined for the Tutela Heights Area since it was not located in the primary study area.

Erosion Thresholds

Erosion thresholds (discharge, velocity) are typically determined to inform stormwater management. The erosion threshold of the North Brantford and Tutela Heights watercourses has not yet been determined. Quantification of an erosion threshold typically applies to the most sensitive reach within a zone of influence downstream of a proposed stormwater management facility. When quantifying the erosion threshold of study area watercourses, consideration must be given to the non-alluvial erosive processes that are relevant to cohesive materials. That is, typical methods of sediment entrainment and transport analyses, of the sensitive fraction of substrate materials, may not apply. The complexity of cohesive boundary material erosion must be recognized and considered in the quantification of erosion thresholds within the study area.

2.8.8 Channel Processes and Functions

Through the desktop and field assessments completed for this study, insight into channel conditions, functions and processes have been gained, and gaps in understanding identified. This section provides a brief discussion of the study understanding that has been established. The summary is focused primarily on the North Boundary area, since the field assessments of Phelps Creek in the Tutela Heights was limited. Many of the channel processes may apply to Phelps Creek; this requires confirmation through field assessment.

An annotated profile has been developed that provides a spatial representation of existing conditions (Figure 2-38). Review of this profile enables linkages to be made between different aspects of the fluvial geomorphic assessment. For example, the channel stability bar graph, in reference to the profile, demonstrates a general downstream decline in channel stability; this may reflect a downstream cumulative impact and response to changes in sediment loading and/or hydrology from contributing tributaries. The annotated profile also demonstrates a shift from overall channel bed lowering/degradation processes to a more dominant aggradational process; the aggradation/deposition may reflect inputs from tributaries and deposition of upstream derived sediment.

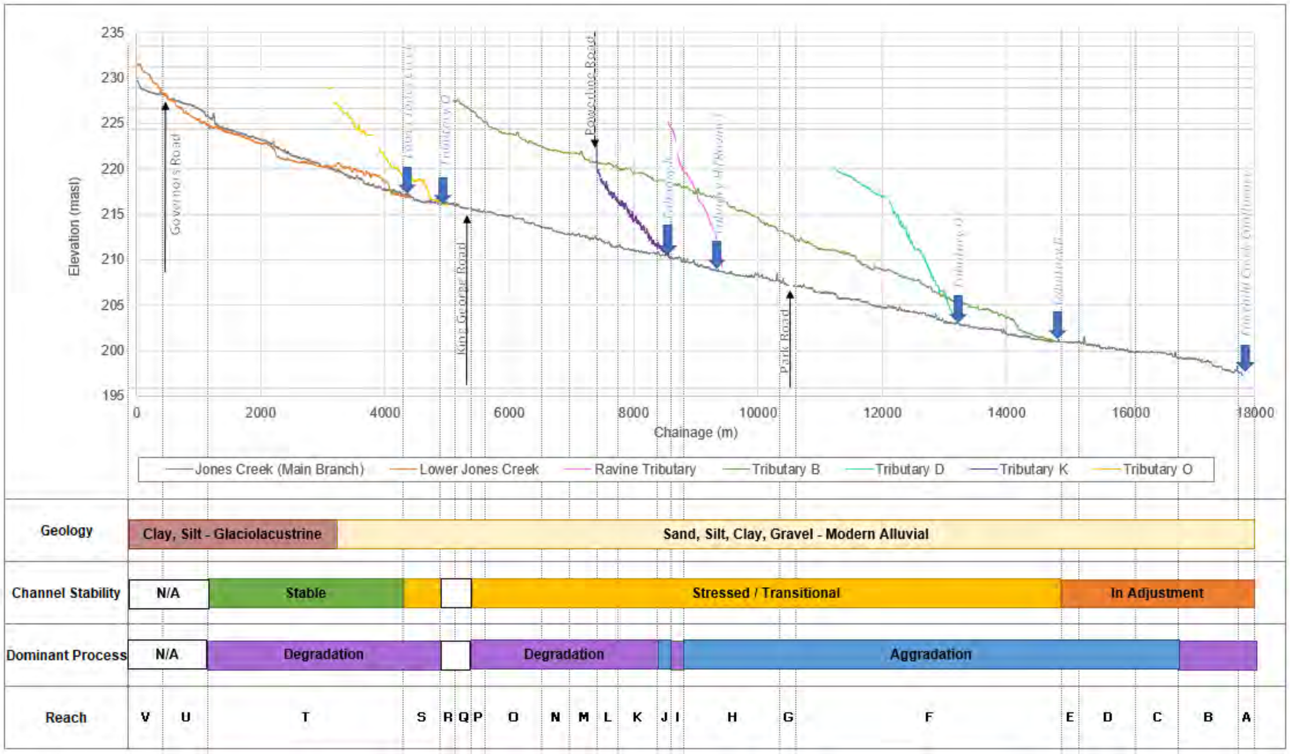


Figure 2-38: Annotated Jones Creek and Drainage Network Profile

Boundary Materials

As outlined in Section 2.8.2, boundary materials exert an important influence on channel conditions and processes. In the North Brantford study area, there is a general lack of gravel and cobble sized source material available along the channel corridor that would, in other watercourses, provide the building materials for riffle features. The exceptions occur locally in Reaches JC- L, JC-N, JC – O where limited gravel sized sediment was observed in thin units within the bank stratigraphy. The general lack of gravel sized sediment has implications for the physical habitat that the watercourses can provide for aquatic species.

Jones Creek Tributary K and Silver Creek have incised into a firm/stiff till (diamicton) unit. A local area of Reach JC-O exhibited the till unit as well. Within the fine-grained matrix, gravel sized sediment was observed. It is likely that the till unit underlies the silty clay sediment observed along the creek corridor; confirmation would occur through geotechnical borehole assessment.

Cohesive Boundary Materials

Cohesive boundary watercourses are not alluvial and thus channel forming processes differ from alluvial channels. Indeed, Nanson and Croke (1992) who developed a genetic classification of floodplains based on the relation between a stream's ability to entrain and transport sediment and the erosional resistance of floodplain alluvium that forms the channel boundary, identify low-energy cohesive (silt and clay) floodplains as a distinct floodplain class. In general, this classification appears fitting for Jones Creek and its drainage network which include the following description (Nanson and Croke, 1992):

- Specific stream power at bankfull is < 10 W/m^2
- The floodplains are usually associated with laterally stable single-thread or anastomosing channels
- Low stream power may be a function of low slope
- Floodwaters readily spill onto the floodplain.
- Bank resistance is high because of the fine-grained cohesive composition which inhibits lateral migration
- Floodplains develop by vertical accretion of fine-grained deposits and infrequent channel avulsion.

Evidence of historical planforms and floodplain scour were observed on topographic data (LIDAR), and during the reach assessment of Jones Creek (Section 2.8.4**)**

With respect to sediment transport and depositional processes, the scientific literature identifies various factors that influence these processes. A summary is provided in Table 2-13. Based on this, and similar information, the 'soft' layer of sediment that was observed on the 'benches' along the bank toe, in Jones Creek, is depositional. Further, establishing erosion thresholds to inform erosion controls for stormwater management is complex (note: erosion thresholds reported in the literature are recommended to be developed through jet testing).

Table 2-13: Overview of Erosional and Depositional Processes of Cohesive Materials

Source	Key Findings
Utley and Wynn, 2008	• Chemical interaction between the soil pore water and the eroding fluid • Cohesive soils erode as aggregates, therefore intrepid bonding is important • The erosion resistance of cohesive soils is affected by changes in the amount and physical state of soil pore water. • Significant increases in soil erodibility have been correlated to freeze-thaw cycling • For cohesive soils, critical shear stress (of erosion) is difficult to predict accurately there is no precise definition of critical shear stress of cohesive soils and soil properties

	• Prediction of fluvial entrainment rates based on soil physical properties has had limited success. • Soils with a plasticity index of less than 10 are classified as cohesionless.
Van Dijk, et al., 2013	• The effect of cohesive silt on bank stability was tested and showed that an increase in silt reduced erosion rates by a factor of 2 • Overbank flow led to deposition of silt and two styles of cohesive floodplain were observed: 1) overbank, vertical-accretion of silt and (this led to a reduction of bank erosion) 2) lateral point bar accretion with silt on the scrolls and in swales (this reduced excavation of chutes). • Sedimentation of fine cohesive material on the floodplain by discharge exceeding bankfull is a necessary condition for meandering.
Grabowski et al., 2011	• Clay minerals are less than 2 µm and are the most electrochemically active portion of sediment; they are responsible for the sticky, cohesive nature of mud. • Particles smaller than 1 µm represent the colloidal fraction of clay minerals; they do not readily settle out of suspension. • Clay minerals have high surface area to volume ratios and carry strong electro-chemical charges. • Clay minerals coagulate; the presence of organic material and microbes facilitate the development larger aggregates through flocculation • Cohesive sediment is generated by the deposition and consolidation of suspended sediment; the processes of flocculation and coagulation occur in the water column • Cohesive mud is more difficult to erode than silt or sand.
Huang et al., 2006	<u>Deposition</u> • For clay, interparticle forces, not gravitational forces, dominate the behaviour of sediment; settling velocity is no longer a function of only particle size. • Cohesive sediment consists of inorganic minerals and organic material. • Cohesive sediment is linked to water quality; pollutants such as heavy metals, pesticides and nutrients preferentially adsorb to cohesive sediment; the turbidity caused by the sediment can restrict penetration of sunlight and affect aquatic light. • Cohesive sediment can bind together (aggregate) to form large, low density units (i.e., flocs); flocs grow when they collide with other particles or other flocs. • Floc structure determines the settling velocity; settling velocity increases with sediment concentration up to a maximum value • Deposition (of flocs) is controlled by the bed shear stress, turbulence processes in the zone near the bed, settling velocity, depth of flow, type of sediment etc. <u>Erosion</u> • Parameters affecting erodibility include: clay content, water content, clay type, temperature, bulk density, pore pressure • When soils contain > 10% clay, clay particles will assume control of soil properties. • Electrochemical factors affect erodibility
Partheniades, 2009	• When sediment concentration is between 300 – 10,000 ppm, increased collisions between particles results in larger aggregates with higher settling rates and shear strength; they can deposit faster. • Flocs formed in fresh water were found to become larger and structurally complex with increasing clay concentration in suspension.

Channel Alteration and Hydromodification

As noted in Section 2.8.2, the land use changes that have occurred within the North Brantford and Tutela Heights study area have resulted in changes to the drainage network, hydrologic regime, and sediment loading of the study area watercourses. When a change in flow and/or sediment regime occur, the equilibrium form of a channel may become unbalanced; in response, the watercourse adjusts to regain a sense of equilibrium.

Straightening of channel planforms results in a loss of channel length and a decrease in sinuosity; both of which will lead to an increase in channel gradient, drainage efficiency and modification of hydrologic routing thereby affecting the hydrograph of receiving watercourses.

The loss of surface channels, and the creation of an artificial drainage network of tile drains and stormwater pipes increases the drainage efficiency of a catchment area. Through the artificial drainage system, water is routed more quickly to a receiving watercourse, contributing to an increase in peak flow and a decrease in time-to-peak. This effect is exacerbated when the volume of surface runoff increases due to impervious area and no stormwater management controls are in place. When the frequency of flows and flow magnitude increases, then erosion in may become exacerbated. It is likely that the uncontrolled discharge into Tributary K and Silver Creek has contributed to their incised condition.

Based on a review of historical air photos for the study area, it appears that Tributary K was not visible in 1954. It is possible that, with the discharge of uncontrolled urban runoff since before the 1980s, that Tributary K has incised into the landscape over the last ~ 40 years. The eroded sediment would have been delivered to Jones Creek. Results of the desktop analyses and Reach level RGA assessment suggest that the energy of Jones Creek, downstream of the Tributary K confluence is low and that the area was identified as aggradational. Given the low slope of Jones Creek, it appears that its capacity to move sediment is limited, contributing to the overall aggradational tendency of the watercourse.

When both the slope of a watercourse and the magnitude of flows conveyed through it increases, a substantial increase in stream power occurs. As a result, the observed stream type may no longer be sustainable under the new energy conditions and the channel becomes stressed and/or begins adjustments towards establishing a new stream type. Both Jones Creek Tributary K and Silver Creek are likely examples of this process.

Sediment Loading

Prevalent along the main branches of Jones Creek and Fairchild Creek in the North Brantford area was the occurrence of 'soft' sediment situated on the channel bed and toe of bank. While 'soft' sediment may be the result of sediment hydration at the sediment-water interface, it is more likely that the sediment is depositional. This assertion is based on a review of cohesive boundary channel deposition and erosion processes as summarized in Table 2-13. A predominant factor that influences the depositional tendency of Jones Creek is the low gradient along the main branch and low stream power.

Given the steep gradient of the tributaries (see profiles in Figure 2-29) in comparison to the main branch of Jones Creek (i.e., Lower Jones), and the known condition of Tributary K, the tributaries are a source of sediment to Jones Creek. It is expected that Silver Creek is likewise a source of sediment to Fairchild Creek in the North Brantford Area.

Within the North Brantford area, numerous rills and gullies were observed in the landscape. While some of these features were discontinuous, others were directly connected to the active drainage network. The rills and gullies provide a source of sediment to the watercourses. With land development, these features are typically removed from the landscape.

Water Storage

In the North Brantford area, following spring melt and after precipitation events, accumulation of water occurred in shallow depressions within the landscape. These features provide temporary storage of water and delay its arrival in receiving watercourses and/or enable shallow groundwater recharge. With land development, these features are typically removed from the landscape, but can be replicated.

Headwater Drainage Features

As noted in Section 2.8.5, HDF represent approximately 63% of the overall drainage density in North Brantford area and 75% in the Tutela Heights area. This is a substantial proportion of the drainage network. Appropriate management strategies should be in place to support the healthy functioning of both Jones Creek and Phelps Creek in the future that emulate the existing hydrograph characteristics.

Drainage Efficiency

Results of the drainage network and morphometric characterization (Section 2.8.3) suggested that due to the generally clayey soils, the drainage density and bifurcation ratios were relatively high. This typically means that water accumulates as surface runoff and is conveyed efficiently to the main branch of a watercourse. The profile of the Jones Creek drainage network (Figure 2-29) showed that the gradient of tributaries was much steeper than of the main branch of Jones Creek. Likewise, the stream power of the main branch was very low. These characteristics suggest that while water may be relatively efficiently drained from the landscape, the routing of this water through Lower Jones Creek may be delayed. Indeed, results of the detailed field site assessments indicated that, for the given flows (Section 2.7), the cross-section capacity appeared to be over-sized. Further, evidence of floodplain access/overtopping flows was observed along Lower Jones Creek, suggesting that water is inefficiently drained from this portion of the drainage network.

This notion of inefficient water may be supported by anecdotal observations provided by landowners. Landowners along Lower Jones Creek and the Karek Tributaries both indicated that, since upstream urbanization, the drainage of certain lengths of channel appear to be less efficient. This has resulted in longer duration of wet fields along the channel corridor and/or loss of productive agricultural land.

Physiography

The gradient of Lower Jones Creek is low. This has implications for the rate of channel change and response to disturbances within the watershed. The gradient also influences the energy available for sediment transport and efficiency of flow conveyance. As noted above, the low energy grade of Lower Jones Creek in North Brantford likely contributes to the aggradational tendency of the watercourse in that area. Similar trends may occur along other study area watercourses.

2.8.9 **Data Gaps**

Based on the geomorphic assessment completed, the following data gaps have been identified:

- Stream power assessment along all watercourses within the North Brantford and Tutela Heights area was limited due to the scarcity of hydrologic data. Further assessment will provide insight into energy conditions and sediment transport capabilities within each watercourse.
- Field assessments were focused along Lower Jones Creek as a focus within the primary and secondary study areas. Further assessment and documentation of existing conditions within the overall Jones Creek drainage network should be undertaken to complete the subwatershed understanding.
- HDF assessments were incomplete due to a lack, or delay in, property access permission through the study areas. The most substantial gap occurs in the Tutela Heights area and along the Garden Avenue tributary.

- There is a general lack of hydrologic flow estimates for the study area; this would be beneficial to verify field-based calculations and support further system understanding.
- Sediment load from Jones Creek was identified as a dominant source of sediment to Fairchild Creek. Boundary material erosion and depositional processes are not well understood, due to the fine grained (silt, clay) and cohesive nature of the materials. Monitoring of suspended sediment loading along the drainage network and further analyses will provide insight into the sediment load contribution to Fairchild Creek and should identify mitigation measures to enable enhancement of existing conditions.
- Establishment of erosion thresholds requires further understanding and consideration of the cohesive boundary erosion processes.
- In the North Brantford area, delineation of the River Slope Erosion Allowance appears to be incomplete. The appropriateness of extending this allowance to the Jones Creek corridor west of Park Road should be reviewed.
- The mapping of regulated features (Figure 2-34) should be reviewed and updated. That is, some watercourses such as Fairchild Creek, in North Brantford, are shown as unregulated; given the size of this watercourse, regulation is expected. Likewise, some headwater drainage features are shown as regulated, but are virtually non-existent in the landscape. Updated mapping is recommended, by GRCA, to support future studies and provide guidance to future land development planning processes.
- Physiographic mapping does not appear to accurately reflect channel boundary materials and should be confirmed; borehole data will enhance the study area understanding of erodibility and source materials for channel processes.
- Field investigations along Phelps Creek in the Tutela Heights area were limited to scoped HDF assessments; reconnaissance level reach assessments would provide further insight into channel processes occurring in this area.

2.9 Water Quality, Aquatic Life, and Fish Habitat

2.9.1 Water Quality

Water quality parameters influence the aquatic life within the waterbodies. Critical factors for fish include water temperature, dissolved oxygen, shelter, food, habitat variety, suitable substrate, and adequate stream flow. Many factors including biological, chemical and physical characteristics can influence water quality within a watercourse; this includes climate, soil type, geology, flow conditions, vegetation, runoff sources (point and non-point source), groundwater inputs, timing of year, surrounding land use, pollution, among others.

For most large watercourses within southern Ontario, background records of water quality parameters are available from previous studies; unfortunately, few water quality data records exist for North Brantford (Jones Creek, Silver Creek, Garden Avenue tributary, and Fairchild Creek) or Tutela Heights (Phelps Creek).

During the reconnaissance level field assessment of geomorphic reaches, locations of observed groundwater seepage were mapped, and spot measurements of select water quality parameters were compiled (See Figure 2-39**).** Water quality parameters were collected with a Hanna HI98130 and included pH, electrical conductivity/total dissolved solids and temperature instrument; this was supplemented with data from an YSI Ecosense DO and Temperature Meter. Factors that may contribute to the measured values of water quality parameters include water depth, substrate, and wetted width; these were recorded for each geomorphic reach (see Section 2.8.4.). The water quality measurements, channel geometry, substrate characterization and reach photos are provided in reach summaries in Appendix D-1. No water quality parameters were measured within Phelps Creek due to a lack of property access permission.

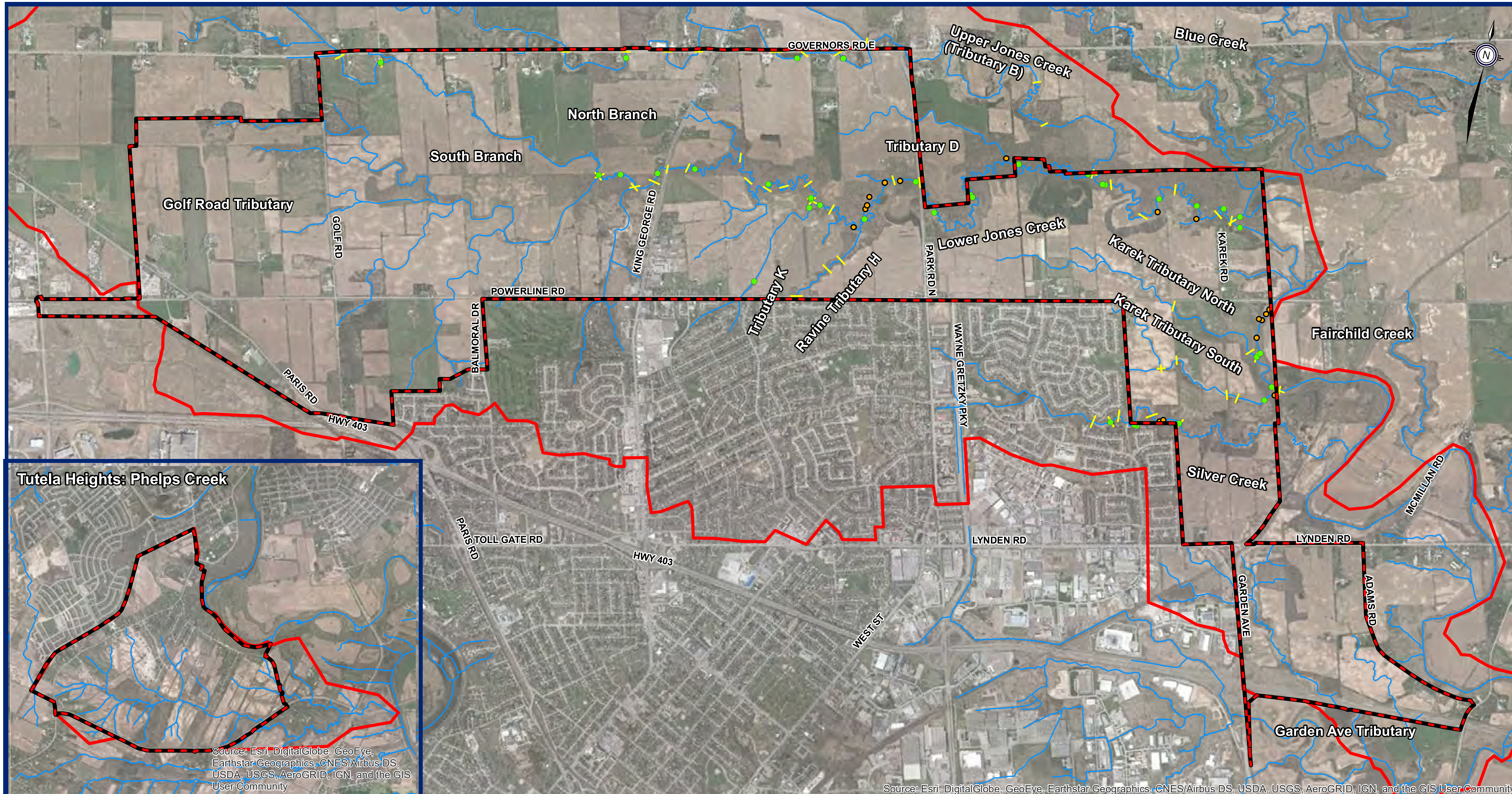
The number of water quality measurements collected during the geomorphic reach assessments varied between tributaries and reflects the length of channel assessed; the most (26) measurements were collected along Jones Creek and the least (2) were collected along the Karek Tributaries. The difference in data points may create a bias in interpretation of the data presented (Table 2-14); a larger sample of measurements provides more confidence in its representation of actual conditions than a smaller sample which could be affected by local influences.

Review of the data presented in Table 2-14 shows that the surface water quality data collected within each tributary generally showed little variation and were very similar along the lengths of each assessed watercourse. Comparison of the data collected between watercourses showed variability with respect to total dissolved solids, electrical conductivity, and dissolved oxygen. Temperature and pH was relatively similar between the watercourses.

Table 2-14. Average water quality data collected for each tributary in the north Brantford Boundary Expansion Lands area

Creek Name	2018 Sample Dates	Number of samples		Temperature (°C)	pH	TDS (ppm)	Electrical Conductivity (µS)	Dissolved Oxygen (mg/L)
Jones Creek	Aug. 30 – Sept. 6	26	**Range**	15 – 19.9	7.83 – 8.38	323 – 1384	643 – 2777	6.75 – 12.32
			Average	18.39	8.24	455.86	911.52	9.33
Fairchild Creek	Aug. 15 (Downstream of Karek Tributaries) Aug. 30 (Upstream of Karek Tributaries)	4	**Range**	20.7 – 22.9	8.01 – 8.07	336 – 658	329 – 724	6.3 – 6.45
			Average	21.38	8.04	428	609.75	3.19
Silver Creek	Sept. 7	4	**Range**	17.3 – 19.2	7.77 – 8.15	538 – 906	1080 – 1811	7.75 – 8.75
			Average	18.28	7.99	710.5	1422.25	8.24
Karek Tributaries	Aug. 15	2	**Range**	18.7 – 20.8	7.82 – 8.03	336 – 523	103.5	-
			Average	19.75	7.93	429.50	-	-

[1]See Appendix D1 for full record of reach-based water quality measurements



Brantford Growth Plan

- Study Area
- Tertiary Study Area
- Water Quality Sample
- Property Parcel
- Reach Break
- Drainage Network
- Seepage Observation

Figure 2-39
Watercourse Characterization
Water Quality Sampling Locations

May, 2020
NAD 1983 UTM Zone 17N

Temperature

Review of Table 2-14 indicates that the lowest temperature recorded during the 2018 geomorphic reach assessments occurred in Jones Creek, followed by Silver Creek. Fairchild Creek had the highest recorded water temperature during the 2018 field season. Groundwater contributions contribute to the thermal regime of the North Brantford area watercourses. MacVeigh et al., (2016) suggest that wetlands and groundwater seeps in the Galt Moraine System provide cold water to Jones Creek. Observations of groundwater seepage, during the geomorphic reach level assessments in the North Brantford area were recorded and are illustrated on Figure 2-39).

Dissolved Oxygen

Table 2-14 suggests that the dissolved oxygen is low within Fairchild Creek; all other creeks had dissolved oxygen levels which can support abundant fish populations. Oxygen depletion within Fairchild Creek impacts the ability of many fish to survive; dissolved oxygen below 6 mg/L typically does not support spawning.

Electrical Conductivity

Electrical conductivity varied between all North Brantford watercourses. Within a typical freshwater watercourse, fish cannot tolerate large increases in conductivity of the water as they would not survive. Most aquatic organisms have a relatively narrow range of conductivity in which they can live. Water temperature and conductivity tend to trend together, they increase in summer and decrease in the winter.

pH

Surface water systems typically range between 6.5 to 8.5 pH. All watercourses within North Brantford fall within the normal range.

While the 2018 field measurements provide some insight into the water quality conditions within the North Brantford watercourses, substantial water quality information is lacking (e.g., nutrients, suspended sediment, seasonal variation, wet vs dry events etc.,). No background data was located for Phelps Creek. Given the limited data, full characterization of the North Brantford and Tutela Height is not yet feasible.

In MacVeigh et al., (2016), a review of Best Management Practices within the Fairchild Creek watershed revealed that livestock restriction, tree planting, and nutrient management plans have been implemented in select locations within the Jones Creek watershed (Stone, 2004). It is likely that these actions were in response to degraded conditions within the watershed and would have resulted in water quality improvements.

MacVeigh et al., (2016) suggest that Jones Creek is a substantial contributor of the sediment load that is conveyed through Fairchild Creek. No background data has been located to date, that quantifies this sediment loading.

2.9.2 **Aquatic Life and Fish Habitat**

Temperature ranges play a key role in determining which fish species may be present within the system. Thermal regimes impact growth, survival and reproduction of fish species. Warm streams typically have a greater diversity of fish than coldwater streams. Within southern Ontario, many of the historically coldwater streams have been degraded and altered to become warm water streams due to a variety of reasons, most of which are anthropogenic causes such as vegetation removal, change in land use and nutrient loading. All watercourses require protection, but coldwater streams, due to their scarcity within the landscape, are especially vulnerable and require efforts to maintain, or to enhance current features; they require protection and are heavily regulated.

Three main temperature categories are widely accepted based on summer water temperatures:

- Cold <19 Celsius
- Cool 19-25 Celsius
- Warm >25 Celsius

Approximately 20% of watercourses in the Fairchild watershed have been classified by the Ontario Ministry of Natural Resources and Forestry (MNRF) in terms of their fish communities and thermal classification (MacVeigh et al., 2016). Beyond the headwaters, which support cold and cool water streams, most watercourses in the Fairchild Creek basin support warm water fish habitat. Exceptions to this are Jones Creek and Blue Creek, both of which support cold water fish habitat; Jones Creek is in the North Brantford boundary expansion area. Review of the water temperature data recorded during the geomorphic reconnaissance level reach assessment (Table 2-14) confirms the cool/cold thermal regime classification for each of the watercourses included in the North Brantford assessment.

Through review of background information, it became apparent that there is a notable absence of background (current and/or historical) data for the watercourses that drain both the North Brantford (i.e., Jones Creek, Silver Creek, and Garden Ave. tributary) and Tutela Heights (Phelps Creek) subwatershed areas. Limited generalizations of watercourse conditions can be made of the North Brantford area watercourses, based on their occurrence within the Fairchild Creek drainage network; a fulsome characterization is not possible at this time due to the lack of existing data.

2.9.3 **Jones Creek**

Jones Creek is a tributary of Fairchild Creek. The water quantity, quality and temperature of Jones Creek establishes it as a unique feature within the Fairchild Creek watershed as it supports a cool and cold-water fish habitat system (MacVeigh et al., 2016). The 2018 water temperature data supports the cool/cold water classification. Groundwater seeps contribute cold water (8-10^{o}C) to in-channel flows, allowing temperature sensitive species such as brook trout to be supported within Jones Creek. In conjunction with the geomorphic characterization of Jones Creek, field observations of seepage were recorded (See Figure 2-39); reach scale summaries of channel conditions, measurements of channel form, and observations of substrate and profile configuration are provided in Section 2.8.4. Detailed geomorphic field site data collection was completed in four locations within the Jones Creek drainage network in the North Brantford area (See Section 2.8.6)

MNRF fish collection inventory records from 1999 and 2003 identified many fish and minnow species in Jones Creek, including blacknose dace, brook stickleback, brook trout, brown trout, creek chub, common white sucker, golden shiner, Johnny darter, pearl dace, and pumpkinseed. Jones creek support Brown trout and provincially vulnerable American brook lamprey.

While the occurrence of Brook Trout is typically associated with gravel bed streams, studies have shown that the need for groundwater flow at redds may be more important than substrate composition in redd site selection (Blanchfield & Ridgway, 1997; Witzel and MacCrimmon 1983); Witzel and MacCrimmon (1983) have suggested that substrate composition and other hydraulic conditions are secondary in determining where nests will be constructed. Blanchfield and Ridgway (1997) observed brook trout spawning over a wide range of gravel substrate sizes. Brook trout are also documented to have spawned on an aggregation of waterlogged sticks and wood chips beside a beaver lodge. Fraser (1982) observed brook trout (*Salvelinus fontinalis*) spawning successfully by a groundwater seep on a 0.3 m thick aggregation of waterlogged sticks, woodchips, and debris overlying the soft ooze bottom of a small Precambrian Shield lake. Witzel and MacCrimmon (1983) suggest that preference for groundwater seepage by brook trout was so pronounced in some sites, that redd sites were selected even in areas covered by depths (to 3 cm) of silt and organic matter. Based on the foregoing, further characterization of Jones Creek is needed to support future land use planning.

2.9.4 Fairchild Creek

Only a small portion of Fairchild Creek is located within the North Brantford subwatershed area. Reach scale summaries of channel conditions, measurements of channel form, and observations of substrate and profile configuration are provided in Section 2.8.4. Aquatic characteristics of this portion of Fairchild Creek (i.e., fish community, sediment levels and water quality parameters) are directly influenced by Jones Creek and Silver Creek. Analysis of Fairchild Creek water quality data available from the 2016 Fairchild Creek Characterization study completed by GRCA provides evidence to suggest that Jones Creek is a significant contributor of suspended sediment and phosphorus to the Grand River. This contribution from Fairchild Creek is higher than any other tributary of the Grand River and is attributed to be from excessive in-stream bank erosion and bed scouring (MacVeigh et al., 2016). Previous studies have shown that high phosphorus concentrations are strongly correlated to suspended sediment concentrations in Fairchild Creek; this supports the findings presented in the 2016 study (Cook, 2006).

Fairchild Creek is a silt laden water system, due to surrounding agricultural land use and soil composition. As a result, the composition of the local fish species is tolerant of high turbid waters and warmer temperatures (PLAN B Natural Heritage et al., 2014). Overall, forty-seven (47) native and non-native fishes have been found within Fairchild watercourses through electrofishing surveys at various stations in 1975, 1987, 1988, 1990, 2006, 2007 (MacVeigh et al., 2016). A list of Provincially Significant Species found within the Fairchild Creek basin is provided in Table 2-15. The full inventory of aquatic species recorded in the Fairchild Creek basin is provided in Table 2-16 along with their thermal preference. Of these documented fish, seven species (5 fish, 2 mussels) are provincially significant and four of these species (2 fish, 2 mussels) are protected under the Provincial Legislature *Endangered Species Act* or *Federal Species at Risk Act* (MacVeigh et al., 2016).

Table 2-15: Provincially Significant Species found within the Fairchild Creek Basin

Common Name	Scientific Name	Provincial Rank[1]	Provincial Status[2]	Federal Status[3]	Source
Herpetofauna					
Blanding's Turtle	*Emydoidea blandingii*	S3 - Vulnerable	THREATENED	THREATENED	NHIC 2014, Schwetz 2014, Schwetz and Martel 2014
Eastern Hog-nosed Snake	*Heterodon platirhinos*	S3 - Vulnerable	THREATENED	THREATENED	NHIC 2014, Schwetz 2014, Schwetz and Martel 2014
Eastern Milksnake	*Lampropeltis triangulum*	S3 - Vulnerable	SPECIAL CONCERN	SPECIAL CONCERN	NHIC 2014, Schwetz 2014, Schwetz and Martel 2014
Eastern Ribbonsnake	*Thamnophis sauritus*	S3 - Vulnerable	SPECIAL CONCERN	SPECIAL CONCERN	Schwetz 2014, Schwetz and Martel 2014
Jefferson Salamander	*Ambystoma jeffersonianum*	S2 - Imperiled	ENDANGERED	ENDANGERED	NHIC 2014, Schwetz 2014, Schwetz and Martel 2014

Jefferson X Blue-spotted Salamander, Jefferson genome dominates	*Ambystoma* hybrid pop. 1	S2 - Imperiled			Schwetz 2014, Schwetz and Martel 2014
Northern Map Turtle	*Graptemys geographica*	S3 - Vulnerable	SPECIAL CONCERN	SPECIAL CONCERN	NHIC 2015
Snapping Turtle	*Chelydra serpentina*	S3 - Vulnerable	SPECIAL CONCERN	SPECIAL CONCERN	NHIC 2015, Schwetz 2014, Schwetz and Martel 2014
Western Chorus Frog	*Pseudacris triseriata*	S3 - Vulnerable		SPECIAL CONCERN	NRSI 2013, Schwetz 2014, Schwetz and Martel 2014
Fishes					
American Brook Lamprey	*Lethenteron appendix*	S3 - Vulnerable			Art Timmerman, OMNRF, Pers. Comm., 2015
Black Redhorse	*Moxostoma duquesni*	S2 - Imperiled	THREATENED	THREATENED	Art Timmerman, OMNRF, Pers. Comm., 2015
Brindled Madtom	*Noturus miurus*	S2 - Imperiled			NHIC 2015
Eastern Sand Darter	*Ammocrypta pellucida*	S2 - Imperiled	ENDANGERED	THREATENED	COSEWIC 2009
Greater Redhorse	*Moxostoma valenciennesi*	S3 - Vulnerable			NHIC 2015
Mussels					
Rainbow Mussel	*Villosa iris*	S2S3 – Vulnerable to Imperiled	THREATENED	ENDANGERED	Art Timmerman, OMNRF, Pers. Comm., COSEWIC 2006
Round Pigtoe	*Pleurobema sintoxia*	S1 - Critically Imperiled	ENDANGERED	ENDANGERED	Art Timmerman, OMNRF Pers. Comm., COSEWIC 2004

*Reproduced from: MacVeigh et al., 2016
[1] Natural Heritage Information Centre 2015
[2] Endangered Species Act 1997, O. Reg. 139/14, s. 2
[3] Federal Species at Risk Act 2002 (Schedules 1-3)
*Table modified from (MacVeigh et al., 2016)

Table 2-16: Full Inventory of Aquatic Species Recorded in Fairchild Creek Watershed and their Conservation Status

Common Name	Scientific Name	NHIC Rank	ESA Status	SARA Status	Thermal Preference
Fishes					

American Brook Lamprey	*Lethenteron appendix*	S3 - Vulnerable			Coldwater
Brown Trout	*Salmo trutta**	Not Assessed			Coldwater
Brook Trout	*Salvelinus fontinalis*	S5 - Secure			Coldwater
Central Mudminnow	*Umbra limi*	S5 - Secure			Coolwater
Northern Pike	*Esox lucius*	S5 - Secure			Coolwater
Goldfish	*Carassius auratus**	Not Assessed			Warmwater
Northern Redbelly Dace	*Chrosomus eos*	S5 - Secure			Coolwater
Finescale Dace	*Chrosomus neogaeus*	S5 - Secure			Coolwater
Common Carp	*Cyprinus carpio**	Not Assessed			Warmwater
Spotfin Shiner	*Cyprinella spiloptera*	S4 - Apparently Secure			Warmwater
Brassy Minnow	*Hybognathus hankinsoni*	S5 - Secure			Coolwater
Common Shiner	*Luxilus cornutus*	S5 - Secure			Coolwater
Northern Pearl Dace	*Margariscus nachtriebi*	S5 - Secure			Coolwater
Hornyhead Chub	*Nocomis biguttatus*	S4 - Apparently Secure			Coolwater
Golden Shiner	*Notemigonus crysoleucus*	S5 - Secure			Coolwater
Blacknose Shiner	*Notropis heterolepis*	S5 - Secure			Coolwater
Rosyface Shiner	*Notropis rubellus*	S4 - Apparently Secure			Coolwater
Mimic Shiner	*Notropis volucellus*	S5 - Secure			Coolwater

Bluntnose Minnow	*Pimephales notatus*	S5 - Secure			Warmwater
Fathead Minnow	*Pimephales promelas*	S5 - Secure			Warmwater
Longnose Dace	*Rhinichthys cataractae*	S5 - Secure			Coolwater
Western Blacknose Dace	*Rhinichthys obtusus*	Not Ranked			Coolwater
Creek Chub	*Semotilus atromaculatus*	S5 - Secure			Coolwater
White Sucker	*Catostomus commersonii*	S5 - Secure			Coolwater
Silver Redhorse	*Moxostoma anisurum*	S4 - Apparently Secure			Coolwater
Black Redhorse	*Moxostoma duquesni*	S2 - Imperiled	THREATENED		Coolwater
Golden Redhorse	*Moxostoma erythrurum*	S4 - Apparently Secure			Coolwater
Shorthead Redhorse	*Moxostoma macrolepidotum*	S5 - Secure			Coolwater
Greater Redhorse	*Moxostoma valenciennesi*	S3 - Vulnerable			Warmwater
Brown Bullhead	*Ameiurus nebulosus*	S5 - Secure			Warmwater
Stonecat	*Noturus flavus*	S4 - Apparently Secure			Warmwater
Brindled Madtom	*Noturus miurus*	S2 - Imperiled			Warmwater
Brook Stickleback	*Culaea inconstans*	S5 - Secure			Coolwater
Rock Bass	*Ambloplites rupestris*	S5 - Secure			Coolwater
Pumpkinseed	*Lepomis*	S5 - Secure			Warmwater

	gibbosus				
Smallmouth Bass	*Micropterus dolomieui*	S5 - Secure			Warmwater
Largemouth Bass	*Micropterus salmoides*	S5 - Secure			Warmwater
Black Crappie	*Pomoxis nigromaculatus*	S4 - Apparently Secure			Warmwater
Eastern Sand Darter	*Ammocrypta pellucida*	S2 - Imperiled	ENDANGERED	THREATENED	Warmwater
Greenside Darter	*Etheostoma blennioides*	S4 - Apparently Secure			Coolwater
Fantail Darter	*Etheostoma flabellare*	S4 - Apparently Secure			Coolwater
Johnny Darter	*Etheostoma nigrum*	S5 - Secure			Coolwater
Logperch	*Percina caprodes*	S5 - Secure			Coolwater
Blackside Darter	*Percina maculata*	S4 - Apparently Secure			Coolwater
Yellow Perch	*Perca flavescens*	S5 - Secure			Coolwater
Walleye	*Sander vitreus*	S5 - Secure			Coolwater
Mottled Sculpin	*Cottus bairdii*	S5 - Secure			Coldwater
Mussels					
Rainbow Mussel	*Villosa iris*	S2S3 – Vulnerable to Imperiled	THREATENED	ENDANGERED	n/a
Round Pigtoe	*Pleurobema sintoxia*	S1- Critically Imperiled	ENDANGERED	ENDANGERED	n/a

Thermal Regime	**Species**	
	Number	Percentage
Warmwater	14	29.8

Coolwater	29	61.7
Coldwater	4	8.5
TOTAL	47	100

Sources: [1] Natural Heritage Information Centre; [2] Provincial Endangered Species Act (2007), O. Reg. 139/14, s.2; [3] Federal Species At Risk Act 2002, Schedules 1-3; [4] Eakins (2014); [5] GRCA 1998. Checklist order follows Scott and Crossman (1998).
*denotes an introduced species
** Table modified from (MacVeigh et al., 2016)

2.9.5 Data Gaps

The intent of the water quality and aquatic assessments for this study was to consist of a background information review and to draw from the geomorphic field assessment. Through this process, the following gaps were identified.

- Comprehensive water quality documentation for a full suite of parameters does not exist
- Surface water temperature monitoring is limited
- Understanding of the sediment load and sediment origins is not well established
- Fish community assessments do not appear to have been completed.
- Benthic macroinvertebrate assessments do not appear to have been completed.
- Aquatic habitat assessments have not been completed.
- Understanding of groundwater/surface water interactions have not been established.

Further understanding of the existing aquatic conditions within each of the study area watercourses is needed to establish baseline understanding, identify sensitivities, and identify opportunities for natural environment enhancement. The aquatic systems conditions should be documented and understood prior to development within the study area. The existing natural environment conditions will determine project constraints, provide environmental protection and allow for sustainable development.

These studies are imperative to understand the current aquatic conditions within these systems. Establishing a baseline understanding of existing watercourses conditions will enable ecologically significant watercourses to be identified, and appropriate protection measures to be determined.

2.10 Natural Environment

The appended Comprehensive EIS will focus on aspects of vegetation, wildlife, aquatic recourses and significant natural heritage features. This can be found in Appendix B.

2.11 Preliminary Natural Heritage System

The natural environment features within the North Brantford and Tutela Heights study area were evaluated in the context of the Natural Heritage Reference Manual (MNR 2010), which is the companion document to the Provincial Policy Statement (MMAH 2020). The natural environment features within the study area were previously evaluated, as part of the County of Brant Official Plan (2012). The core components of the Natural Heritage System (NHS) within the study area, as identified in the County of Brant Official Plan, include provincially significant wetlands (PSW), woodlands and vegetation, watercourses, and hazard lands (i.e. floodplains and slope/erosion hazards).

Natural heritage features and areas that represent a constraint to development under the County Official Plan policies include: woodlands, Provincially significant woodlands and vegetation, areas of natural and scientific interest (ANSI), significant valleylands; watercourses and other surface water features, wetlands which have been evaluated by MNRF and are not considered to be Provincially significant, and fish habitat.

The County of Brant currently has 13% woodland or forest coverage (County of Brant Official Plan 2012). Environment Canada (2013) has reported that 30% woodland cover is the minimum requirement to support healthy habitat conditions for wildlife and plants. The limited woodland cover within the County of Brant and the study area underscores the importance of protecting all remaining woodlands and increasing woodland cover on the landscape.

Based on the above overview of existing conditions and environmental constraints, the recommended natural heritage system framework for the North Brantford and Tutela Heights study area. The NHS incorporates the following features:

- Growth Plan NHS;
- PSW's;
- Unevaluated (naturally occurring) wetlands 0.5 ha in area or larger;
- Anthropogenic wetlands 2.0 ha in area or larger;
- Woodlands 4.0 ha in area or larger;
- Watercourses - Jones Creek, Fairchild Creek, and Phelps Creek - defined valleylands and riparian corridors, including bottomland/floodplain and valley slope vegetation, fish and wildlife habitat, and corridor/linkage functions;
- Headwater drainage features to be "conserved", as defined by ERI (2019);
- Grand River – Significant Valleyland, critical habitat for species at risk, species dispersal corridor;
- Floodplains and valley slope/erosion hazards;
- Habitat for species at risk protected under the Endangered Species Act (2007); and,
- A minimum 30 m protective buffer from all NHS components.

The NHS was identified largely on the basis of a desktop analysis of background information sources and GIS layers provided by the GRCA, MNRF, County of Brant, and the City of Brantford. Aerial photograph interpretation, windshield surveys, and in-season wildlife surveys on selective accessible properties were used to confirm and refine the limits of the recommended NHS.

The NHS for the North Brantford and Tutela Heights study area also includes portions of the Growth Plan NHS. Refinements to the Growth Plan NHS (described below) were made in selective locations to better reflect current conditions and constraints, and to be consistent with the NHS framework for the study area.

Floodplains and slope erosion hazards are included within the NHS where they coincide with wetlands, riparian bottomlands, woodlands, and vegetated valley slopes. Portions of floodplains and slopes that occurred in cultivated agricultural land were not included as part of the NHS. The limits of the floodplain and stable top of slope in these areas will need to be reviewed in consultation with the GRCA at the block plan or draft plan of subdivision stage to determine the extent to which these areas should be included as part of the NHS.

It should be noted that the scope of the Comprehensive EIS did not allow for the identification, evaluation, and mapping of significant valleylands, significant wildlife habitat or fish habitat. Notwithstanding this, the recommended NHS for the North Brantford and Tutela Heights study area does protect existing valleyland features (i.e. Jones Creek, Fairchild Creek, Phelps Creek), wildlife habitat features/functions, and fish habitat with minimum 30 m buffers.

3. IMPACTS, SCENARIOS, AND DIRECTIONS

In characterizing the North Brantford and Tutela Heights subwatershed areas, a thorough review of the natural environment has been captured in Section 2. The following section of the report focusses on the analysis of the study area and determines potential impacts to the study with consideration of possible future development scenarios. As will be seen in Section 4, several further investigations will be required to update the characterization of the subwatershed areas. Given the incomplete nature of the data available, the following review of impacts is general and preliminary in nature. Following the completion of the field investigations, the Comprehensive Subwatershed Study Update will include a more detailed review of impacts and specific recommendations related to mitigation.

3.1 Potential Impacts to Groundwater Resources and Mitigative Measures

The potential impacts of development on groundwater resources include the following:

- Development results in the increase in impervious surfaces which will reduce groundwater recharge if no infiltration measures are incorporated in the stormwater design.
- High groundwater levels may incidentally lowered by foundation drainage if foundations are not installed above the existing groundwater table elevation.
- Intake Protection Zones are vulnerable to water quality impacts from development, especially due to discharge from industrial lands or large stormwater management facilities.
- Based on the review of these hydrogeological aspects (i.e. recharge/discharge areas), Catchment areas UJ-1 through UJ-4 and NO-1 may contain recharge areas that are instrumental in maintaining the coldwater conditions in Jones Creek: these areas should be subject to detailed study prior to development so that the discharge regime may be maintained.
- A small area in the western portion of the North Brantford expansion area is identified as a Highly Vulnerable Aquifer

Measures for mitigation that may make up the ultimate recommendations include:

- Inclusion of LID and infiltration strategies within the stormwater management system to maintain existing groundwater recharge levels.
- Grade the development lands to raise the proposed grades such that foundation drains are not impacting the groundwater levels.
- Decommissioning of private wells and septic systems during development of the Boundary Adjustment Lands.
- Decommissioning or maintenance of tile drainage systems during development of the Boundary Adjustment Lands.
- Avoid stormwater management facilities that serve employment areas 100 hectares or larger.
- When developments are planned, a review of source protection policies should be completed again to ensure that planning and development accounts for any revisions to the policies.
- Zoning should restrict the usage of Intake Protection Zone lands from industrial uses (e.g. nutrient storage facilities, facilities that would be required to report to the National Pollutant Release Inventory).
- The western portion of the North Brantford expansion area should include enhanced recharge facilities to maintain water balance in this area. Stormwater design for these areas must account for the potential for contaminants to enter the groundwater via Low Impact Development (LID) facilities. The City may also consider precluding or restricting certain industrial land uses (e.g. fuel storage, processes using organic solvents).

3.2 Potential Impacts to Drainage and Hydrology and Mitigative Measures

The potential impacts of development on drainage and hydrology include the following:

- Increase of runoff due to the increase in impermeable surfaces, which could result in flooding, and erosion
- Alteration of the existing drainage patterns to the natural heritage features
- Adjustment to existing stormwater outfalls
- Degradation of water quality (salt, suspended solids etc.) entering receiving waterbodies
- Increase in temperature to receiving waterbodies
- Challenge of managing runoff from the City, south of Powerline Road

Measures for mitigation that may make up the ultimate recommendations include:

- Use of stormwater management ponds to provide quantity control and enhanced quality control (80% TSS removal)
- Incorporation of Low Impact Development techniques to promote groundwater recharge
- Use of Oil Grit Separators to act as upstream pre-treatment to the stormwater management ponds
- Generation of policies to ensure that 100% of runoff from impervious area drains to a treatment facility
- Recommendation that 100% of outfalls to sensitive watercourses have upstream control measures unless study shows not required
- Implementation of criteria to control post-development peak flows to the pre-development level for a full range of storms
- Implementation of criteria to ensure that groundwater recharge balance is being met

3.3 Potential Impacts to Stream Geomorphology and Mitigative Measures

As identified in Section 2, the areas of most concern are:

- In the North Brantford expansion area, Tributary K of the Jones Creek drainage network and Silver Creek, a tributary of Fairchild Creek, appear to be the most impacted from existing urbanization and alterations in flow regime. These watercourses are incised and disconnected from their floodplain
- The reaches downstream of the Upper and Lower Jones Creek confluence are degraded and in adjustment.
- Inefficient drainage along low gradient portions of the drainage network (e.g., Lower Jones Creek, Karek Tributaries)

The potential impacts of development on geomorphological stream processes include the following:

- Alteration of hydrologic regime that will increase erosion and/or incision of tributaries; an altered hydrologic regime could also lead to excess aggradation.
- Cumulative impact from multiple stormwater management facilities
- Loss of headwater drainage feature functions (HDF) (e.g., flow attenuation)
- Loss of channel length through realignment
- Loss of buffers along watercourses

Measures for mitigation that may make up the ultimate recommendations include:

- Establish stormwater management for existing uncontrolled stormwater discharge into the Jones Creek, Fairchild Creek, and Silver Creek drainage networks.
- Implement erosion control for future stormwater management and develop overall stormwater management plan for the area that considers cumulative impacts to the drainage networks.
- Implement Low Impact Development measures to mitigate hydrological impacts and replicate HDF functions.

- Maintain or increase channel length compared to existing conditions.
- Establish channel corridor to protect natural channel functions and protect public from erosion hazard risk
- Restoration and/or enhancement of degraded watercourses for geomorphic form and function
- Improved floodplain connectivity where connectivity has been lost
- Consider cohesive channel form, function and processes when developing any channel enhancement or restoration designs to promote long term sustainability (e.g., there is a lack of gravel sized sediment in the area stratigraphy, based on observations made to date).

Results from the headwater drainage feature (HDF) assessment completed to date have led to the development of preliminary management recommendations. These are outlined in **Appendix D-2**; final management recommendations will need to be informed by further field assessment to fulfill all requirements of the HDF assessment guidelines provided by CVC and TRCA (2014).

It is important to note that permission from the GRCA is required to develop in river or stream valleys, wetlands, shorelines or hazardous lands; alter a river, creek, stream or watercourse; or interfere with a wetland. Within these regulated areas, GRCA Policies for the Administration of the Development, Interference with Wetlands and Alterations to Shorelines and Watercourses Regulation apply (Ontario Regulation 150/06). Recommendations derived from the HDF assessment are in addition to, but do not supersede, regulatory requirements

3.4 Potential Impacts to Water Quality and Aquatic Systems and Mitigative Measures

The areas of most concern are:

- Each of the perennially flowing watercourses within the North Brantford and Tutela Heights subwatershed areas including Jones Creek, Silver Creek, Garden Avenue tributary, and Phelps Creek

The potential impacts of development on water quality and aquatic habitat include the following:

- Increase in water temperature impacting thermal regime of watercourses (including downstream receiving waterbodies)
- Altered flow regime
- Fragmentation of habitat
- Barriers to fish passage
- Degradation of fish habitat to levels unable to support a diversity of fish species (change in fish abundance, production rates, mobility and behavioural ecology)
- Decrease in water quality parameters (potential to impact aquatic habitat system)
- Loss of assemblage diversity, richness and biotic integrity (sensitive species may disappear, and increasingly tolerant species become abundant)
- Increase in contaminants that impact water quality (heavy metal, nutrients, etc.)
- Alteration of natural hydrological processes
- Reduction in ecosystem health
- Loss of aquatic habitat

Measures for mitigation that may make up the ultimate recommendations include:

- Implementation of LID measures to minimize thermal effects from urban runoff
- In-stream barrier mitigation and/or online pond mitigation to maintain or enhance thermal regime and habitat connectivity in Jones Creek.
- Appropriate sizing of watercourse crossings to minimize impact to in-stream flow hydraulics during key flow events.
- Maintain/or increase natural buffers along all watercourses to limit impacts to aquatic systems
- Promotion of soil conservation management strategies

- Establishment of pre and post development monitoring plan for water quality, aquatic habitat, benthic macroinvertebrate sampling, fish community assessment, and terrestrial habitat assessment
- Implementation of sustainable building practices
- Installation and maintenance of erosion and sediment controls installation
- Compensation program for any loss of habitat (installation of fish habitat features)
- Channel restoration and enhancement of degraded watercourses for aquatic habitat enhancements should consider interception of groundwater sources, where possible and promote the long-term stability of the channel with respect to any gravel sized sediment placed within the channel.

3.5 Potential Impacts on the Natural Environment and Mitigative Measures

The potential impacts and mitigation measures relating to the natural environment are identified in the Comprehensive EIS, found in Appendix B.

3.6 Preliminary Stormwater Management Strategy

The following section outlines a preliminary stormwater management plan for the North Brantford and Tutela Heights expansion areas. For more details, refer to Tech Memo 2 – Preliminary Stormwater Management Strategy for Expansion Lands in Appendix F. The details below are very general at this time and will be further developed following the selection of the preferred Land Use option for the expansion areas. The final stormwater management strategy will be completed following the field program and will be part of the Comprehensive Update to the Subwatershed Study.

3.6.1 General Objectives

General objectives for stormwater management include the following:

- Water Quality
  - 100% coverage
  - 80% suspended solids (SS) removal
  - Temperature reduction based on the thermal regime of the receiving watercourse
- Water Quantity
  - Control post-development peak flows to the pre-development level for a full range of storms
  - Maintain overall drainage patterns
- Water Balance
  - Maintain annual recharge volumes under post-development conditions

3.6.2 Approach

The stormwater management approach for the Expansion Lands will include a combination of lot-level controls and end-of-pipe stormwater management facilities.

For employment and commercial lands, total on-site controls will be required where development parcels are adjacent to the existing natural features (i.e. wetland or watercourse) and where the site discharges to the existing feature under current conditions. Partial on-site control, including infiltration of clean rooftop water, will be required for all other employment lands. The use of Low Impact Development techniques for on-site stormwater management will be highly encouraged.

For residential lands, high density zones will include partial and on-site controls, including infiltration where feasible. In general, low and medium density zones will be conveyed to stormwater management facilities, however infiltration may be considered for these lands as well.

3.6.3 Issues and Constraints

Potential stormwater challenges that will be managed as the stormwater management strategy is further developed include the following:

- Managing runoff from the City south of Powerline Road
- Maintaining groundwater recharge within high recharge area on the west side of the expansion lands
- Establishing trunk conveyance for current stormwater outfalls
- Maintaining drainage to existing natural heritage features

Constraints related to stormwater management that need to be managed as the stormwater management strategy is further developed include the following:

- Aligning the stormwater management strategy with the proposed land use plans to mitigate impacts to the natural environment
- Locating appropriate outlets and conveyance networks in areas not in proximity to a watercourse (i.e. use of trunk conveyance)
- Minimizing the number of ponds that will become City infrastructure, while also ensuring that a reasonable drainage area is allotted to each pond

4. SECONDARY PLAN AREAS

The City of Brantford (the City) initiated a Secondary Servicing Plan, under separate cover, in support of a Municipal Comprehensive Review (MCR) as input to the City's new Official Plan. The Secondary Servicing Plan relates to determining the land uses within the settlement boundary expansion area, as well as the transportation infrastructure, servicing infrastructure, environmental management, and urban design guidelines necessary to implement the new urban land uses.

The key objective of the Secondary Servicing Plan is to outline the servicing infrastructure needed to implement the new urban land use. The Secondary Servicing Plan builds on previous studies and creates a forward-looking document to support the City, aligning with the City's Master Servicing Plan (MSP) and long-term infrastructure planning needs. Included in this report are:

- A servicing strategy to meet the needs of the new urban land uses that can be phased cost-effectively as the area grows over time
- A defensible framework and implementation plan for servicing the new urban land uses: North and East Expansion Lands, and Tutela Heights
- The justification, capacity, timing and triggers for new infrastructure
- Servicing policies that further foster sustainable planning, implementation and infrastructure investment within the area.

4.1 Land Use

4.1.1 Existing

The existing land use within the North Expansion Lands currently consists largely of unserviced agricultural lands, vacant lands and a few areas of commercial and residential uses. Most commercial properties are located along King George Road, which are serviced by municipal water only, while residential lands, all unserviced, are located along Powerline Road, Park Road, and Golf Road.

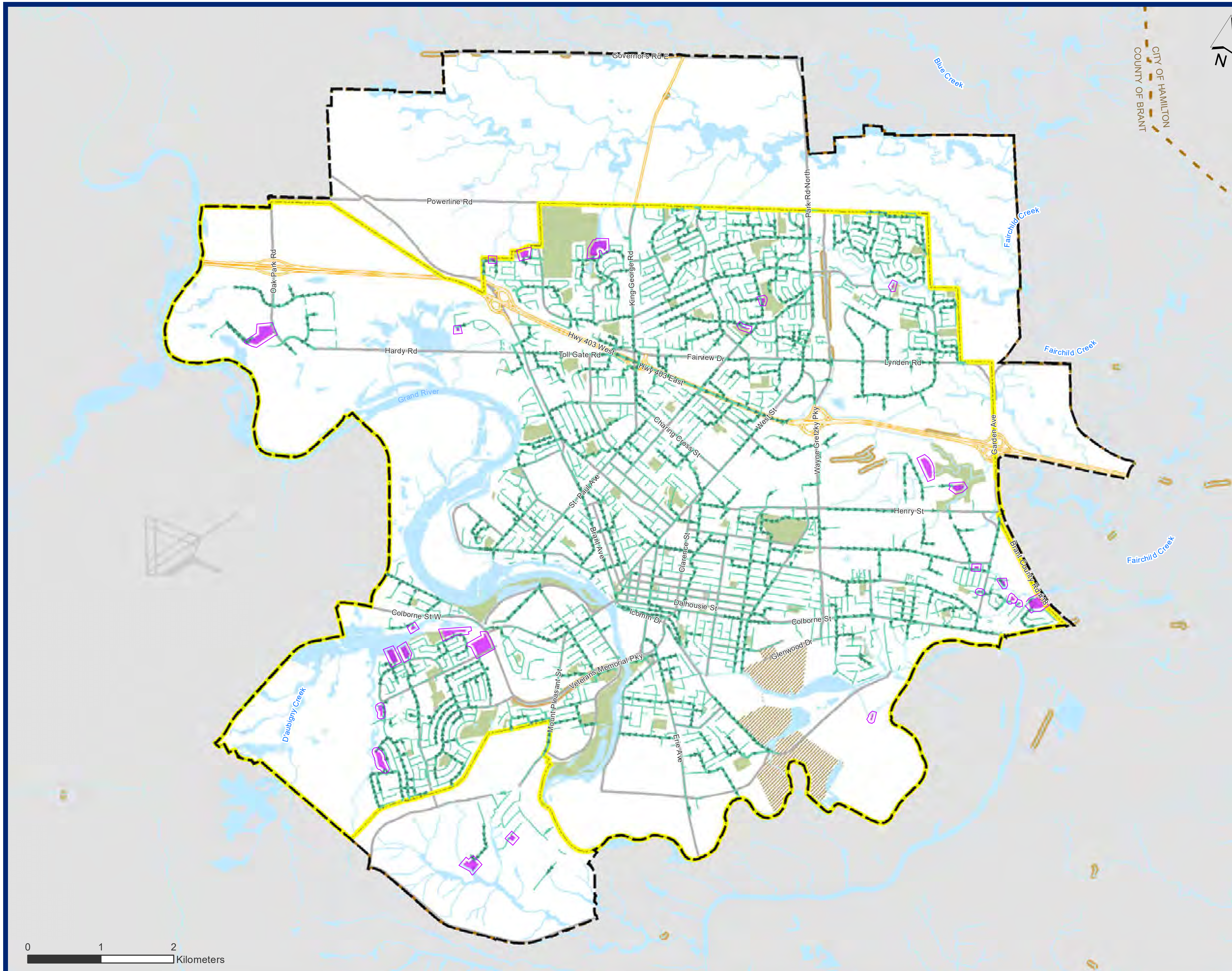
The existing land use within the East Expansion Lands currently consists largely of unserviced agricultural lands.

The existing land use within Tutela Heights, which has existing water and stormwater municipal services, consists primarily of existing residential lands, vacant lands, and agricultural lands. Most residential clusters are located along Mt. Pleasant Road and Tutela Heights Road. The existing stormwater system is presented in **Figure 4-1**.

4.1.2 Future

The proposed land use consists predominantly of residential and employment lands to support future growth metrics. Portions of the Secondary Plan Areas are within the GRCA floodplain and the Natural Heritage System; as such, urban development is not permitted in these portions of the new urban land uses due to their environmental sensitivity and the importance of maintaining existing land uses. Additionally, the boundary expansion areas contain Trigger Lands, which are lands held for future build-out following substantial development of the proposed intensification areas. Intensification corridors are proposed along King George Road, a major arterial road, Park Road North, a minor arterial road, and Mt. Pleasant Road, a minor arterial road.

Figure 4-2 presents the proposed future land use. The North Expansion Lands are envisioned to contain a mixed-use community, with residential lands primarily in the east and employment lands primarily in the west. The East Expansion Lands are envisioned to contain employment lands to the south. Tutela Heights is envisioned to mainly include residential lands. Additional information on the proposed land use can be found under separate cover, in the *Municipal Comprehensive Review Settlement Area Boundary Expansion Servicing Plan*, 2020.



THE CORPORATION OF THE CITY OF BRANTFORD

Brantford Growth Plan

Stormwater Network

- Ditches
- Detention Ponds
- Wetlands
- Stormwater Pipes (< 450 mm)
- Stormwater Pipes (>= 450 mm)

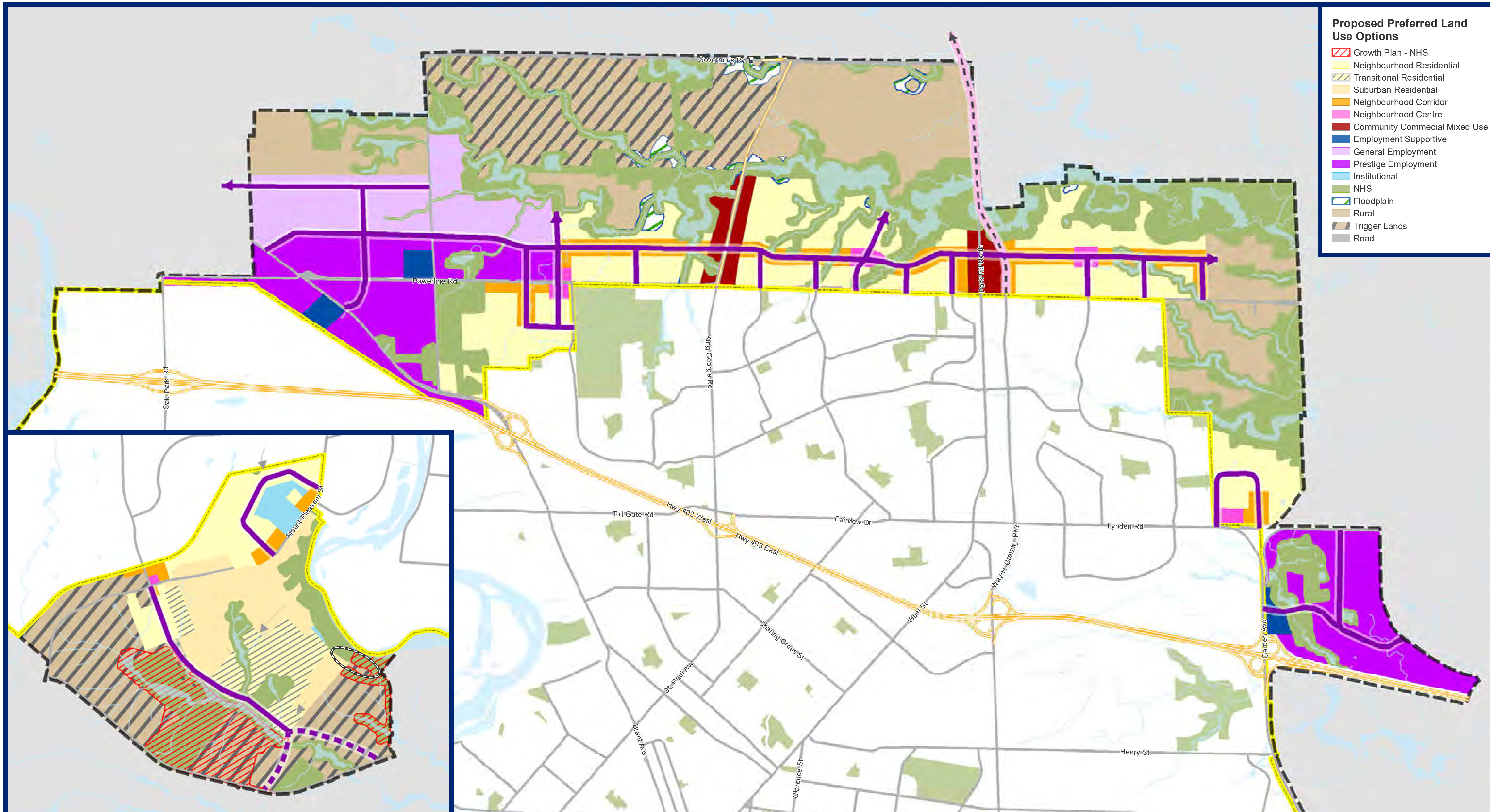
General Features

- Expressway / Highway
- Arterial and Collectors
- 2016 Municipal Boundary
- New Municipal Boundary
- Six Nations of the Grand River Territory
- Outside Municipalities
- Parks
- Waterbody

Figure 4-1
Existing Stormwater System

GM BluePlan ENGINEERING

November 2020
717036-SW-001
NAD 1983 CSRS UTM Zone 17N



The Corporation of the City of Brantford

BRANTFORD

Brantford Growth Plan

Figure 4-2

Preferred Land Uses

4.2 Urban Boundary Expansion Areas – Stormwater Servicing Concepts

The following are the servicing alternatives considered within the Secondary Plan Areas:

- End-of-pipe controls
  - Quality and quantity control ponds
  - "Traditional" stormwater management strategies
- Conveyance (in-line) controls
  - In-line underground storage technologies (stormwater chambers)
  - In-line quality control measures (oil-grit separators and/or filtration systems)
- Lot-level controls
  - Policies implemented requiring lot-level controls for future development
  - These include rooftop storage, on-site storage, and on-site quality control technologies
- Low Impact Development (LID) technologies
  - Infiltration trenches and galleries, soakaway pits, and perforated pipe systems
  - Bioretention facilities
  - Bio-swales
  - Green roofs
  - Rainwater harvesting
  - Etobicoke Exfiltration System

Historically, a "traditional approach" to stormwater management consisting predominantly of conveyance to stormwater ponds was identified as the preferred stormwater servicing approach. As development within southern Ontario and the Greater Golden Horseshoe has progressed, the industry has shifted its stormwater management philosophy to include sustainable stormwater practices. The "traditional approach" to stormwater management was designed to provide relief to the receiving bodies of water, limiting the impacts of development; however, traditional stormwater management practices overlooked the impacts of infiltration on groundwater recharge and ultimately the water balance that exists in a pre-development scenario. The *Low Impact Development Stormwater Management Planning and Design Guide* (CVC & TRCA, 2010)[1] recommends a "treatment-train" approach to stormwater management in which multiple stormwater management technologies and strategies are implemented in series or parallel to better simulate the natural environment (pre-development scenario) following development.

As discussed in **Section 2.5**, most of the North Expansions Lands and Tutela Heights fall within the Norfolk Sand Plain. The expansion lands predominantly consist of clay soils, with pockets of sandy soils meandering along reaches of Jones Creek (North Expansion Lands) and the Grand River (Tutela Heights). The western and southwestern areas within the North Expansion Lands contain pockets of gravel, pockets of sand, and pockets of diamicton. The topography within the North Expansion Lands is hummocky which contributes to significant depression storage. Although most of the soils are clay, the depression storage from the hummocky landscape provides up to 300 mm/yr contributing to groundwater recharge. Per the GRCA GIS mapping, most of the expansion lands contribute approximately 25 mm/yr of groundwater recharge, which is expected due to the low hydraulic conductivity of the clay soils.

4.3 Preferred Stormwater Servicing Strategy

The preferred stormwater servicing strategy detailed in the following section and stormwater infrastructure upgrade needs are presented in **Figure 4-3**.

[1] Credit Valley Conservation & Tornoto and Region Conservation Authority. (2010). *Low Impact Development Stormwater Management Planning and Design Guide*. Retrieved from: https://sustainabletechnologies.ca/home/urban-runoff-green-infrastructure/low-impact-development/low-impact-development-stormwater-management-planning-and-design-guide/

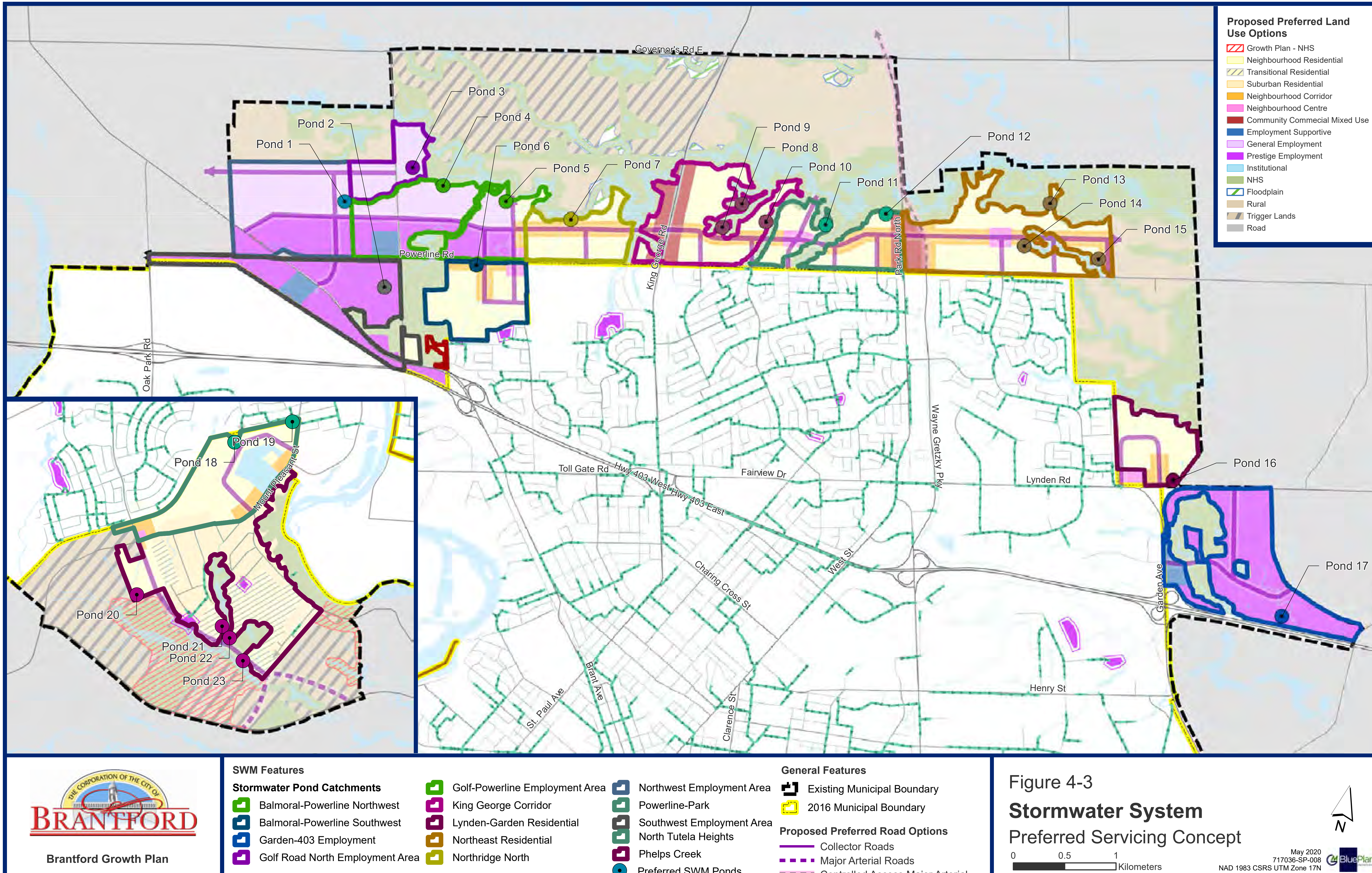


Figure 4-3
Stormwater System
Preferred Servicing Concept

4.4 Basis of Stormwater Design

Table 4-1 summarizes the draft stormwater technical level of service criteria that will be utilized as the decision-making rationale triggering upgrades for the stormwater system capacity needs.

Table 4-1: Summary of Stormwater Design Criteria

Criteria		Draft Targets
Stormwater Flows	Imperviousness	- Parks, Open Space – 35% impervious - Low and Medium Density Residential – 65% impervious - Downtown, High Density Residential – 75% impervious - Institutional, Commercial – 80% impervious - Industrial – 90% impervious
	Depression Storage	- 1.5 mm for impervious areas - 3.5 mm for pervious areas
	Synthetic Design Storm	- 3-hour Chicago (minor system)
Sewer System Performance	Design Return Period	- 2 or 5 year design storm
	HGL Target (existing)	- Below ground level
	d/D Target (new)	- d/D ≤ 0.7
Facility Assessment – Quantity Control/ Erosion Control	Coverage	- 100% of outfalls to sensitive watercourses have upstream control or downstream control measures. All new development to implement appropriate controls to manage post development runoff volumes to greater of: o Match pre development flows under both minor flow system level of service objective (2 year or 5 year design storm) and 100 year design storm o Capture and manage the first 25 mm of site runoff for erosion control. - Meet other water quality obligations applicable to the sub-catchment.
Facility Assessment – Quality Control	Coverage (existing)	- Minimum 50% of impervious area drains to water quality facility
	Coverage (new)	- 100% of impervious area drains to water quality facility
	Target	- 80% Suspended solids removal - 70% Suspended solids removal (Grand River)
	Thermal Mitigation	- Per Subwatershed Studies or individual studies if a subwatershed study is not available
Facility Assessment – Water Balance		- Per Subwatershed Studies or individual studies if a subwatershed study is not available

Specifically, the stormwater management and conveyance system for both the North Expansion Lands and Tutela Heights must meet the following minimum control requirements across the entirety of the Secondary Plan Areas:

- Quantity control
  - Peak control – post-development peak flowrates controlled to pre-development peak flowrates and durations.
- Major system controls
  - All land development must have a major system in place capable of conveying the 100-year storm event
- Quality control
  - MECP Enhanced treatment (80% Total Suspended Solids (TSS) removal)

- Erosion control & water balance
    - Extended detention of the 4hr, 25mm Chicago storm

4.5 Level of Service

A minimum level of service for new developments is required to protect against flooding events. The following is the minimum level of service required for the North Expansion Lands & Tutela Heights Secondary Plan Areas:

- Minor System Level of Service
    - Conveyance of the 5-year storm event
- Major System Level of Service
    - Conveyance of the 100-year storm event

4.6 Stormwater Servicing Review & Needs Assessment

In the following subsections, land parcels have been split into drainage catchments based on their ultimate outlet location, the land use contained within the subcatchment, and the applicable control measures.

4.6.1 Northwest Employment Area (Pond #1) Preferred Strategy

The Northwest Employment Area subcatchment consists of approximately 109 ha of Prestige Employment and Supportive Employment lands along the northern and western boundary of the North Expansion Lands. The subcatchment is bound by agricultural lands to the north, east, and west, and Powerline Road to the south.

Under existing conditions, the subcatchment consists of agricultural land (RC=0.25, 0% impervious area) split between multiple parcels. Surface topography and historical aerial photography indicate that overland flows ultimately discharge to the South Branch of Lower Jones Creek via overland flow and minor channelization within the agricultural lands. **Section 2.8** has identified areas of slope erosion along the valley walls of Lower Jones Creek as well as significant slope erosion through Fairchild Creek. As Jones Creek discharges to Fairchild Creek, 48-72 hr extended detention up to the first 25mm of rainfall is required to protect the receiving bodies from erosion. Existing surface topography of the lands surrounding the subcatchment indicate that the external agricultural lands to the west sheet flow east towards the subcatchment. Further investigation of external flows is required to confirm the extent of losses (infiltration, evapotranspiration, hummocky pockets of standing water) and extent of external drainage entering the Northwest Employment Area.

Stormwater from Northwest Employment Area will be conveyed to SWM Pond #1, located north of Powerline Road and west of Golf Road. The pond will be sized to control the subcatchment's 100-year post-development peak flowrate back to the pre-development peak flowrate. To achieve post-to-pre flow control, a pond size of approximately 5.4 ha with an effective active storage depth of 1.25 m is required. In addition to providing peak flow (quantity) controls, the pond is proposed to provide TSS quality control treatment and thermal mitigation treatment. **Table 4-2** provides additional information on required pond sizing for quantity control.

Table 4-2: High-Level Pond Calculations

100-year Pre-Development Peak Flowrate (m^3/s)	100-year Uncontrolled Post-Development Peak Flowrate (m^3/s)	Required Effective Active Pond Volume (m^3)
5.25	35.05	67,000

All lands developed within the Northwest Employment Lands will require site-specific quality controls to ensure adequate TSS removal prior to discharge into SWM Pond #1, municipal conveyance infrastructure, or waterbodies. A minimum TSS removal of 80% (MECP Enhanced Removal) is required for the subcatchment.

The Northwest Employment Lands' surficial geology consists of a mixture of gravel, sand, diamicton, and clay, with the majority of the subcatchment consisting of clay and diamicton. Due to the hydraulic conductivity of the soil types present in the subcatchment, a groundwater recharge rate varying between <100 – 400 mm/yr (averaging approximately 300 mm/yr) is present under the pre-development conditions. As such, site-specific hydrogeological investigations will be required to ensure that post-development groundwater recharge meets the pre-development levels. A treatment-train approach is recommended with the inclusion of site-specific LIDs to achieve the required groundwater recharge. Additionally, the eastern portion of the subcatchment falls within a significant groundwater recharge area. As such, all development within the significant groundwater recharge area requires quality control pre-treatment prior to any forms of infiltration. Only clean water is permitted for infiltration to meet the groundwater recharge requirements. Additional information on groundwater recharge vulnerability is found in the **Section 2.6**.

A summary of the final preferred servicing strategy is contained in **Table 4-3**.

Table 4-3: Servicing Strategy for Applicable Control Criteria Requirements

Criteria	Control Requirement	Servicing Strategy
Minor System Conveyance	5-year storm event	• Underground linear conveyance infrastructure
Major System Conveyance	100-year storm event	• Overland flow conveyance to SWM Pond #1
Peak flow control (100-year storm event)	Post-development to pre-development peak flowrates	• Peak flow control via SWM Pond #1
Quality Control	MECP Enhanced (80% TSS removal)	• Site specific controls (OGS, LIDs, etc.) in treatment train with SWM Pond #1
Water balance/infiltration	Post-development to pre-development infiltration volume	• Site specific infiltration via LIDs, ensuring clean water in areas of significant groundwater recharge
Erosion control	Retain up to the 25mm event with 48-72 hr extended detention	• Extended detention via site specific LIDs or Pond #1
Thermal Mitigation	SWM Pond requires thermal mitigation at outlet	• Low Impact Development (LID) strategies or cooling trench at pond outlet required to mitigate thermal impact from development

4.6.2 Southwest Employment Area (Pond #2) Preferred Strategy

The Southwest Employment Area subcatchment consists of approximately 97 ha of Prestige Employment and Supportive Employment land uses along the western boundary of the North Expansion Lands. The subcatchment is bound by Powerline Road to the north, Golf Road to the east, and the CN railway to the south and west.

Under existing conditions, the subcatchment consists of agricultural land (RC=0.25, 0% impervious area) split between multiple parcels. Paris Road divides the subcatchment into two distinct halves. Surface topography indicates that overland flows ultimately discharge to the South Branch of Lower Jones Creek via overland flow and minor, temporary channelization within the agricultural lands. **Section 2.8** has identified areas of slope erosion along the valley walls of Lower Jones Creek as well as significant slope erosion through Fairchild Creek. As Jones Creek discharges to Fairchild Creek, 48-72 hr extended detention up to the first 25mm of rainfall is required to protect the receiving bodies from erosion. Existing surface topography of the lands surrounding the subcatchment indicate that there are no significant external flows entering the subcatchment. Further investigation of external flows entering the Northwest Employment Area is required due to the preliminary nature of the available information.

Stormwater from the Southwest Employment Area will be conveyed to SWM Pond #2, located west of Golf Road. The pond will be sized to control the subcatchment's 100-year post-development peak flowrate back to the pre-development peak flowrate. To achieve post-to-pre flow controls, a pond size of approximately 5.0 ha with an effective active storage depth of 1.25 m is required. In addition to providing peak flow (quantity) controls, the pond will provide TSS quality control treatment and thermal mitigation treatment. **Table 4-4** provides information on required pond sizing for quantity control.

Table 4-4: High-Level Pond Calculations

100-year Pre-Development Peak Flowrate (m^3/s)	100-year Uncontrolled Post-Development Peak Flowrate (m^3/s)	Required Effective Active Pond Volume (m^3)
4.62	31.70	62,000

All lands developed within the Southwest Employment Area will require site-specific quality controls to ensure adequate TSS removal prior to discharge into SWM Pond #2, municipal conveyance infrastructure, or waterbodies. A minimum TSS removal of 80% (MECP Enhanced Removal) is required for the subcatchment.

The Southwest Employment Lands' surficial geology predominantly consists of a mixture of gravel and sand, with small areas of diamicton. Due to hydraulic conductivity of the soil types present in the subcatchment, an average groundwater recharge rate of approximately 300 mm/yr is present under the pre-development conditions. As such, site-specific hydrogeological investigations will need to be conducted to ensure that post-development groundwater recharge meets the pre-development levels. A treatment-train approach is recommended with the inclusion of site-specific LIDs to achieve the required groundwater recharge. Additionally, the lands within the southeast corner of the subcatchment lie above a highly vulnerable aquifer. As such, all development within the highly vulnerable aquifer area requires quality control pre-treatment prior to any forms of infiltration. Only clean water is permitted for infiltration to meet the groundwater recharge requirements. Additional information on the highly vulnerable aquifer is found in the **Section 2.6**.

A summary of the final preferred servicing strategy is contained in **Table 4-5**.

Table 4-5: Servicing Strategy for Applicable Control Criteria Requirements

Criteria	Control Requirement	Servicing Strategy
Minor System Conveyance	5-year storm event	• Underground linear conveyance infrastructure
Major System Conveyance	100-year storm event	• Overland flow conveyance to SWM Pond #2
Peak flow control (100-year storm event)	Post-development to pre-development peak flowrates	• Peak flow control via SWM Pond #2
Quality Control	MECP Enhanced (80% TSS removal)	• Site specific controls (OGS, LIDs, etc.) in treatment train with SWM Pond #2
Water balance/infiltration	Post-development to pre-development infiltration volume	• Site specific infiltration via LIDs, ensuring clean water due to highly vulnerable aquifer
Erosion control	Retain up to the 25mm event with 48-72 hr extended detention	• Extended detention via site specific LIDs or Pond #2
Thermal Mitigation	SWM Pond requires thermal mitigation at outlet	• Low Impact Development (LID) strategies or cooling trench at pond outlet required to mitigate thermal impact from development

4.6.3 Golf Road North Employment Area (Pond #3) Preferred Strategy

The Golf Road North Employment Area subcatchment consists of approximately 28 ha of General Employment lands along the northern boundary of the North Expansion Lands. The subcatchment is bound by rural and natural heritage lands to the north, east, south, and west, with Golf Road running through the center of the subcatchment.

Under existing conditions, the subcatchment consists of agricultural land (RC=0.25, 0% impervious area) split between multiple parcels. The subcatchment contains a natural drainage channel which conveys drainage from the agricultural lands to the South Branch of Lower Jones Creek. The **Section 2.8** has identified areas of slope erosion along the valley walls of Lower Jones Creek as well as significant slope erosion through Fairchild Creek. As Jones Creek discharges to Fairchild Creek, 48-72 hr extended detention up to the first 25mm of rainfall is required to protect the receiving bodies from erosion.

Existing surface topography of the lands surrounding the subcatchment indicate that the external agricultural lands to the north and west drain naturally towards the subcatchment. The external flows are conveyed from west to east through the subcatchment via the South Branch of Lower Jones Creek. Additionally, a segment of the South Branch of Lower Jones Creek aligns with the southern border of the subcatchment within a Natural Heritage Area. This section of the creek conveys flows from the Northwest Employment Area from west to east. Further investigation of external flows is required to confirm the extent of losses (infiltration, evapotranspiration, hummocky pockets of standing water) and extent of external drainage entering the Golf Road North Employment Area.

Stormwater from Golf Road North Employment Area will be conveyed to SWM Pond #3, located east of Golf Road, at the southeast corner of the subcatchment where the existing drainage channel is located. The pond will be sized to control the subcatchment's 100-year post-development peak flowrate back to the pre-development peak flowrate. To achieve post-to-pre flow controls, a pond size of approximately 1.3 ha with an effective active storage depth of 1.25 m is required. In addition to providing peak flow (quantity) controls, the pond is proposed to provide TSS quality control treatment and thermal mitigation treatment. **Table 4-6** provides additional information on required pond sizing for quantity control.

Table 4-6: High-Level Pond Calculations

100-year Pre-Development Peak Flowrate (m^3/s)	100-year Uncontrolled Post-Development Peak Flowrate (m^3/s)	Required Effective Active Pond Volume (m^3)
1.82	9.17	16,000

All lands developed within the Golf Road North Employment Lands will require site-specific quality controls to ensure adequate TSS removal prior to discharge into SWM Pond #3, municipal conveyance infrastructure, or waterbodies. A minimum TSS removal of 80% (MECP Enhanced Removal) is required for the subcatchment.

The Golf Road North Employment Lands' surficial geology consists predominantly of clay soils with a portion of diamicton. Due to the hummocky nature of the soils present in the subcatchment, a groundwater recharge rate averaging approximately 300 mm/yr is present under the pre-development conditions. As such, site-specific hydrogeological investigations will be required to ensure that post-development groundwater recharge meets the pre-development levels. A treatment-train approach is recommended with the inclusion of site-specific LIDs to achieve the required groundwater recharge. Additional information on groundwater recharge is found in the **Section 2.6**.

A summary of the final preferred servicing strategy is contained in **Table 4-7**.

Table 4-7: Servicing Strategy for Applicable Control Criteria Requirements

Criteria	Control Requirement	Servicing Strategy
Minor System Conveyance	5-year storm event	• Underground linear conveyance infrastructure
Major System Conveyance	100-year storm event	• Overland flow conveyance to SWM Pond #3
Peak flow control (100-year storm event)	Post-development to pre-development peak flowrates	• Peak flow control via SWM Pond #3
Quality Control	MECP Enhanced (80% TSS removal)	• Site specific controls (OGS, LIDs, etc.) in treatment train with SWM Pond #3
Water balance/infiltration	Post-development to pre-development infiltration volume	• Site specific infiltration via LIDs
Erosion control	Retain up to the 25mm event with 48-72 hr extended detention	• Extended detention via site specific LIDs or Pond #3
Thermal Mitigation	SWM Pond requires thermal mitigation at outlet	• Low Impact Development (LID) strategies or cooling trench at pond outlet required to mitigate thermal impact from development

4.6.4 Golf-Powerline Employment Area (Pond #4) Preferred Strategy

The Golf-Powerline Employment Area subcatchment consists of approximately 62 ha of Prestige Employment, Supportive Employment, and General Employment lands along the northern and western boundary of the North Expansion Lands. The subcatchment is bound by agricultural lands to the north, east, and west, and Powerline Road to the south, with Golf Road running through the center of the subcatchment.

Under existing conditions, the subcatchment consists of agricultural land (RC=0.25, 0% impervious area) split between multiple parcels. The subcatchment is surrounded by small natural outlet channels to both the north and east, with the natural drainage outlet at the northeast corner of the subcatchment. Stormwater from the Golf-Powerline Employment Area subcatchment ultimately discharges to the South

Branch of Lower Jones Creek. The **Section 2.8** has identified areas of slope erosion along the valley walls of Lower Jones Creek as well as significant slope erosion through Fairchild Creek. As Jones Creek discharges to Fairchild Creek, 48-72 hr extended detention up to the first 25mm of rainfall is required to protect the receiving bodies from erosion.

Existing surface topography of the lands surrounding the subcatchment indicate that the external agricultural lands to the south and east naturally drain towards the Natural Heritage lands bordering the northern and eastern extents of the subcatchment. The external flows are conveyed along the borders of the subcatchment via the South Branch of Lower Jones Creek, including stormwater from proposed Pond #1, 2, and 3. Further investigation of external flows is required to confirm the extent of losses (infiltration, evapotranspiration, hummocky pockets of standing water) and extent of external drainage conveyed along the borders of the Golf-Powerline Employment Area.

Stormwater from Golf-Powerline Employment Area will be conveyed to SWM Pond #4, located along the northern border of the subcatchment, north of Powerline Road and east of Golf Road. The pond will be sized to control the subcatchment's 100-year post-development peak flowrate back to the pre-development peak flowrate. To achieve post-to-pre flow controls, a pond size of approximately 3.2 ha with an effective active storage depth of 1.25 m is required. In addition to providing peak flow (quantity) controls, the pond is proposed to provide TSS quality control treatment and thermal mitigation treatment. **Table 4-8** provides additional information on required pond sizing for quantity control.

Table 4-8: High-Level Pond Calculations

100-year Pre-Development Peak Flowrate (m^3/s)	100-year Uncontrolled Post-Development Peak Flowrate (m^3/s)	Required Effective Active Pond Volume (m^3)
2.78	20.12	40,000

All lands developed within the Golf-Powerline Employment Lands will require site-specific quality controls to ensure adequate TSS removal prior to discharge into SWM Pond #4, municipal conveyance infrastructure, or waterbodies. A minimum TSS removal of 80% (MECP Enhanced Removal) is required for the subcatchment.

The Golf-Powerline Employment Lands' surficial geology consists of predominantly clay soils with a small portion of diamicton and sand. Due to the hummocky nature of the soils present in the subcatchment, a groundwater recharge rate averaging approximately 300 mm/yr is present under the pre-development conditions. As such, site-specific hydrogeological investigations will be required to ensure that post-development groundwater recharge meets the pre-development levels. A treatment-train approach is recommended with the inclusion of site-specific LIDs to achieve the required groundwater recharge. Additionally, the southwestern portion of the subcatchment falls within a significant groundwater recharge area. As such, all development within the significant recharge area requires quality control pre-treatment prior to any forms of infiltration. Only clean water is permitted for infiltration to meet the groundwater recharge requirements. Additional information on groundwater recharge vulnerability is found in the **Section 2.6**.

A summary of the final preferred servicing strategy is contained in **Table 4-9**.

Table 4-9: Servicing Strategy for Applicable Control Criteria Requirements

Criteria	Control Requirement	Servicing Strategy
Minor System Conveyance	5-year storm event	• Underground linear conveyance infrastructure
Major System Conveyance	100-year storm event	• Overland flow conveyance to SWM Pond #4
Peak flow control (100-year storm event)	Post-development to pre-development peak flowrates	• Peak flow control via SWM Pond #4
Quality Control	MECP Enhanced (80% TSS removal)	• Site specific controls (OGS, LIDs, etc.) in treatment train with SWM Pond #4
Water balance/infiltration	Post-development to pre-development infiltration volume	• Site specific infiltration via LIDs, ensuring clean water in areas of significant groundwater recharge
Erosion control	Retain up to the 25mm event with 48-72 hr extended detention	• Extended detention via site specific LIDs or Pond #4
Thermal Mitigation	SWM Pond requires thermal mitigation at outlet	• Low Impact Development (LID) strategies or cooling trench at pond outlet required to mitigate thermal impact from development

4.6.5 Balmoral-Powerline Northwest (Pond #5) Preferred Strategy

The Balmoral-Powerline Northwest subcatchment consists of approximately 42 ha of mixed-use lands, including a portion of the neighbourhood corridor lands north of Powerline Road. The subcatchment is bound by natural heritage lands to the north, agricultural lands to the east, and west, and Powerline Road to the south.

Under existing conditions, the subcatchment consists of agricultural land (RC=0.25, 0% impervious area) split between multiple parcels. The subcatchment is surrounded by small natural outlet channels to the north, east, and west, with the natural drainage outlet along the northern border of the subcatchment. Stormwater from the Balmoral-Powerline Northwest subcatchment ultimately discharge to the South Branch of Lower Jones Creek. The **Section 2.8** has identified areas of slope erosion along the valley walls of Lower Jones Creek as well as significant slope erosion through Fairchild Creek. As Jones Creek discharges to Fairchild Creek, 48-72 hr extended detention up to the first 25mm of rainfall is required to protect the receiving bodies from erosion.

Existing surface topography of the lands surrounding the subcatchment indicate that the external agricultural lands to the south drain through the eastern limits of the Balmoral-Powerline subcatchment. Specifically, stormwater is conveyed from the subdivision north of the Paris Road interchange northerly through the Balmoral-Powerline Southwest subcatchment, entering the Balmoral-Powerline Northwest at the southeast corner and ultimately being conveyed north to the South Branch of Lower Jones Creek. A portion of the public golf course southeast of the subcatchment is also conveyed through the Balmoral-Powerline Southwest subcatchment via the same drainage pathway. The channel conveying the external flows is not within the Natural Heritage Area, which may provide the ability to bury the channel, subject to approval by the GRCA for any features within their jurisdiction. Further investigation of external flows is required to confirm the extent of losses (infiltration, evapotranspiration, hummocky pockets of standing water) and extent of external drainage conveyed along through the Balmoral-Powerline Northwest subcatchment.

Stormwater from Balmoral-Powerline Northwest subcatchment will be conveyed to SWM Pond #5, located along the northern border of the subcatchment. The pond will be sized to control the subcatchment's 100-year post-development peak flowrate back to the pre-development peak flowrate. To achieve post-to-pre flow controls, a pond size of approximately 2.0 ha with an effective active storage depth of 1.25 m is required. In addition to providing peak flow (quantity) controls, the pond is proposed to provide TSS quality control treatment and thermal mitigation treatment. **Table 4-10** provides additional information on required pond sizing for quantity control.

Table 4-10: High-Level Pond Calculations

100-year Pre-Development Peak Flowrate (m^3/s)	100-year Uncontrolled Post-Development Peak Flowrate (m^3/s)	Required Effective Active Pond Volume (m^3)
1.82	12.56	25,000

All lands developed within the Balmoral-Powerline Northwest subcatchment will require site-specific quality controls to ensure adequate TSS removal prior to discharge into SWM Pond #5, municipal conveyance infrastructure, or waterbodies. A minimum TSS removal of 80% (MECP Enhanced Removal) is required for the subcatchment.

The Balmoral-Powerline Northwest subcatchment's surficial geology consists entirely of clay soils. Due to the hummocky nature of the soils present in the subcatchment, a groundwater recharge rate averaging approximately 300 mm/yr is present under the pre-development conditions. As such, site-specific hydrogeological investigations will be required to ensure that post-development groundwater recharge meets the pre-development levels. A treatment-train approach is recommended with the inclusion of site-specific LIDs to achieve the required groundwater recharge. Additional information on groundwater recharge is found in the **Section 2.6**.

A summary of the final preferred servicing strategy is contained in **Table 4-11**.

Table 4-11: Servicing Strategy for Applicable Control Criteria Requirements

Criteria	Control Requirement	Servicing Strategy
Minor System Conveyance	5-year storm event	• Underground linear conveyance infrastructure
Major System Conveyance	100-year storm event	• Overland flow conveyance to SWM Pond #5
Peak flow control (100-year storm event)	Post-development to pre-development peak flowrates	• Peak flow control via SWM Pond #5
Quality Control	MECP Enhanced (80% TSS removal)	• Site specific controls (OGS, LIDs, etc.) in treatment train with SWM Pond #5
Water balance/infiltration	Post-development to pre-development infiltration volume	• Site specific infiltration via LIDs
Erosion control	Retain up to the 25mm event with 48-72 hr extended detention	• Extended detention via site specific LIDs or Pond #5
Thermal Mitigation	SWM Pond requires thermal mitigation at outlet	• Low Impact Development (LID) strategies or cooling trench at pond outlet required to mitigate thermal impact from development

4.6.6 Balmoral-Powerline Southwest (Pond #6) Preferred Strategy

The Balmoral-Powerline Southwest subcatchment consists of approximately 60 ha of predominantly Neigbourhood Residential lands, including portions of the Neighbourhood Corridor lands and Neighbourhood Centre lands south of Powerline Road. The subcatchment is bound by Powerline Road to the north, a golf course to the east, a residential subdivision to the south, and natural heritage lands to the west.

Under existing conditions, the subcatchment consists of agricultural land (RC=0.25, 0% impervious area) split between multiple parcels. There are stormwater management ponds adjacent to the subcatchment boundaries located in both the golf course to the east and the residential subdivision to the south. The adjacent stormwater ponds discharge overland to the Balmoral-Powerline Southwest subcatchment, with stormwater conveyed south to north through the subcatchment. The stormwater leaves the Balmoral-Powerline Southwest subcatchment, is conveyed through the Balmoral-Powerline Northwest subcatchment, and ultimately discharges to the South Branch of Lower Jones Creek. The **Section 2.8** has identified areas of slope erosion along the valley walls of Lower Jones Creek as well as significant slope erosion through Fairchild Creek. As Jones Creek discharges to Fairchild Creek, 48-72 hr extended detention up to the first 25mm of rainfall is required to protect the receiving bodies from erosion.

Existing surface topography of the lands surrounding the subcatchment indicates that there are negligible external overland flows entering the Balmoral-Powerline Southwest subcatchment; however, City's stormwater infrastructure data indicates that stormwater is conveyed from both the subdivision north of the Paris Road interchange and the golf course east of Balmoral Drive into the Balmoral-Powerline Southwest subcatchment. The stormwater enters via both the eastern and southern border of the subcatchment and is currently conveyed overland to the Balmoral-Powerline Northwest subcatchment. The channel conveying the external flows is not within the Natural Heritage Area, which may provide the ability to bury the channel, which may provide the ability to bury the channel, subject to approval by the GRCA for any features within their jurisdiction. Further investigation of external flows is required to confirm the extent of losses (infiltration, evapotranspiration, hummocky pockets of standing water) and extent of external drainage conveyed into the Balmoral-Powerline Southwest subcatchment. Under existing conditions, there are inadequate overland flow pathways to control the major storm event. Prior to development, an adequate overland flow path will be required. A future study reviewing the potential oversizing of the culvert crossing Powerline Road is recommended to potentially handle major overland flows.

Stormwater from the Balmoral-Powerline Southwest subcatchment will be conveyed to SWM Pond #6, located along the northern border of the subcatchment, south of Powerline Road. The pond will be sized to control the subcatchment's 100-year post-development peak flowrate back to the pre-development peak flowrate. To achieve post-to-pre flow controls, a pond size of approximately 1.5 ha with an effective active storage depth of 1.25 m is required. In addition to providing peak flow (quantity) controls, the pond is proposed to provide TSS quality control treatment and thermal mitigation treatment. **Table 4-12** provides additional information on required pond sizing for quantity control.

Table 4-12: High-Level Pond Calculations

100-year Pre-Development Peak Flowrate (m^3/s)	100-year Uncontrolled Post-Development Peak Flowrate (m^3/s)	Required Effective Active Pond Volume (m^3)
2.92	11.79	19,000

All lands developed within the Balmoral-Powerline Southwest subcatchment will require site-specific quality controls to ensure adequate TSS removal prior to discharge into SWM Pond #6, municipal conveyance infrastructure, or waterbodies. A minimum TSS removal of 80% (MECP Enhanced Removal) is required for the subcatchment.

The Balmoral-Powerline Southwest subcatchment's surficial geology consists partially of clay soils and partially of sand. Due to the hummocky nature and high hydraulic conductivity of the sandy soils present in the subcatchment, a groundwater recharge rate ranging from 0 to 400 mm/yr is present under the pre-development conditions, averaging approximately 300 mm/yr. As such, site-specific hydrogeological investigations will be required to ensure that post-development groundwater recharge meets the pre-development levels. A treatment-train approach is recommended with the inclusion of site-specific LIDs to achieve the required groundwater recharge. Additional information on groundwater recharge is found in the **Section 2.6**.

A summary of the final preferred servicing strategy is contained in **Table 4-13**.

Table 4-13: Servicing Strategy for Applicable Control Criteria Requirements

Criteria	Control Requirement	Servicing Strategy
Minor System Conveyance	5-year storm event	• Underground linear conveyance infrastructure
Major System Conveyance	100-year storm event	• Overland flow conveyance to SWM Pond #6
Peak flow control (100-year storm event)	Post-development to pre-development peak flowrates	• Peak flow control via SWM Pond #6
Quality Control	MECP Enhanced (80% TSS removal)	• Site specific controls (OGS, LIDs, etc.) in treatment train with SWM Pond #6
Water balance/infiltration	Post-development to pre-development infiltration volume	• Site specific infiltration via LIDs
Erosion control	Retain up to the 25mm event with 48-72 hr extended detention	• Extended detention via site specific LIDs or Pond #6
Thermal Mitigation	SWM Pond requires thermal mitigation at outlet	• Low Impact Development (LID) strategies or cooling trench at pond outlet required to mitigate thermal impact from development

4.6.7 Northridge North (Pond #7) Preferred Strategy

The Northridge North subcatchment consists of approximately 45 ha of predominantly Neigbourhood Residential and Neighbourhood Corridor lands north of Powerline Road. The subcatchment is bound by natural heritage lands to the north and east, Powerline Road to the south, and agricultural lands to the west.

Under existing conditions, the subcatchment consists of agricultural land (RC=0.25, 0% impervious area) split between multiple parcels. There are stormwater conveyance channels/pathways conveying stormwater through the subject lands from both the Northridge Public Golf Course and the Balmoral-Powerline Southwest subcatchment. Ultimately, the external drainage, as well as drainage from the Northridge North subcatchment are conveyed to the South Branch of Lower Jones Creek. The **Section 2.8** has identified areas of slope erosion along the valley walls of Lower Jones Creek as well as significant slope erosion through Fairchild Creek. As Jones Creek discharges to Fairchild Creek, 48-72 hr extended detention up to the first 25mm of rainfall is required to protect the receiving bodies from erosion.

Existing surface topography of the lands surrounding the subcatchment indicates that a portion of the golf course to the south drains through the middle of the Northridge North subcatchment, ultimately being conveyed north to the South Branch of Lower Jones Creek. The channel conveying the external flows is not within the Natural Heritage Area, which may provide the ability to bury the channel, which may provide the ability to bury the channel, subject to approval by the GRCA for any features within their jurisdiction. The eastern limit of the subcatchment borders natural heritage lands which contain a channel conveying stormwater from the residential subdivision south of Powerline Road to the South Branch of Lower Jones Creek to the north of the subcatchment. Further investigation of external flows is required to confirm the extent of losses (infiltration, evapotranspiration, hummocky pockets of standing water) and extent of external drainage conveyed along through the Northridge North subcatchment.

Stormwater from the Northridge North subcatchment will be conveyed to SWM Pond #7, located along the northern border of the subcatchment, south of the natural heritage lands. The pond will be sized to control the subcatchment's 100-year post-development peak flowrate back to the pre-development peak flowrate. To achieve post-to-pre flow controls, a pond size of approximately 1.1 ha with an effective active storage depth of 1.25 m is required. In addition to providing peak flow (quantity) controls, the pond is proposed to provide TSS quality control treatment and thermal mitigation treatment. **Table 4-14** provides additional information on required pond sizing for quantity control.

Table 4-14: High-Level Pond Calculations

100-year Pre-Development Peak Flowrate (m^3/s)	100-year Uncontrolled Post-Development Peak Flowrate (m^3/s)	Required Effective Active Pond Volume (m^3)
2.55	9.13	14,000

All lands developed within the Northridge North will require site-specific quality controls to ensure adequate TSS removal prior to discharge into SWM Pond #7, municipal conveyance infrastructure, or waterbodies. A minimum TSS removal of 80% (MECP Enhanced Removal) is required for the subcatchment.

The Northridge North subcatchment's surficial geology consists entirely of clay soils. Due to the hummocky nature and high hydraulic conductivity of the sandy soils present in the subcatchment, a groundwater recharge rate averaging approximately 300 mm/yr is present under the pre-development conditions. As such, site-specific hydrogeological investigations will be required to ensure that post-development groundwater recharge meets the pre-development levels. A treatment-train approach is recommended with the inclusion of site-specific LIDs to achieve the required groundwater recharge. Additional information on groundwater recharge is found the **Section 2.6**.

A summary of the final preferred servicing strategy is contained in **Table 4-15**.

Table 4-15: Servicing Strategy for Applicable Control Criteria Requirements

Criteria	Control Requirement	Servicing Strategy
Minor System Conveyance	5-year storm event	• Underground linear conveyance infrastructure
Major System Conveyance	100-year storm event	• Overland flow conveyance to SWM Pond #7
Peak flow control (100-year storm event)	Post-development to pre-development peak flowrates	• Peak flow control via SWM Pond #7
Quality Control	MECP Enhanced (80% TSS removal)	• Site specific controls (OGS, LIDs, etc.) in treatment train with SWM Pond #7
Water balance/infiltration	Post-development to pre-development infiltration volume	• Site specific infiltration via LIDs
Erosion control	Retain up to the 25mm event with 48-72 hr extended detention	• Extended detention via site specific LIDs or Pond #7
Thermal Mitigation	SWM Pond requires thermal mitigation at outlet	• Low Impact Development (LID) strategies or cooling trench at pond outlet required to mitigate thermal impact from development

4.6.8 King George Corridor (Pond #8, 9, & 10) Preferred Strategy

The King George Corridor subcatchment consists of approximately 84 ha of Neigbourhood Residential and Neighbourhood Corridor lands north of Powerline Road, as well as the Intensification Corridor lands along King George Road and Neighbourhood Centre lands along a future intersection north of Powerline Road. The subcatchment is bound by natural heritage lands to the north and west, agricultural lands to the east, and Powerline Road to the south.

Under existing conditions, the subcatchment consists of agricultural land (RC=0.25, 0% impervious area) split between multiple parcels. There are stormwater conveyance channels/pathways along both the east and west borders of the subcatchment, with the easterly channel conveying drainage from the existing King George Corridor subcatchment and the westerly channel conveying drainage from a residential subdivision south of Powerline Road and west of King George Road. Ultimately, the external drainage and drainage from the King George Corridor are conveyed to Lower Jones Creek. The **Section 2.8** has identified areas of slope erosion along the valley walls of Lower Jones Creek as well as significant slope erosion through Fairchild Creek. As Jones Creek discharges to Fairchild Creek, 48-72 hr extended detention up to the first 25mm of rainfall is required to protect the receiving bodies from erosion.

Existing surface topography of the lands surrounding the subcatchment indicate that negligible external drainage enters the King George Corridor subcatchment. The eastern (Tributary K) and western limits of the subcatchment border natural heritage lands which both contain channels conveying stormwater from residential subdivisions south of Powerline Road to Lower Jones Creek, north of the King George Corridor subcatchment. Further investigation of external flows is required to confirm the extent of losses (infiltration, evapotranspiration, hummocky pockets of standing water) and extent of external drainage conveyed along through the King George Corridor subcatchment.

Stormwater from the King George Corridor subcatchment will be conveyed to SWM Pond #8, 9, or 10, south of the natural heritage lands. The ponds will be sized to control the subcatchment's 100-year post-development peak flowrate back to the pre-development peak flowrate. To achieve post-to-pre flow controls, Pond #8, 9, and 10 combine for an area of approximately 2.6 ha with an effective active storage depth of 1.25 m. In addition to providing peak flow (quantity) controls, the ponds are proposed to provide TSS quality control treatment and thermal mitigation treatment. **Table 4-16** provides additional information on required pond sizing for quantity control.

Table 4-16: High-Level Pond Calculations

Pond #	100-year Pre-Development Peak Flowrate (m^3/s)	100-year Uncontrolled Post-Development Peak Flowrate (m^3/s)	Required Effective Active Pond Volume (m^3)
8	3.06	10.54	16,000
9	1.30	5.82	10,000
10	0.94	3.45	6,000

All lands developed within the King George Corridor subcatchment will require site-specific quality controls to ensure adequate TSS removal prior to discharge into SWM Pond #8, 9, or 10, municipal conveyance infrastructure, or waterbodies. A minimum TSS removal of 80% (MECP Enhanced Removal) is required for the subcatchment.

The King George Corridor subcatchment's surficial geology consists entirely of clay soils. Per the GRCA GIS, groundwater recharge within the King George Corridor subcatchment is negligible. Site-specific hydrogeological investigations will be required to verity preexisting recharge rates to ensure that post-development groundwater recharge meets the pre-development levels. A treatment-train approach is recommended with the inclusion of site-specific LIDs to achieve the required groundwater recharge. Additional information on groundwater recharge is found in the **Section 2.6**.

A summary of the final preferred servicing strategy is contained in **Table 4-17**.

Table 4-17: Servicing Strategy for Applicable Control Criteria Requirements

Criteria	Control Requirement	Servicing Strategy
Minor System Conveyance	5-year storm event	• Underground linear conveyance infrastructure
Major System Conveyance	100-year storm event	• Overland flow conveyance to SWM Pond #8, 9, and 10
Peak flow control (100-year storm event)	Post-development to pre-development peak flowrates	• Peak flow control via SWM Pond #8, 9, and 10
Quality Control	MECP Enhanced (80% TSS removal)	• Site specific controls (OGS, LIDs, etc.) in treatment train with SWM Pond #8, 9, and 10
Water balance/infiltration	Post-development to pre-development infiltration volume	• Site specific infiltration via LIDs
Erosion control	Retain up to the 25mm event with 48-72 hr extended detention	• Extended detention via site specific LIDs or Pond #8, 9, and 10
Thermal Mitigation	SWM Pond requires thermal mitigation at outlet	• Low Impact Development (LID) strategies or cooling trench at pond outlet required to mitigate thermal impact from development

4.6.9 Powerline-Park (Pond #11 & 12) Preferred Strategy

The Powerline-Park subcatchment consists of approximately 56 ha of Neigbourhood Residential, Neighbourhood Corridor, Neighbourhood Centre, and Intensification Corridor lands north of Powerline Road and west of Memorial Drive. The subcatchment is bound by natural heritage lands to the north and west, Memorial Drive to the east, and Powerline Road to the south.

Under existing conditions, the subcatchment consists of agricultural land (RC=0.25, 0% impervious area) split between multiple parcels. There are stormwater conveyance channels/pathways along both the western border as well as through the middle of the subcatchment. Ultimately, the external drainage as well as drainage from the Powerline-Park subcatchment are conveyed to the Lower Jones Creek. The **Section 2.8** has identified areas of slope erosion along the valley walls of Lower Jones Creek as well as significant slope erosion through Fairchild Creek. As Jones Creek discharges to Fairchild Creek, 48-72 hr extended detention up to the first 25mm of rainfall is required to protect the receiving bodies from erosion.

Existing surface topography of the lands surrounding the subcatchment indicate that external drainage from south of Powerline Road enters the King George Corridor subcatchment via a watercourse/channel (Ravine Tributary H) flowing south to north, ultimately discharging to Lower Jones Creek. The western limits (Tributary K) of the subcatchment borders natural heritage lands which contain a channel conveying stormwater from a residential subdivision south of Powerline Road to Lower Jones Creek, north of the Powerline-Park subcatchment. Further investigation of external flows is required to confirm the extent of losses (infiltration, evapotranspiration, hummocky pockets of standing water) and extent of external drainage conveyed along through the Powerline-Park subcatchment.

Stormwater from the Powerline-Park subcatchment will be conveyed to SWM Pond #11 and 12, south of the natural heritage lands. The ponds will be sized to control the subcatchment's 100-year post-development peak flowrate back to the pre-development peak flowrate. To achieve post-to-pre flow controls, Pond #11 and 12 combine for an area of approximately 1.6 ha with an effective active storage depth of 1.25 m. In addition to providing peak flow (quantity) controls, the ponds are proposed to provide TSS quality control treatment and thermal mitigation treatment. **Table 4-18** provides additional information on required pond sizing for quantity control.

Table 4-18: High-Level Pond Calculations

Pond #	100-year Pre-Development Peak Flowrate (m^3/s)	100-year Uncontrolled Post-Development Peak Flowrate (m^3/s)	Required Effective Active Pond Volume (m^3)
11	1.46	4.64	7,000
12	1.95	8.08	13,000

All lands developed within the Powerline-Park subcatchment will require site-specific quality controls to ensure adequate TSS removal prior to discharge into SWM Pond #11 or 12, municipal conveyance infrastructure, or waterbodies. A minimum TSS removal of 80% (MECP Enhanced Removal) is required for the subcatchment.

The Powerline-Park subcatchment's surficial geology consists of approximately half clay soils and half sand soils. Per the GRCA GIS, groundwater recharge within the Powerline-Park subcatchment varies between 0 mm/yr and 400 mm/yr. Site-specific hydrogeological investigations will be required to ensure that post-development groundwater recharge meets the pre-development levels. A treatment-train approach is recommended with the inclusion of site-specific LIDs to achieve the required groundwater recharge. Additional information on groundwater recharge is found in the **Section 2.6**.

A summary of the final preferred servicing strategy is contained in **Table 4-19**.

Table 4-19: Servicing Strategy for Applicable Control Criteria Requirements

Criteria	Control Requirement	Servicing Strategy
Minor System Conveyance	5-year storm event	• Underground linear conveyance infrastructure
Major System Conveyance	100-year storm event	• Overland flow conveyance to SWM Pond #11 and 12
Peak flow control (100-year storm event)	Post-development to pre-development peak flowrates	• Peak flow control via SWM Pond #11 and 12
Quality Control	MECP Enhanced (80% TSS removal)	• Site specific controls (OGS, LIDs, etc.) in treatment train with SWM Pond #11 and 12
Water balance/infiltration	Post-development to pre-development infiltration volume	• Site specific infiltration via LIDs
Erosion control	Retain up to the 25mm event with 48-72 hr extended detention	• Extended detention via site specific LIDs or Pond #11 and 12
Thermal Mitigation	SWM Pond requires thermal mitigation at outlet	• Low Impact Development (LID) strategies or cooling trench at pond outlet required to mitigate thermal impact from development

4.6.10 Northeast Residential (Pond #13, 14, & 15) Preferred Strategy

The Northeast Residential subcatchment consists of approximately 111 ha of Neigbourhood Residential, Neighbourhood Corridor, Neighbourhood Centre, and Intensification Corridor lands north of Powerline Road and east of Memorial Drive. The subcatchment is bound by natural heritage lands to the north, agricultural lands to the east, Powerline Road to the south, and Memorial Drive to the west.

Under existing conditions, the subcatchment consists of agricultural land (RC=0.25, 0% impervious area) split between multiple parcels. There are stormwater conveyance channels/pathways along both the northern border as well as through the middle of the subcatchment contained within natural heritage lands, discharging through the southeast corner of the subcatchment. Existing surface topography of the lands surrounding the subcatchment indicate that negligible external drainage enters the Northeast Residential subcatchment. Approximately 41 ha of the drainage is conveyed to Lower Jones Creek, while the remaining 70 ha is conveyed to Karek Trubutary North. Ultimately, the contents of both Lower Jones Creek and Karek Tributary North discharge to Fairchild Creek. The **Section 2.8** has identified areas of slope erosion along the valley walls of Lower Jones Creek as well as significant slope erosion through Fairchild Creek. As both Jones Creek and Karek Tributary discharge to Fairchild Creek, 48-72 hr extended detention up to the first 25mm of rainfall is required to protect the receiving bodies from erosion.

Stormwater from the Northeast Residential subcatchment will be conveyed to SWM Pond #13, 14, and 15. The ponds will be sized to control the subcatchment's 100-year post-development peak flowrate back to the pre-development peak flowrate. To achieve post-to-pre flow controls, Pond #13, 14, and 15 combine for an area of approximately 3.2 ha with an effective active storage depth of 1.25 m. In addition to providing peak flow (quantity) controls, the ponds are proposed to provide TSS quality control treatment and thermal mitigation treatment. **Table 4-20** provides additional information on required pond sizing for quantity control.

Table 4-20: High-Level Pond Calculations

Pond #	100-year Pre-Development Peak Flowrate (m^3/s)	100-year Uncontrolled Post-Development Peak Flowrate (m^3/s)	Required Effective Active Pond Volume (m^3)
13	2.64	8.72	13,000
14	2.10	11.77	22,000
15	1.42	3.66	5,000

All lands developed within the Northeast Residential subcatchment will require site-specific quality controls to ensure adequate TSS removal prior to discharge into SWM Pond #12, 13, or 14, municipal conveyance infrastructure, or waterbodies. A minimum TSS removal of 80% (MECP Enhanced Removal) is required for the subcatchment.

The Northeast Residential subcatchment's surficial geology consists entirely of clay soils. Per the GRCA GIS, groundwater recharge within the Northeast Residential subcatchment varies between 0 mm/yr to 100 mm/yr. Site-specific hydrogeological investigations will be required to ensure that post-development groundwater recharge meets the pre-development levels. A treatment-train approach is recommended with the inclusion of site-specific LIDs to achieve the required groundwater recharge. Additional information on groundwater recharge is found in the **Section 2.6**.

A summary of the final preferred servicing strategy is contained in **Table 4-21**.

Table 4-21: Servicing Strategy for Applicable Control Criteria Requirements

Criteria	Control Requirement	Servicing Strategy
Minor System Conveyance	5-year storm event	• Underground linear conveyance infrastructure
Major System Conveyance	100-year storm event	• Overland flow conveyance to SWM Pond #13, 14, and 15
Peak flow control (100-year storm event)	Post-development to pre-development peak flowrates	• Peak flow control via SWM Pond #13, 14, and 15
Quality Control	MECP Enhanced (80% TSS removal)	• Site specific controls (OGS, LIDs, etc.) in treatment train with SWM Pond #13, 14, and 15
Water balance/infiltration	Post-development to pre-development infiltration volume	• Site specific infiltration via LIDs
Erosion control	Retain up to the 25mm event with 48-72 hr extended detention	• Extended detention via site specific LIDs or Pond #13, 14, and 15
Thermal Mitigation	SWM Pond requires thermal mitigation at outlet	• Low Impact Development (LID) strategies or cooling trench at pond outlet required to mitigate thermal impact from development

4.6.11 Lynden-Garden Residential (Pond #16) Preferred Strategy

The Lynden-Garden Residential subcatchment consists of approximately 51 ha of Neigbourhood Residential, Neighbourhood Corridor, and Neighbourhood Centre lands north of the intersection of Lynden Road and Garden Avenue. The subcatchment is bound by natural heritage lands to the north, agricultural lands to the east, Lynden Road and Garden Avenue to the south, and a residential subdivision to the west.

Under existing conditions, the subcatchment consists of agricultural land (RC=0.25, 0% impervious area) split between multiple parcels. There is a stormwater conveyance channel/pathway along the northern border contained within natural heritage lands, discharging at the northeast corner of the subcatchment. Existing surface topography of the lands surrounding the subcatchment indicate that negligible external drainage enters the Lynden-Garden Residential subcatchment. Ultimately, drainage from the Lynden-Garden Residential subcatchment is conveyed to Fairchild Creek. The **Section 2.8** has identified areas of significant slope erosion through Fairchild Creek. 48-72 hr extended detention up to the first 25mm of rainfall is required to protect the receiving bodies from erosion.

Stormwater from the Lynden-Garden Residential subcatchment will be conveyed to SWM Pond #16. The pond will be sized to control the subcatchment's 100-year post-development peak flowrate back to the pre-development peak flowrate. To achieve post-to-pre flow controls, Pond #16 has an area of approximately 1.2 ha with an effective active storage depth of 1.25 m. In addition to providing peak flow (quantity) controls, the pond is proposed to provide TSS quality control treatment and thermal mitigation treatment. **Table 4-22** provides additional information on required pond sizing for quantity control.

Table 4-22: High-Level Pond Calculations

Pond #	100-year Pre-Development Peak Flowrate (m^3/s)	100-year Uncontrolled Post-Development Peak Flowrate (m^3/s)	Required Effective Active Pond Volume (m^3)
16	3.05	10.13	15,000

All lands developed within the Lynden-Garden Residential subcatchment will require site-specific quality controls to ensure adequate TSS removal prior to discharge into SWM Pond #16, municipal conveyance infrastructure, or waterbodies. A minimum TSS removal of 80% (MECP Enhanced Removal) is required for the subcatchment.

The Lynden-Garden Residential subcatchment's surficial geology consists entirely of clay soils, groundwater recharge within the Lynden-Garden subcatchment varies between 0 mm/yr to 100 mm/yr. Site-specific hydrogeological investigations will be required to ensure that post-development groundwater recharge meets the pre-development levels. A treatment-train approach is recommended with the inclusion of site-specific LIDs to achieve the required groundwater recharge. Additional information on groundwater recharge is found in the **Section 2.6**.

A summary of the final preferred servicing strategy is contained in **Table 4-23**.

Table 4-23: Servicing Strategy for Applicable Control Criteria Requirements

Criteria	Control Requirement	Servicing Strategy
Minor System Conveyance	5-year storm event	• Underground linear conveyance infrastructure
Major System Conveyance	100-year storm event	• Overland flow conveyance to SWM Pond #16
Peak flow control (100-year storm event)	Post-development to pre-development peak flowrates	• Peak flow control via SWM Pond #16
Quality Control	MECP Enhanced (80% TSS removal)	• Site specific controls (OGS, LIDs, etc.) in treatment train with SWM Pond #16
Water balance/infiltration	Post-development to pre-development infiltration volume	• Site specific infiltration via LIDs
Erosion control	Retain up to the 25mm event with 48-72 hr extended detention	• Extended detention via site specific LIDs or Pond #16

4.6.12 Garden-403 Employment (Pond #17) Preferred Strategy

The Garden-403 Employment subcatchment consists of approximately 111 ha of Prestige Employment and Employment Supportive lands northeast of the intersection of Highway 403 and Garden Avenue. The subcatchment is bound by agricultural lands to the north and east, Highway 403 to the south, and Garden Avenue to the west.

Under existing conditions, the subcatchment consists of agricultural land (RC=0.25, 0% impervious area) split between multiple parcels. There are stormwater conveyance channels/pathways internal to the subcatchment near both the eastern and western borders, discharging along the southern limits of the subcatchment. Ultimately, drainage from the Garden-403 Employment subcatchment is conveyed to Fairchild Creek. The **Section 2.8** has identified areas of significant slope erosion through Fairchild Creek. 48-72 hr extended detention up to the first 25mm of rainfall is required to protect the receiving bodies from erosion.

Existing surface topography of the lands surrounding the subcatchment indicate that external drainage from north and west of Garden Avenue enters the Garden-403 Employment subcatchment via a watercourse/channel flowing north to south, ultimately discharging to Fairchild Creek. The watercourse/channel conveying the external drainage is contained within a natural heritage corridor. Further investigation of external flows is required to confirm the extent of losses (infiltration, evapotranspiration, hummocky pockets of standing water) and extent of external drainage conveyed along through the Garden-403 Employment subcatchment.

Stormwater from the Garden-403 Employment subcatchment will be conveyed to SWM Pond #17. The pond will be sized to control the subcatchment's 100-year post-development peak flowrate back to the pre-development peak flowrate. To achieve post-to-pre flow controls, Pond #17 has an area of approximately 5.8 ha with an effective active storage depth of 1.25 m. In addition to providing peak flow (quantity) controls, the pond is proposed to provide TSS quality control treatment and thermal mitigation treatment. **Table 4-24** provides additional information on required pond sizing for quantity control.

Table 4-24: High-Level Pond Calculations

Pond #	100-year Pre-Development Peak Flowrate (m^3/s)	100-year Uncontrolled Post-Development Peak Flowrate (m^3/s)	Required Effective Active Pond Volume (m^3)
17	4.64	35.98	72,000

All lands developed within the Garden-403 Employment subcatchment will require site-specific quality controls to ensure adequate TSS removal prior to discharge into SWM Pond #17, municipal conveyance infrastructure, or waterbodies. A minimum TSS removal of 80% (MECP Enhanced Removal) is required for the subcatchment.

The Garden-403 Employment subcatchment's surficial geology consists predominantly of clay soils, with areas of sandy soils surrounding the internal watercourses. Per the GRCA GIS, groundwater recharge within the Garden-403 Employment subcatchment varies between 0 mm/yr to 200 mm/y. Site-specific hydrogeological investigations will be required to ensure that post-development groundwater recharge meets the pre-development levels. A treatment-train approach is recommended with the inclusion of site-specific LIDs to achieve the required groundwater recharge. Additional information on groundwater recharge is found in the **Section 2.6**.

A summary of the final preferred servicing strategy is contained in **Table 4-25**.

Table 4-25: Servicing Strategy for Applicable Control Criteria Requirements

Criteria	Control Requirement	Servicing Strategy
Minor System Conveyance	5-year storm event	• Underground linear conveyance infrastructure
Major System Conveyance	100-year storm event	• Overland flow conveyance to SWM Pond #17
Peak flow control (100-year storm event)	Post-development to pre-development peak flowrates	• Peak flow control via SWM Pond #17
Quality Control	MECP Enhanced (80% TSS removal)	• Site specific controls (OGS, LIDs, etc.) in treatment train with SWM Pond #17
Water balance/infiltration	Post-development to pre-development infiltration volume	• Site specific infiltration via LIDs
Erosion control	Retain up to the 25mm event with 48-72 hr extended detention	• Extended detention via site specific LIDs or Pond #17

4.6.13 Tutela Heights North (Pond #18 & 19) Preferred Strategy

The Tutela Heights North subcatchment consists of approximately 82 ha of Neighbourhood Residential, Suburban Residential, Neighbourhood Corridor, and Institutional lands north of Mt. Pleasant Road. The subcatchment is bound by residential lands to the north and west, and Mt. Pleasant Road to the east and south.

Under existing conditions, the subcatchment consists of a mixture of agricultural, large lot residential, and institutional land (RC=0.25, 10% impervious area) split between multiple parcels. There are existing stormwater conveyance channels/pathways internal to the subcatchment along both the eastern border and directly through the center of the subcatchment. Existing surface topography of the lands surrounding the subcatchment indicate that negligible external drainage enters the Tutela Heights North subcatchmant. There are no natural heritage lands within or impacting the subcatchment. Drainage from the Tutela Heights North subcatchment is conveyed, via existing infrastructure and ditches, to the Grand River Southwest subcatchment which ultimately discharges to the Grand River via the existing underground infrastructure.

Stormwater from the Tutela Heights North subcatchment will be conveyed to SWM Pond #18 and 19. The ponds will be sized to control the subcatchment's 100-year post-development peak flowrate back to the pre-development peak flowrate. To achieve post-to-pre flow controls, Pond #17 and 18 have a combined area of approximately 2.1 ha with an effective active storage depth of 1.25 m. In addition to providing peak flow (quantity) controls, the ponds are proposed to provide TSS quality control treatment and thermal mitigation treatment. **Table 4-26** provides additional information on required pond sizing for quantity control.

Table 4-26: High-Level Pond Calculations

Pond #	100-year Pre-Development Peak Flowrate (m^3/s)	100-year Uncontrolled Post-Development Peak Flowrate (m^3/s)	Required Effective Active Pond Volume (m^3)
18	2.97	11.05	17,000
19	1.59	5.90	9,000

All lands developed within the Tutela Heights North subcatchment will require site-specific quality controls to ensure adequate TSS removal prior to discharge into SWM Pond #18 or 19, municipal conveyance infrastructure, or waterbodies. A minimum TSS removal of 80% (MECP Enhanced Removal) is required for the subcatchment.

The Tutela Heights North subcatchment's surficial geology consists entirely of clay soils. Per the GRCA GIS, groundwater recharge within the Tutela Heights North subcatchment varies between 0 mm/yr to 100 mm/yr. Site-specific hydrogeological investigations will be required to ensure that post-development groundwater recharge meets the pre-development levels. A treatment-train approach is recommended with the inclusion of site-specific LIDs to achieve the required groundwater recharge. Additional information on groundwater recharge is found in the **Section 2.6**.

A summary of the final preferred servicing strategy is contained in **Table 4-27**.

Table 4-27: Servicing Strategy for Applicable Control Criteria Requirements

Criteria	Control Requirement	Servicing Strategy
Minor System Conveyance	5-year storm event	• Underground linear conveyance infrastructure
Major System Conveyance	100-year storm event	• Overland flow conveyance to SWM Pond #18 and 19
Peak flow control (100-year storm event)	Post-development to pre-development peak flowrates	• Peak flow control via SWM Pond #18 and 19
Quality Control	MECP Enhanced (80% TSS removal)	• Site specific controls (OGS, LIDs, etc.) in treatment train with SWM Pond #18 and 19
Water balance/infiltration	Post-development to pre-development infiltration volume	• Site specific infiltration via LIDs
Erosion control	N/A	• There are no erosion concerns for subcatchments ultimately discharging into the Grand River through the storm sewer network

4.6.14 Phelps Creek (Pond #20 – 23) Preferred Strategy

The Phelps Creek subcatchment consists of approximately 149 ha of Neighbourhood Residential, Suburban Residential, and Transitional lands southeast of Mt. Pleasant Road and north of Phelps Road. The subcatchment is bound by Mt. Pleasant Road to the north and west, agricultural lands to the east, Phelps Road to the south.

Under existing conditions, the subcatchment consists of a mixture of agricultural and large estate residential land (RC=0.25, 10% impervious area) split between multiple parcels. There are existing stormwater conveyance channels/pathways internal to the subcatchment which convey stormwater from the undeveloped/agricultural portions of the subcatchment to Phelps Creek. Additionally, there are two existing stormwater management ponds and underground storm sewers which convey and control stormwater from the built out residential properties. These stormwater management ponds and the associated infrastructure are to be maintained in all future build-out. The existing stormwater management ponds within the Phelps Creek subcatchment ultimately discharges to the Grand River via Phelps Creek.

Existing surface topography of the lands surrounding the subcatchment and GRCA GIS data indicate that external drainage from west of Mt. Pleasant Road enters the Phelps Creek subcatchment via multiple watercourses/channels flowing west to east, ultimately discharging to Phelps Creek. The watercourses/channels within the subcatchment are contained within natural heritage lands. Further investigation of external flows is required to confirm the extent of losses (infiltration, evapotranspiration, hummocky pockets of standing water) and extent of external drainage conveyed along through the Phelps Creek subcatchment.

Stormwater from the Phelps Creek subcatchment will be conveyed to SWM Pond #20 – 23. The ponds will be sized to control the subcatchment's 100-year post-development peak flowrate back to the pre-development peak flowrate. To achieve post-to-pre flow controls, Pond #20 – 23 have a combined area of approximately 3.3 ha with an effective active storage depth of 1.25 m. In addition to providing peak flow (quantity) controls, the ponds are proposed to provide TSS quality control treatment and thermal mitigation treatment. There is potential to remove the SWM facility Rue Chateaux Terrace and combine it with a facility further downstream. **Table 4-28** provides additional information on required pond sizing for quantity control.

Table 4-28: High-Level Pond Calculations

Pond #	100-year Pre-Development Peak Flowrate (m^3/s)	100-year Uncontrolled Post-Development Peak Flowrate (m^3/s)	Required Effective Active Pond Volume (m^3)
20	1.14	2.87	4,000
21	2.38	8.08	12,000
22	3.25	12.19	19,000
23	1.37	4.27	6,000

All lands developed within the Phelps Creek subcatchment will require site-specific quality controls to ensure adequate TSS removal prior to discharge into SWM Pond #20 – 23, municipal conveyance infrastructure, or waterbodies. A minimum TSS removal of 80% (MECP Enhanced Removal) is required for the subcatchment.

The Phelps Creek subcatchment's surficial geology consists predominantly of clay soils, with sandy soils along Tutela Heights Road nearby the Grand River. Per the GRCA GIS, groundwater recharge within the Phelps Creek subcatchment varies between 0 mm/yr to 400 mm/yr. Site-specific hydrogeological investigations will be required to ensure that post-development groundwater recharge meets the pre-development levels, as well as determine seasonal high groundwater levels and the impacts on proposed development. A treatment-train approach is recommended with the inclusion of site-specific LIDs to achieve the required groundwater recharge. Additional information on groundwater recharge is found in the **Section 2.6**.

A summary of the final preferred servicing strategy is contained in **Table 4-29**.

Table 4-29: Servicing Strategy for Applicable Control Criteria Requirements

Criteria	Control Requirement	Servicing Strategy
Minor System Conveyance	5-year storm event	• Underground linear conveyance infrastructure
Major System Conveyance	100-year storm event	• Overland flow conveyance to SWM Pond #20 – 23
Peak flow control (100-year storm event)	Post-development to pre-development peak flowrates	• Peak flow control via SWM Pond #20 – 23
Quality Control	MECP Enhanced (80% TSS removal)	• Site specific controls (OGS, LIDs, etc.) in treatment train with SWM Pond #20 – 23
Water balance/infiltration	Post-development to pre-development infiltration volume	• Site specific infiltration via LIDs
Erosion control	Retain up to the 25mm event with 48-72 hr extended detention	• Extended detention via site specific LIDs or Ponds #20-23

4.7 Phasing

4.7.1 General

The North Expansion lands and Tutela Heights could require different servicing timing based on actual development approval and the land use being serviced. Analysis has been undertaken through the Secondary Servicing Plan to guide the timing/phasing of key projects that provide a system-wide benefit beyond just local servicing.

4.7.2 Phasing and Timing of Stormwater Infrastructure

The North Expansion Lands do not have any existing infrastructure outside of the natural streams, conveyance channels, and ditches present throughout the lands. Tutela Heights is partially services by existing infrastructure but also contains natural streams, conveyance channels, and ditches, like the North Expansion Lands.

The infrastructure and development phasing plan will need to incorporate the timing of water and stormwater infrastructure and other factors such as:

- Understanding infrastructure sizing for initial phases of the network as well as the ultimate network,
- Understanding the operational impacts of partial servicing,
- Maintaining level of service at each stage, and
- Ensuring that downstream servicing capacity is not impacted by development within the North Expansion Lands and Tutela Heights.

5. WATERSHED PLAN IMPLEMENTATION

This subwatershed study follows a staged approach, with Phase 2 and Phase 3 yet to be completed. Phase 2 consists of completing further field investigations, and Phase 3 will use this data to complete the Comprehensive Update to the Subwatershed Study for the Urban Boundary Expansion Lands.

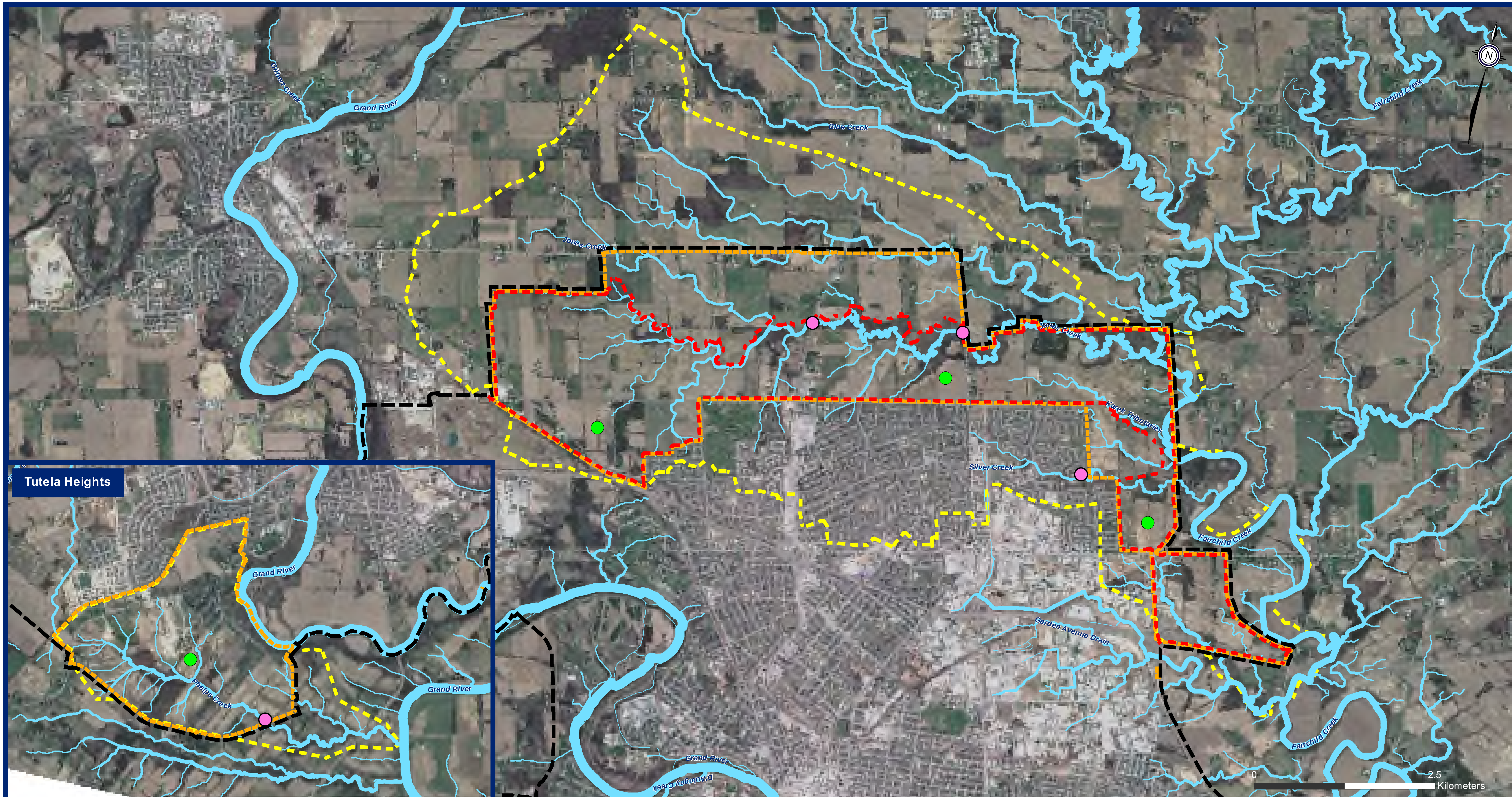
5.1 Recommended Field Investigations

Several field programs have been identified which must be completed as part of the field work of Phase 2. **Figure 5-1** provides details of recommended field program and monitoring locations for the North Brantford and Tutela Heights areas. These programs include the following for both North Brantford and Tutela Heights, as applicable:

5.1.1 Groundwater

It is recommended that a hydrogeological study be completed, including the following:

- Single piezometers/monitoring wells installed in dry, upland locations of varying elevation to generally characterize the seasonal fluctuation of groundwater levels as well as seasonal high groundwater levels.
    - Northern Expansion Area
        - 3 monitoring points, with at least one in the Paris-Galt Moraine headwaters of Jones Creek
    - Tutela Heights
        - 1 monitoring points
- In conjunction with the water level data, additional investigation activities shall be undertaken to provide more detailed data to support refined analyses for estimating annual recharge. To help generalize testing, the study area may be divided into "characteristic zones" (e.g. 4 zones for the northern expansion area and 3 for Tutela Heights) based on similarities in ground cover, soil type, and other features. In each zone a test plot may be established in which to perform various investigation activities, such as:
    - Test holes or boreholes to assess soil types, soil moisture
    - Infiltration testing (e.g. double-ring infiltrometer testing, Guelph Permeameter testing, slug testing)
    - Installation of 2 to 3 additional piezometer(s)/monitoring wells to monitor groundwater flow gradients
    - Potential evapotranspiration trials
    - Ground cover assessment
- Any further work required to characterize the contribution of karst to groundwater recharge within the study area.
- Additionally, a survey of commercial well users near the Primary Study Area (and/or areas to be developed) to determine water-taking and discharge practices to assist in water balance exercises should be completed, where applicable.



Brantford Growth Plan

Subwatershed Study Area

- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Watercourse
- Municipal Boundary
- Recommended Piezometers
- GRCA Stream Gauges

Note: All locations are approximate only.
Final locations shall be per the discretion of the consultant completing the work

Figure 5-1
Recommended Piezometers and GRCA Stream Gauges

June 2020
717003-G-004
NAD 1983 UTM Zone 17N

5.1.2 Drainage and Hydrology

Field programs relating to drainage and hydrology which will also be important to the geomorphology studies, are recommended below:

- Implement continuous flow monitors to develop stage-discharge rating curves in support of erosion threshold analyses and confirm study area flow estimates. Results will confirm bankfull flow estimates and to enhance the study area characterization (e.g., stream power) that has already been completed based on available information. This should include Jones Creek and its dominant tributaries in addition to other watercourses within the study area (Silver Creek, Phelps Creek). It is recommended that stream gauge sites collect data monthly during a 3-year period. Figure 5-1 illustrates the recommended locations for stream monitors in the North Brantford and Tutela Heights areas.
- Install rain gauges in the study area so that rain events may be captured accurately. This should include two rain gauges within the Northern Brantford secondary study area, one east and one west of Highway 24, and one rain gauge located in Tutela Heights.
- Floodplains are currently estimated within the study area and need to be verified by an engineering floodplain study. This shall include a topographic survey of creek cross sections every +/- 500m along Jones Creek, Fairchild Creek, and Phelps Creek, within the Primary Study Areas. The floodplain analysis will then use software such as HEC-RAS to confirm the location of the floodplain.

5.1.3 Stream Geomorphology

The following recommendations were identified based on the existing gaps and/or need for a more robust understanding of the study area and its fluvial systems:

- Reach level assessment:
  - Document existing conditions along Phelps Creek and its tributaries
- Sediment Transport:
  - Sampling of suspended sediment concentrations to identify sources and sinks for the sediment within the Jones Creek drainage network (i.e., along main branch, and of tributaries)
    - Analyses of suspended sediment composition (particle size) and relevance of flocculation as an important sediment transport/deposition process, if possible.
  - Determine sediment loading to Fairchild Creek
- Headwater drainage feature assessments:
  - Review of the Rapid Method of HDF assessment completed to date and filling of gaps for those watercourses where the HDF within the Settlement Area is incomplete (i.e., where landowner permission was received during, or after, the sampling seasons)
  - HDF assessment for the Tutela Heights area has not yet been completed
  - Augment existing HDF assessment with the Fish and Fish Habitat Classification and Terrestrial Habitat Classification
  - Review management recommendations and update with the additional HDF classifications
  - Consultation with GRCA to finalize HDF management classification
- Monitoring:
  - Monitor detailed geomorphology field sites already established in the study area to develop a better understanding of the adjustment processes and functions of Jones Creek and its tributaries
  - Develop a greater understanding of the cohesive bed processes occurring within the study area
  - Establish multi-disciplinary field monitoring sites (e.g., water quality, aquatic (benthic, fish), geomorphology, flow) to enable establishment of linkage and connectivity between

the different disciplines. Sites should be strategically located to establish baseline conditions to inform future proposed development and enable assessment of development impacts.

- Erosion Thresholds:
  - Quantify erosion thresholds that consider the complexities of the cohesive boundary materials. This may require substrate and bank material sampling.
  - Erosion thresholds should be defined for the most sensitive reaches situated downstream of the zone of influence of proposed SWM facilities.

5.1.4 Aquatic Life, Fish Habitat. and Water Quality

Documentation of existing aquatic conditions will establish baseline characterization, identify sensitivities, and identify opportunities for natural environment enhancement. The aquatic systems conditions should be documented and understood prior to development within the study area. The existing natural environment conditions will determine project constraints, provide environmental protection and allow for sustainable development. The following studies are recommended to help better understand aquatic life, fish habitat, and water quality.

- Aquatic Life:
  - Benthic macroinvertebrate assessments (3 stations per tributary annually for a 3-year monitoring period)
  - Aquatic habitat assessments (1 detailed survey to be conducted in conjunction with fish community habitat assessment)
- Fish Habitat:
  - Fish community assessments (minimum 1 survey per creek to determine baseline fish community)
- Water Quality:
  - Baseline water quality assessment at a minimum, upstream and downstream of the boundary area expansion areas of the dominant watercourses that drain the existing urban areas or Settlement Areas (e.g., Silver Creek, Phelps Creek).
  - Water quality assessments of key tributaries that enter Jones Creek
  - Water quality index assessment
  - Ambient water quality assessment
  - Diurnal water quality assessment
  - Continuous water temperature assessment during the summer to quantify maximum water temperature
  - Surface water temperature and quality testing (twice annually for a 3-year period).
  - Suspended sediment concentration sampling to support geomorphic assessment in all watercourses and to quantify sediment loading into Fairchild Creek.
  - Dissolved oxygen (DO) monitoring or sampling for tributaries where the DO levels are critical to the resident fisheries
- Sediment Quality:
  - Stream bed sediment quality assessment and compare results against compared against Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (SQGs) and Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario (PSQGs).

These studies are imperative to understand the current aquatic conditions within these systems, identify sensitivities, and provide opportunities for natural environment enhancement. The aquatic systems conditions should be documented and understood prior to development within the study area. The existing natural environment conditions will determine project constraints, provide environmental protection and allow for sustainable development.

5.1.5 Natural Environment

Additional studies that may be required to support the future Comprehensive Update to the Subwatershed Study are:

- A stable slope analysis to confirm hazard land limits and setback requirements.

5.1.6 Developer Studies

In addition to the studies completed as part of Phase 2, we anticipate the following will be required by individual developers during the block planning process or to support their draft plans:

- Geotechnical investigations
- Wildlife studies
- Tree inventories
- Aquatic inventories
- Wetland/woodlot, cultural vegetation (old field meadows, thickets), and hedgerow mapping in conjunction with the GRCA
- Vegetation and soils inventories in accordance with the Ecological Land Classification System for Southern Ontario will be required, particularly within wetland areas
- Site level environmental impact studies
- Any other studies required by the GRCA

5.2 Subwatershed Plan Updates

Following completion of the Phase 2 Field Investigation, a Comprehensive Update to the Subwatershed Study will be completed. This report will include:

- A summary of the findings of the field program
- Detailed analysis and model development utilizing the field investigation to provide more quantitative direction on the required stormwater management targets for individual development areas.
- An outline of an appropriate implementation and monitoring plan.
- Final stormwater management criteria for new developments.

This study will need to be completed under the MEA EA process and will require additional Public Consultation.

A Comprehensive Update to the Subwatershed Study will then form a guiding document that the City will use to manage growth within the Urban Boundary Expansion Lands.

APPENDIX A:
LIST OF REFERENCES

References

Bajc, A.F., Marich, A.S., Priebe, E.H., and Rainsford, D.R.B. 2018. Evaluating the groundwater resource potential of the Dundas buried bedrock valley, southwestern Ontario: an integrated geological and hydrogeological case study. Can. J. Earth Sci. 55:659-676.

Alexander, RB & Smith, Richard & Schwarz, Gregory. (2000). Effect of stream channel size on the delivery of nitrogen to the Gulf of Mexico. Nature. 403. 758-61.

AquaResources Inc (ARI). 2009a. *Integrated Water Budget Report Grand River Watershed Final Report June 2009*. Grand River Conservation Authority, Cambridge, Ontario.

Blackport Hydrogeology Incorporated and AquaResources Incorporated (ARI). 2009. Review of the State of Knowledge for the Waterloo and Paris/Galt Moraines. Ministry of the Environment Land and Water Policy Branch, Toronto, Ontario.

Blanchfield, P. J., & Ridway, M. S. (1997). Reproductive timing and use of redd sites by lake-spawning brook trout (*Salvelinus fontinalis*). The Canadian Journal of Fisheries and Aquatic Sciences, 54: 747-756.

Chapman, L.J., and Putnam, D.F. 1984. The Physiography of Southern Ontario: Ontario Geological Survey, Special Volume 2

Chapman, L.J. and Putnam, D.F. 2007. Physiography of southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 228.

Chorley, R.J. 1969. *Introduction to Physical Hydrology.* U.S.A: Methuen & Co. Ltd. 211pp.

COSEWIC. 2004. *COSEWIC assessment and status report on the round pigtoe Pleurobema sintoxia in Canada.* Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 33 pp.

COSEWIC. 2006. *COSEWIC assessment and status report on the Rainbow mussel Villosa iris in Canada*. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 38 pp

COSEWIC. 2009. *COSEWIC assessment and status report on the Eastern Sand Darter Ammocrypta pellucida, Ontario populations and Quebec populations, in Canada*. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 49 pp.

Credit Valley Conservation (CVC). 2009. Headwaters Subwatershed Study, Subwatershed 19. Phase 1: Characterization Report.

Credit Valley Conservation (CVC) & Toronto and Region Conservation Authority (TRCA). 2010. Low Impact Development Stormwater Management Planning and Design Guide.

Credit Valley Conservation (CVC) & Toronto and Region Conservation Authority (TRCA). 2014. Evaluation, Classification and Management of Headwater Drainage Features Guidelines.

Dunne, T. & Leopold, L. B. 1978. *Water in Environmental Planning*. W. H. Freeman and Company, New York.

Fraser, H. and Fleming, R. 2001. Environmental benefits of tile drainage – literature review. University of Guelph. Prepared for Land Improvement Contractors of Ontario (LICO).

Fraser, J. M. (1982). An atypical brook charr (*Salvelinus fontinalis*) spawning area. Environmental Biology of Fishes, 7(4): 385-388.

Gabowski, R.C., I.G. Droppo and G. Wharton. 2011. Erodibility of cohesive sediment: The importance of sediment properties

Gomi, R. C., J. Sidle, and S. Richardson. 2002. Understanding Processes and Downstream Linkages of Headwater Systems: Headwaters differ from downstream reaches by their close coupling to hillslope processes, more temporal and spatial variation, and their need for different means of protection from land use, *BioScience*, Volume 52, Issue 10, 1 Pgs 905–916, https://doi.org/10.1641/0006-3568(2002)052 [0905: UPADLO]2.0.CO;2

Government of Canada. 2018. Canadian Climate Normals 1981 – 2010 Station Data. (http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProv&lstProvince=ON&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=4737&dispBack=0) (accessed July 12, 2018).

Grand River Conservation Authority (GRCA). 2008. Grand River Characterization Report (DRAFT). Prepared by Lake Erie Source Water Region Technical Team. 318 pp.

Grand River Conservation Authority (GRCA). 2018. Grand River Information Network – Geospatial Data.

Gregory, K & D.E., Walling (1968). The Variation of Drainage Density Within a Catchment. Hydrological Sciences Journal-journal Des Sciences Hydrologiques - HYDROLOG SCI J. 13. 61-68.

Holysh, S., Boyd, D., and J. Pitcher. 2001. *Grand River Regional Groundwater Study Technical Report.* Grand River Conservation Authority, Cambridge, Ontario. Horton (1945)

Horton, R.E., 1945. Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology. *Bulletin of the Geological Society of America.* 56: 275 – 370.

Huang, J., R.C. Hilldale and B.P. Greimann. 2006. Chapter 4: Cohesive Sediment Transport. In: Erosion and Sedimentation Manual. U.S. Department of the Interior, Bureau of Reclamation. Technical Service Center, Sedimentation and River Hydraulics Group

Knighton, D. 1998. *Fluvial Forms and Processes: a new perspective*. London: Edward Arnold. 383 pp.

MacVeigh, B., T. Zammit and J. Ivey. 2016. Fairchild Creek Subwatershed Characterization Study. Version 1.0. Cambridge, ON: Grand River Conservation Authority

Ministry of Natural Resources (MNR). 2002. Technical Guide – River & Stream Systems: Erosion Hazard Limit. Produced by the Water Resources Section.

Morse, J.C., J.W., Chaping, D.D. Herlong, and R.S. Harvey. 1983. Aquatic Insets of Upper Three Runs Creek, Savannah River Plant, South Carolina. Part II.Diptera. Journal of the Georgia Entomological Society18: 300-316.

Nanson, G. & Croke, J. 1992. A genetic classification of floodplains. Geomorphology, 4 (6), 459-486.

Natural Heritage Information Centre (NHIC). 2014. Element Occurrence Database. Natural Heritage Information Centre. Ontario Ministry of Natural Resources and Forestry.

Natural Heritage Information Centre (NHIC). 2015. Element Occurrence Database. Natural Heritage Information Centre. Ontario Ministry of Natural Resources and Forestry.

Natural Resources Solutions Inc (NRSI). 2013. *St. George Area Study Natural Heritage Study Report*. Prepared for Empire Communities, Activa Group, and Riverview Highlands Holdings.

Ontario Headwaters Institute (OHI). 2016. The Importance of Headwaters to Watershed Health and Why Ontario Needs Indicators of Headwater Health in Watershed Monitoring and Reporting. A concept paper.

Ontario Geological Survey 2010. Surficial geology of Southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 128-REV

Ontario Ministry of the Environment (2003) Stormwater Management Planning and Design Manual, Queen's Printer for Ontario.

Ontario Ministry of Municipal Affars. 2017. Growth Plan for the Greater Golden Horseshoe (2017). Queen's Printer for Ontario. Released May 2017.

Ontario Ministry of Natural Resources (OMNR) and Grand River Conservation Authority (GRCA). 1998. *Grand River Fisheries Management Plan.*

Partheniades, E. 2009. Cohesive Sediments in Open Channels: properties, transport, and applications. Elsevier.

Peterson, B.J., Wollheim, W.M., Mulholland, P.J., Webster, J.R., Meyer, J.L., Tank, J.L., Marti, E., Bowden, W.B., Valett, H.M., Hershey, A.E., McDowell, W.H., Dodds, W.K., Hamilton, S.K., Gregory, S., and Morrall, D.D. 2001. Control of nitrogen export from watersheds by headwater streams. Science, Vol. 292.

Rosgen, D.L. and H.L. Silvey. 1996. *Applied River Morphology*. Wildland Hydrology Books, Fort Collins, CO.

Schlosser, I.J. 1991. Stream fish ecology: a landscape perspective. BioScience, Vol. 41

Schollen & Company, Aquafor Beech, The Planning Partnership, Lura Consulting. Draft 2006. *Markham Small Streams Study*. Prepared for the Town of Markham.

Schumm, S.A. 1977. The Fluvial System. John Wiley and Sons, New York.

Schwetz, N. 2014. 2014. *Nature Counts 2 Project, Hamilton Natural Areas Inventory, 3rd Edition*. Species Summary Document. 287 pp.

Schwetz, N. and T. Martel. 2014. *Nature Counts 2 Project, Hamilton Natural Areas Inventory, 3rd Edition*. Site Summaries Document. 763 pp.

Stanfield, L.W. and Jackson, D.A. 2011. Understanding the factors that influence headwater stream flows in response to storm events. Journal of the American Water Resources Associated, Vol. 47 (2).

Statistics Canada. 2017. Brantford [Population centre], Ontario and Northwest Territories [Territory] (table). Census Profile. 2016 Census Statistics Canada Catalogue no. 98-316-X2016001. Ottawa. Released November 29, 2017. https://www.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E (accessed July 13, 2018).

Stone, M. 2004. *Suspended Sediment Monitoring and Characterization in Fairchild Creek.* School of Planning and Department of Geography University of Waterloo, Waterloo, Ontario.

Strahler, A. N. 1957. Quantitative analysis of watershed geomorphology. *Transactions of the American Geophysical Union* (38):913-920

Toronto and Region Conservation Authority (TRCA). 2007. The Natural Functions of Headwater Drainage Features: A Literature Review.

Utley, B.C., and T.M. Wynn, 2008. Cohesive Soil Erosion: Theory and Practice. World Environmental and Water Resources Congress, 2008: Ahupua'A. Proceedings. Honolulu, Hawaii, May 12-16. Sponsored by the Environmental and Water Resources Institute of ASCE.

Van Dijk, W., W.I. van de Lageweg, and M. G. Kleinhans. 2013. Formation of a cohesive floodplain in a dynamic experimental meandering river. Earth Surface Processes and Landforms 38: 1550-1565.

Wallace, J. B., S. L. Eggert, J. L. Meyer, and J. R. Webster. 1997. Multiple trophic levels of a forest stream linked to terrestrial litter inputs. Science'277:102-104.

Witzel, D., & Macrimmon, H. R. (1983). Redd-Site Selection by Brook Trout and Brown Trout in Southwestern

APPENDIX B:
COMPREHENSIVE ENVIRONMENTAL IMPACT STUDY REPORT

PLAN B Natural Heritage

Comprehensive Environmental Impact Statement

North Brantford and Tutela Heights

City of Brantford

Prepared for:

City of Brantford

Prepared by:

PLAN B Natural Heritage

Project No. 2016-146

November 2nd, 2020

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1.0 Introduction & Background

The following Comprehensive Environmental Impact Statement (EIS) was prepared in conjunction with the proposed North Brantford and Tutela Heights land use plans in the City of Brantford. The Comprehensive EIS was completed as part of the Municipal Comprehensive Review (MCR) for the City of Brantford. The results of this study are intended to inform the Subwatershed and Master Servicing Plan studies that are also being completed as part of the MCR and the City of Brantford's Official Plan update.

The study area is located within the proposed Brantford boundary expansion lands, which were annexed from the County of Brant (Figure 1a and Figure 1b). The study area is mainly rural in character and includes existing agriculture, residential, and highway commercial land uses.

Natural environment features within or adjacent to the study area that were investigated as part of the EIS included the following:

- Jones Creek;
- Fairchild Creek;
- Phelps Creek;
- Grand River;
- Wetlands – provincially significant wetlands (PSW), unevaluated wetlands;
- Remnant woodlots; and,
- Cultural habitat (meadow, thicket, woodland).

1.1 Comprehensive EIS – Terms of Reference

The Grand River Conservation Authority (2015) defines a Comprehensive EIS as "*a landscape scale (usually watershed or sub-watershed) study which identifies natural heritage features for protection, potential development areas, and development setbacks that are ecologically sustainable*". It also addresses the potential impacts of development on natural features and ecological functions.

A specific terms of reference was not prepared for the Comprehensive EIS. The format that was followed is outlined below:

- Background information review;
- Data gap analysis to identify information requirements for the land use plans and future development applications;
- Agency consultation[1];
- Ecological Land Classification System descriptions and mapping of vegetation communities based on background information sources, desktop analysis, and roadside surveys;
- Background information review to confirm the temperature regime and fish community for watercourses within the study area;

[1] Meetings with GRCA & MNRF in March, 2017.

- In-season field surveys; wildlife surveys (breeding birds – 2 surveys (late-May to early-July), amphibians – 3 surveys (April/May/June), mammals – incidental observations during the above surveys, and a winter mammal track survey;
- Confirm the presence/absence of species-at-risk habitat and complete a habitat suitability analysis (i.e. desktop exercise with input from MNRF);
- Describe, map and evaluate the natural heritage features/functions within the study area and identify opportunities/constraints to future urban land use (i.e. natural heritage system framework);
- Identify and evaluate the potential impacts of the preferred land use plan;
- Prepare a mitigation strategy (including buffer recommendations) for the preferred land use plan;
- Prepare an environmental management strategy for the protection, restoration and enhancement of the natural heritage system;
- Identify future study requirements for the block plan or draft plan of subdivision stage; and,
- Document findings in a Comprehensive EIS format that is consistent with GRCA guidelines for studies to be completed at a landscape or subwatershed scale.

1.2 Study Purpose

The purpose of the Comprehensive EIS was to address the environmental policy requirements of the Provincial Policy Statement (Natural Heritage and Water policies), the Growth Plan for the Greater Golden Horseshoe, the City of Brantford Official Plan, and the Grand River Conservation Authority Regulations/Guidelines, as it relates to establishing a "sustainable" natural heritage framework for future urban land use in North Brantford and Tutela Heights. To address this objective, this report provides the following information:

- A description and evaluation of the bio-physical resource features within the study area, based largely on existing background information and follow-up in-season roadside surveys;
- Confirmation of natural area boundaries and linkages;
- Identification of opportunities/constraints to future urban development (i.e. Natural Heritage System framework);
- An evaluation of potential impacts of future urban development on natural heritage features/ functions and linkages; and,
- Recommended mitigation/management measures to reduce development related impacts, protect sensitive environmental features, and achieve habitat enhancement, where feasible.

The Comprehensive EIS was prepared in conjunction with the following studies:

- North Brantford and Tutela Heights Subwatershed Study – Stage 1 (GM BluePlan et al. 2019);
- Settlement Area Boundary Expansion: Geomorphic Assessment (Ecosystem Recovery Inc. 2019);
- Headwater Drainage Feature Assessment (Ecosystem Recovery Inc. 2019); and,

- Envisioning Brantford – Municipal Comprehensive Review – Part 3: Preferred Settlement Area Boundary Expansion and Draft Preferred Land Use and Transportation Plan (SGL Planning & Design Inc. et al. 2019).

2.0 Study Methodology

The following tasks were completed as part of the Comprehensive EIS:

- Review of background reports and GIS mapping layers from MNRF LIO, GRCA, County of Brant and the City of Brantford;
- Consultation with GRCA and MNRF staff;
- Review of aerial photography, topography, soils, geology and physiography mapping;
- Reconnaissance level (roadside) field investigations in 2017 and 2018 to document existing conditions and identify a preliminary natural heritage system;
- In-season roadside surveys (2017/2018): amphibians, breeding birds, and ELC to confirm existing conditions, presence/absence of species at risk, and refine the natural heritage system;
- Review of woodland features to determine if they meet the definition of "significant" based on patch size, under the Natural Heritage Reference Manual to the Provincial Policy Statement; and,
- Review of unevaluated wetland features to confirm if they meet the size criteria for "protection" under GRCA policies.

Due to variability in property access permission and the timing of receiving access permission from the landowners, it was determined that the approach for completion of the EIS would be a desktop exercise supplemented by information collected through roadside observations and access on selective properties.

3.0 Existing Conditions

The following section provides an overview level description of the physical and biological conditions within the North Brantford and Tutela Heights study areas.

3.1 Physiography, Geology, Topography & Soils

The study area is located within the Norfolk Sand Plain and the Horseshoe Moraine physiographic regions of Southern Ontario (Chapman and Putnam 1984). The sand plain occupies the majority of the study area and is dissected by Jones Creek, Fairchild Creek, Phelps Creek, and the Grand River. A till moraine (i.e. Galt-Moffat Moraine) is located in the extreme northwest corner of the study area (i.e. west of Golf Road). The moraine is part of a larger moraine complex that extends to the northeast and the southwest of Brantford.

The surficial geology of the sand plain consists of fine and coarse textured glacio-lacustrine deposits comprised of silt, clay and a minor sand and gravel component (Ontario Ministry of Energy, Northern Development and Mines, 2019). The till moraine is comprised of sand and gravel with a minor silt and clay component. Alluvial deposits are associated with Jones Creek, Fairchild Creek, and Phelps Creek. The deposits consist of clay, silt, sand, gravel and some organic material.

In terms of bedrock geology, the northern section of the study area is underlain by the Guelph dolostone formation. The underlying bedrock in the Tutela Heights area is the Salina dolomite formation (GRCA 2008 – *Grand River Watershed Characterization Report*). From a larger watershed perspective, the Guelph formation provides an important groundwater supply function, particularly as a source of municipal drinking water.

The topography of the study area can be described as hummocky to gently undulating/rolling with incised watercourses in the sand plain such as Jones Creek, Fairchild Creek, Phelps Creek, and the Grand River. Sloping topography occurs in association with the main watercourses, particularly the Grand River (Tutela Heights), Fairchild Creek and its tributaries, and Phelps Creek. The valley slopes associated with Jones Creek become more pronounced from west to east, towards the confluence with Fairchild Creek. The topography of the study area is shown on Figure 2a and 2b.

The main soil types within the study area are outlined below in Table 1 (Source: *The Soils of Brant County – Soil Survey Report No. 55*, Acton 1989):

Table 1 – Soil Types

Soil Type	**Parent Materials**	**Drainage**
Alluvium	Variable floodplain deposits – coarse textured sand and gravel, medium textured loam, and fine textured clay	Variable
Beverley	Lacustrine silty clay loam and silty clay	Imperfect
Brantford	Lacustrine silty clay loam and silty clay	Moderately-well
Brant	Lacustrine silt loam and very fine sandy loam	Well
Colwood	Lacustrine silt loam and very fine sandy loam	Poor
Fox	Lacustrine sand and loamy sand	Rapid
Guelph	Loam glacial till	Well
Harrisburg	Silt over silty clay loam or silty clay lacustrine	Well
Plainfield	Lacustrine and Aeolian modified sand	Rapid and well
Teeswater	Silt or loam over fluvial gravelly sand or gravel	Well

Soil Type	Parent Materials	Drainage
Toledo	Lacustrine silty clay loam and silty clay	Poor
Tuscola	Lacustrine silt loam and very fine sandy loam	Imperfect
Woolwich	Silt over loam glacial till	Well

The well drained soils are predominantly associated with the sand plain and the till moraine. Poor to imperfectly drained soils occur in low lying areas, and in association with the bottomlands/floodplains of incised watercourses such as Jones Creek, Fairchild Creek and Phelps Creek, and their associated tributaries.

A more detailed description of the study area physiography and geology is provided in the North Brantford and Tutela Heights Subwatershed Study (GM BluePlan et al. 2019).

3.2 Surface Water and Groundwater Features

Surface water features within the study area are mapped on Figure 3a and 3b. Intake protection zones (IPZ) for the main watercourses in the study area (i.e. Jones Creek, Fairchild Creek and Phelps Creek) are also shown. Protection of surface water quality and quantity within the study area watercourses is critical for protecting *in situ* and downstream aquatic habitat, as well as water quality in the Grand River, which is a source of Municipal drinking water. Significant groundwater recharge areas are identified in the southwest and northwest corner of the North Brantford study area. The recharge areas generally coincide with well-drained soils associated with the till moraine.

The extreme southwest corner of the North Brantford study area also contains a “highly vulnerable aquifer” that contributes to stream base flow in the Grand River, the source of drinking water for the residents of Brantford. The majority of the Tutela Heights study area is located within the IPZ for the adjacent Grand River (Figure 3b). A small portion of a significant groundwater recharge area is located in the extreme southwest corner of Tutela Heights.

Infiltration within the well-drained portions of the study area is critical for sustaining stream baseflow and wetland hydrology, protecting surface water and groundwater quality, and maintaining aquatic/wetland habitat conditions.

A more detailed description of the study area hydrology and hydrogeology is provided in the North Brantford and Tutela Heights Subwatershed Study (GM BluePlan et al. 2019).

3.3 GRCA Regulated Areas

Hazard land features such as watercourses, valley slopes, wetlands and flood-prone areas are regulated by the GRCA under *Ontario Regulation 150/06 Regulation of Development, Interference with Wetlands and Alterations to Shorelines and Watercourses*. An overlay of the GRCA regulation limits is shown on Figure 4a and 4b. Valley slopes and floodplains are shown on Figure 5a and 5b. The regulation limits apply to the following hazard land features:

<u>North Brantford</u>

- Jones Creek and tributaries plus erosion allowance;
- Fairchild Creek and tributaries plus erosion allowance;
- Wetlands – PSW and unevaluated;
- Floodplains – Jones Creek, Fairchild Creek, and headwater drainage features; and,
- Valley slopes – Jones Creek, Fairchild Creek, and cut-off meander bends.

<u>Tutela Heights</u>

- Grand River valley slope plus erosion allowance;
- Phelps Creek and tributaries;
- Valley slopes – Phelps Creek and tributaries;
- Floodplain – Phelps Creek; and,
- Wetlands – unevaluated.

It should be noted that hazard land features not identified on Figure 4a/4b and Figure 5a/5b are still subject to the regulations under GRCA *Regulation 150/06.*

Watersheds within the North Brantford study area include Jones Creek, Fairchild Creek, and a very small portion of the Lower Middle Grand River Subwatershed (Figure 4a). The majority of the Tutela Heights study area is located in the Grand River Lower North Subwatershed, which includes Phelps Creek. The extreme western edge of the Tutela Heights study area is located within the D'Aubigny Creek watershed. D'Aubigny Creek is a coldwater tributary of the Grand River that provides habitat for all three species of trout (i.e. brook, brown and rainbow).

3.4 Vegetation

Vegetation communities within the study area are mapped on Figure 6a and 6b. The mapping was primarily derived from the MNRF LIO vegetation layer with some modifications based on information collected during roadside wildlife surveys. An overview description of the main vegetation communities within the study area is provided below. The plant community types are based on the *Ecological Land Classification for Southern Ontario: First Approximation and Its Application* (Lee et al. 1998).

<u>North Brantford</u>

Vegetation communities within the North Brantford study area are shown on Figure 6a. The main natural features in this area are Jones Creek and Fairchild Creek. The vegetation associated with these drainage systems is a mixture of upland and lowland plant communities. The tableland fringe and stream valley slopes support a mosaic of deciduous forest (FOD), mixed forest (FOM), coniferous forest FOC), conifer plantations (CUP), cultural thicket (CUT)/woodland (CUW), and cultural old field meadow (CUM). Wetland areas associated with the Jones Creek and Fairchild Creek systems consist of marsh (MAM, MAS), thicket swamp (SWT), deciduous swamp (SWD), mixed swamp (SWM), and coniferous swamp (SWC) communities that have established in flood-prone bottomland areas and in association with groundwater seepage zones.

The agricultural tableland areas generally support limited vegetation cover comprised mainly of field border hedgerows, cultural old field meadow and thicket, conifer plantations and small woodlots that have established on former cultivated land. Dug ponds and small wetlands (marsh, thicket swamp) are also present, either in association with headwater drainage features or as isolated features.

The largest blocks of upland tableland vegetation occur in the southwest portion of the study area (i.e. Golf Road –mosaic of conifer plantation, deciduous woodlots, and hedgerows) and in the southeast corner (i.e. east of Garden Avenue – deciduous/mixed woodlot, cultural thicket).

Wetlands associated with the Jones Creek system are designated as part of the Cold Spring Creek Provincially Significant Wetland (PSW) complex. Several unevaluated wetlands also occur within the study area, primarily as isolated features (i.e. depressions, dug ponds) or in association with headwater drainage features (i.e. riparian zone, on-line ponds).

For the most part, the remnant natural vegetation within the North Brantford study area is associated with the floodplain and valley slopes of existing watercourses such as Jones Creek and Fairchild Creek. Due to intensive agricultural on the adjacent tableland areas, natural vegetation cover is limited in extent and is confined to the edges of cultivated fields, fallow fields, and farmsteads. Some conifer plantations occur in association with cut-off meander bends and on former cultivated land. Remnant tableland woodlots are limited in extent and are often in association with wetlands (swamps) or watercourses.

Cultural vegetation features, ornamental plantings and some remnant natural vegetation cover occur in association with existing residences and farmsteads.

Tutela Heights

The main vegetation features in the Tutela Heights study area are associated with the Grand River valley slope and Phelps Creek (Figure 6b). Deciduous forest and mixed forest is the predominant vegetation type in the study area. Deciduous swamp inclusions are associated with some of the woodlot features. Deciduous swamp, thicket swamp and marsh communities occur in association with Phelps Creek and its tributaries.

Field border hedgerows, cultural old field meadow and cultural thicket occur in the agricultural dominated tableland areas and in areas of sloping topography. Some small remnant deciduous woodlots are also present in the vicinity of the rail trail corridor (west edge of the study area) and to the southwest of Davern Road.

The largest blocks of vegetation are associated with the Grand River valley slope and tableland fringe, and to the north of Phelps Road (mosaic of deciduous/mixed forest and swamp).

Several unevaluated wetlands occur in this area, mainly in association with groundwater discharge and seasonal flooding associated with the Phelps Creek drainage system.

Remnant natural vegetation features within the Tutela Heights study area are mainly confined to sloping topography and bottomland areas associated the Phelps Creek drainage system, and the Grand River valley/tableland fringe. Within the agriculturally dominated areas, natural vegetation is confined to field border edges, fallow fields, watercourse margins, and farmsteads. Remnant vegetation and ornamental plantings also occur in association with the existing residential development within Tutela Heights.

3.5 Wildlife

The following section provides a summary of the results of roadside wildlife surveys completed in 2017 and 2018 within the North Brantford and Tutela Heights study areas.

Amphibians

A survey of frogs and toads was completed by T. Hoar on April 27th, May 29th and June 26th, 2018 following the Marsh Monitoring Program protocol (Bird Studies Canada 2008). Nineteen stations were established to capture the habitat conditions within the study area. The location of the survey stations is shown on Figure 7a and 7b.

At each station, the surveyor recorded all calling individuals within a semi-circular 100 m radius. Each station was surveyed three times, at least fifteen days apart, and under favorable weather conditions. Survey routes were nocturnal (30 minutes after sunset for a maximum of 4 hours) and consisted of roadside stations. Each survey consisted of a three minute passive listening period wherein one of the following calling level codes were assigned to each vocalizing frog or toad species:

- Level 1 - Calling individuals did not overlap and could be counted;
- Level 2 - Calling individuals sometimes did overlap and the number of individuals could still be reliably counted; or,
- Level 3 - A full chorus where overlap between calling individuals was continuous and a proper count/estimate of the numbers of individuals was not possible.

The combination of extensive agricultural lands, a limited amount of wetland habitat, and fish free ponds was reflected in the frog/toad calling results within the study area. During the first survey, four areas of high frog calling concentration were recorded (Figure 7a and 7b). The species in these concentration areas were dominated by Spring Peepers with smaller numbers of American Toads. During the second and third surveys, only small numbers of Gray Tree Frog and Green Frog were recorded. These individuals were primarily located in small, isolated dug ponds, and stormwater retention ponds.

The areas of high frog calling concentration were associated with wetland parcels in proximity to survey station number 2 and 3 (Golf Road), stations 13 and 15 (east of Garden Avenue), and station 10 (Phelps Creek).

No frog or toad species at risk were recorded during the 2018 amphibian surveys. The results of the amphibian surveys are provided in Appendix A.

Breeding Birds

A total of fifty-eight point count stations were selected in representative habitats within the study area (Figure 7a and 7b). Eighteen (18) stations were set up in the Tutella Heights study area. Forty (40) stations were established in the North Brantford study area. The point counts followed the second Ontario Breeding Bird Atlas (OBBA) methodology (Cadman et al. 2007). All species and daily numbers of individuals were recorded during each of the site visits. The level of breeding (possible/probable/confirmed) was recorded following the Breeding Bird Atlas methodology (Cadman *et. al*. 2007). The surveys were conducted between 5:00 am and 10:00 am on June 10th, June 16th, July 2nd, and July 9th 2017, and on June 23rd and July 5th 2018.

A total of 69 species were recorded in the study area during the survey visits (Appendix B). The study area is situated within four breeding bird atlas squares (17NH57, 58, 67, and 68). During the OBBA surveys, 132 species were recorded within these atlas squares from 2001 to 2005.

The ten most abundant species comprised 66 % of all individuals recorded. Fifty-five percent of all the species recorded (i.e. 38 species out of 69) had less than 10 individuals recorded during the surveys.

The ten most abundant species recorded during the breeding bird surveys were common generalists, including American Robin, Song Sparrow, Red-winged Blackbird, Northern Cardinal, Mourning Dove, European Starling, Common Grackle, American Crow, Chipping Sparrow, and House Sparrow.

North Brantford

A total of 60 species were recorded within the North Brantford study area. The avian community within the study area was comprised primarily of common, generalist species which favor the urban/rural fringe and agricultural habitat. The mosaic patchwork of fallow fields, row crops, rural residential, and commercial areas favored the dominance of generalist species. The most commonly observed species were Red-winged Blackbird, European Starling, American Robin, Song Sparrow and Common Grackle. The five most common species comprised 49.7% of all individuals recorded during the surveys (Appendix C).

Four of the species observed in the North Brantford study area are federally classified by COSEWIC (Committee on the Status of Endangered Wildlife in Canada) or by the Province as species at risk (SARO). These species included:

- Bobolink Threatened (COSEWIC, SARO)
- Barn Swallow Threatened (COSEWIC, SARO)
- Eastern Wood-Pewee Special Concern (COSEWIC, SARO)
- Eastern Meadowlark Threatened (COSEWIC, SARO)

Three Bobolink were recorded on July 9^{th}, 2017 at stations 22 and 24. While several suitable fields were noted in the vicinity, this species was only recorded on the second survey, and would be considered a possible breeder in the study area.

Sixteen Barn Swallows were observed at seven stations during the surveys. Barn Swallows were mostly observed at point count stations 23, 24 and 25 (Governor’s Road). Several barns and other suitable buildings for nesting were noted in this area.

Eastern Wood-Pewee individuals were recorded at point count stations 15 and 21. This species was likely a probable breeder in the woodlot adjacent to point count station 21.

Eastern Meadowlark was recorded at three stations. At point count station number 18, this species was a probable breeder with two individuals present and birds recorded during both surveys.

Tutela Heights

A total of 52 species were recorded from the Tutela Heights study area. Several species of birds such as Rose-breasted Grosbeak, Least Flycatcher, Pileated Woodpecker, and Mourning Warbler favored the more extensive woodlots and shrubby habitat located in this area. The most common species recorded, representing 37% of all individual birds, were American Robin, Northern Cardinal, Common Grackle, Mourning Dove, and American Goldfinch (Appendix C).

Three species-at-risk were recorded from the Tutella Heights area. These species included:

- Barn Swallow — Threatened (COSEWIC, SARO)
- Eastern Wood-Pewee — Special Concern (COSEWIC, SARO)
- Wood Thrush — Threatened (COSEWIC), Special Concern (SARO)

Barn Swallow were recorded once at stations 1 and 12 in 2017. During 2018, Barn Swallows were recorded once foraging over the storm water pond on Moore Blvd. Several suitable buildings for nesting were noted in the study area.

Individual Eastern Wood Pewees were recorded at stations 5, 6, and 11. The extensive forested areas in Tutela Heights provide suitable habitat for this species.

Four Wood Thrushes were recorded calling once from the large forested area north of Phelps Road (i.e. point count station 5).

<u>Incidental Wildlife Observations</u>

Incidental wildlife observations included the following common rural/urban fringe wildlife species:

- Eastern Grey Squirrel;
- Red Squirrel;
- Eastern Chipmunk;
- Meadow Vole;
- Eastern Cottontail;
- Raccoon;
- Striped Skunk;
- Woodchuck;
- White-tailed Deer;
- Red Fox; and,
- Coyote.

<u>Winter Mammal Track Survey</u>

A survey of visible animal tracks within the snow was undertaken on February 13, 2018. The purpose of the survey was to identify wildlife corridor use within the study area setting. Tracks of White-tailed Deer, Coyote, Red Fox, and Eastern Cottontail were widespread and in low densities. Where riparian corridors bisected roadways, the densities were slightly higher. Two areas had visibly higher densities of mammal tracks. The first area was at the Tutela Heights Road and Davern Road intersection. This area appears to provide a linkage connection between the Grand River and habitat to the south and north of Phelps Road (large blocks of forest/wetland). The second area was located in the North Brantford study area, where the highest densities of mammal tracks (primarily White-tailed Deer) in the overall study area setting were recorded. The wildlife dispersal route in this area was from the woodlots on Golf Road southwest towards the Paris Road and CNR Bridge over Highway 403. South of Highway 403 at the north end of Golf Road at the CNR Bridge, there was a higher density of deer tracks climbing up the embankment toward the bridge. It appears that the resident White-tailed Deer population in North Brantford utilizes the CNR Bridge as a safe corridor to avoid traffic on Highway 403 while moving between the Grand River valley and the study area.

3.6 Corridors & Linkages

Wildlife and plant dispersal corridors in the study area are mainly associated with watercourses. In the North Brantford study area, the main species dispersal corridor is associated with Jones Creek and selective tributaries. In the more heavily farmed areas, the vegetated corridor is very narrow and in some instances ploughed through. Some of the tributaries to Jones Creek provide a linkage between natural areas within the existing urban area of Brantford and the main Jones Creek valley (e.g. south of Powerline Road, and east of Brantwood Park Road). Opportunities exist within the North Brantford study area to re-establish connections between natural features and to strengthen existing corridors (e.g. from Jones Creek southwest to Golf Road woodlands, from the woodlands east of Garden Avenue towards Fairchild Creek and the Growth Plan NHS). As noted above, the existing railway bridge over Highway 403 provides an important “safe” corridor for white-tailed deer moving between the North Brantford study area and the Grand River valley.

In the Tutela Heights study area, the main corridor function is associated with the Grand River valley and Phelps Creek. As noted above, White-tailed Deer move between the Grand River valley and remnant woodland/wetland habitat blocks north and south of Phelps Road. Phelps Creek also provides an east-west corridor function and is connected to the Grand River east of Erie Avenue.

A rail trail is located along the western edge of the Tutela Heights study area. The vegetation associated with the rail trail provides a linkage function between the Frank Grobb Memorial Forest and natural areas to the southwest (i.e. Shellard Lane area). Linkage connections also occur between small, remnant woodlots and Phelps Creek via headwater drainage features with varying extents of riparian vegetation.

Species dispersal corridors in North Brantford and Tutela Heights are shown on Figure A and Figure B, respectively (refer to Appendix D).

3.7 Aquatic Habitat Conditions and Water Quality

The following section provides an overview summary of the aquatic habitat and water quality conditions within the study area, as documented by Ecosystem Recovery Inc. (ERI) (2019). ERI completed an overview level assessment of the watercourses, as part of a fluvial geomorphological investigation. The results of ERI’s aquatic and water quality analysis is summarized below in Table 2.

Table 2 – Aquatic Habitat Conditions and Water Quality

Watercourse	Thermal Regime	Fish Community	Water Quality/Comments
Jones Creek	Cold	Blacknose Dace, Brook Stickleback, Brook Trout, Brown Trout, Creek Chub, Common White Sucker, Golden Shiner, Johnny Darter, Pearl Dace, and Pumpkinseed.	Strong groundwater contributions from stream banks and channel. Permanent flow. Substrate conditions suitable for Brook Trout spawning (i.e. gravel, pebbles). Spawning confirmed by MNRF upstream of Governor’s Rd.[2] Limited water quality data. Strong baseflow transports lighter sediment downstream to confluence with Fairchild Creek.

[2] 27 Brook Trout redds observed by MNR on Oct. 29th, 2003. Spawning not confirmed within study area.

			Headwater drainage features tend to be dry in the summer and do not have a strong groundwater relationship. Agricultural land use contributes to sediment loading and reduced water quality. Variable riparian cover, often less than 30 m in width.
Fairchild Creek	Warm	Fish community tolerant of high turbidity and warmer temperatures. Habitat for aquatic species at risk. Unconfirmed reports of Brown Trout in tributaries (east of Park Road North and north of Powerline Road. Incomplete thermal regime mapping.	Significant source of suspended sediment and Phosphorous loading in the Grand River. Jones Creek contributes to the sediment levels, fish community and water quality parameters. Fairchild Creek adjacent to the study area provides habitat for Rainbow Mussel (Special Concern). Agricultural land use in the subwatershed contributes to sediment loading and reduced water quality. Variable riparian cover.
Phelps Creek	No information	No information	No information
Grand River	Cool-Warm	Rich, diverse fish community comprised of warm, cool and cold water fish species, including species at risk.	DFO Critical habitat for Round Pigtoe and Eastern Sand Darter adjacent to Tutela Heights and confluence of Phelps Creek and the Grand River.
D'Aubigny Creek	Cold	Mix of coldwater species including brook, brown and rainbow trout.	Strong groundwater contributions. DFO Critical habitat for Eastern Sand Darter In Grand River above/below confluence with D'Aubigny Creek.

The Fairchild Creek Subwatershed Characterization Study (GRCA 2016) provides additional information related to Jones Creek, as well as identifying some important data gaps. GRCA (2016) note that Jones Creek exhibits limited riparian vegetation cover in several locations. Brook Trout spawning (redd) surveys were last completed in 2003 by MNRF, who have confirmed the spawning of this species in Jones Creek (upstream of Governor's Road). Numerous groundwater discharge areas have been identified in Jones Creek (GRCA 2016). Stream flow and temperature data are available for Jones Creek, which has been summarized by GM BluePlan et al. (2019) in the North Brantford and Tutela Heights Subwatershed Study.

As part of their geomorphic assessment of watercourses within the study area, ERI completed a headwater drainage feature assessment following the protocol established by TRCA and CVC (2014). The majority of headwater drainage features to the above noted watercourses in the study area are either ploughed through or narrow, grassed swales with little or no channel definition, and ephemeral flow characteristics. As a result of these observations, the majority of the headwater drainage features within the study area were classified by ERI as a low or no constraint. Headwater drainage features identified for protection are discussed in Section 4.0 below. These features were mainly associated with wetland features, riparian corridors, and/or exhibited flow/channel characteristics that required a "conservation" management approach, based on the TRCA/CVC evaluation criteria. A more detailed description of the headwater drainage features within the study area and their classification is provided by ERI (2019).

3.8 Species-at-Risk (MNRF)

In terms of species at risk, the MNRF NHIC database indicates that there are previous records of several species at risk from the study area. Species at risk previously recorded from the 1 km x 1 km squares within the North Brantford and Tutela Heights study area are listed below in Table 3[3].

Table 3 – Species at Risk Previously Recorded from North Brantford and Tutela Heights (Source: MNRF)

Species	Provincial S_Rank	Species at Risk Status	Location/Habitat
Schweinitz's Sedge	S3		North Brantford (NB)-wetlands
Hoary Puccoon	S3		NB-meadows
Pignut Hickory	S3		NB-oak-hickory forest, hedgerows
Pawpaw	S3		NB-deciduous forest
Northern Pin Oak	S3		NB-sandy soils, open woods, hedgerows
Eastern Meadowlark	S4	Threatened	NB/Tutela Heights (TH)-grasslands
Green Dragon	S3	Special Concern	NB-forested stream corridors, lowland forest
Bobolink	S4	Threatened	NB-grasslands
Wood Thrush	S4	Special Concern	NB-deciduous forest
Eastern Wood-pewee	S4	Special Concern	TH-deciduous forest
Rainbow Mussel	S2/S3	Special Concern	NB-Fairchild Creek
Northern Map Turtle	S3	Special Concern	TH-Grand River
Blanding's Turtle	S3	Threatened	TH-Grand River
Black Redhorse	S2	Threatened	TH-Grand River
Silver Shiner	S2/S3	Threatened	TH-Grand River
Greater Redhorse	S3		TH-Grand River
Brindled Madtom	S2		TH-Grand River
Round Pigtoe	S1	Endangered – Critical Aquatic SAR Habitat	TH-Grand River
Eastern Sand Darter	S2	Endangered – Critical Aquatic SAR Habitat	TH-Grand River
Chinese-Hemlock Parsley	S2		TH-seepage zones in swamps and along stream banks

S Rank Codes: S1-Critically Imperiled, S2-Imperiled, S3-Vulnerable, S4-Apparently Secure, S5-Secure.

MNRF Guelph District Office (G. Buck – pers. comm.) confirmed that there were no additional records of species at risk in the province of Ontario from the natural heritage features located within or immediately

[3] Additional species at risk that could be present in the study area include Snapping Turtle, Milksnake, Broad-beach Fern, American Columbo, American Chestnut, Green Dragon and Eastern Meadowlark (GRCA – pers. comm.).

adjacent to the study area. Woodlots within the study area however likely qualify as "candidate" significant wildlife habitat for four endangered bat species (i.e. Eastern Small-footed Myotis, Little Brown Myotis, Northern Myotis, and Tri-colored Bat). Tree cavities and snags within woodlots and structures such as barns could provide summer maternity and/or roosting habitat for endangered bat species.

3.9 Observed Species at Risk

As noted above, species-at-risk observed within the study area during the breeding bird surveys included:

- Eastern Wood-Pewee Special Concern
- Barn Swallow Threatened
- Bobolink Threatened
- Wood Thrush Special Concern

A discussion about the species-at-risk observations was provided in Section 3.5 above. Although breeding could not be confirmed for the bird species at risk observed in the study area, suitable habitat conditions for these species is present. Preferred habitat conditions also occur within the study area for the species at risk listed above in Section 3.8. In light of this, species at risk surveys should be completed at the development application stage to confirm presence/absence of species at risk, and to determine if an Overall Benefit Permit is required from MECP under the *Endangered Species Act,* or whether habitat avoidance measures (buffers) or other mitigation measures are more appropriate.

3.10 Environmental Policy Features

Environmental policy features within or adjacent to the study area include the following:

- Jones Creek, Fairchild Creek, Phelps Creek, and the Grand River – GRCA regulated watercourses (Ontario Regulation 150/06), fish habitat (PPS);
- Grand River, Jones Creek, Fairchild Creek, Phelps Creek– Significant Valleyland (PPS), Ontario Regulation 150/06);
- Significant Woodlands (PPS) – woodlots > 4.0 ha;
- Cold Spring Creek PSW Complex (PPS, Ontario Regulation 150/06);
- Growth Plan for the Greater Golden Horseshoe - NHS;
- GRCA regulated wetlands – Ontario Regulation 150/06 (naturally occurring: > or < 0.5 ha, anthropogenic < or > 2.0 ha); and,
- Floodplains and erosion prone valley slopes regulated by the GRCA under Ontario Regulation 150/06 (associated with Jones Creek, Fairchild Creek, Phelps Creek and the Grand River).

The above features were taken into account during the establishment of the natural heritage system for the North Brantford and Tutela Heights study areas.

3.11 Woodlands

Woodlands within the study area are shown on Figure 8a and Figure 8b. Woodland cover within the North Brantford study area is for the most part confined to the Jones Creek riparian corridor, stretching from Golf Road in the west to the eastern edge of the urban expansion lands. Discrete woodlands (deciduous, conifer plantation) occur in the southwest (Golf Road) and southeast (east of Garden Avenue) corners of the study area.

Within the Tutela Heights study area, woodland cover is mainly associated with the Grand River valley and Phelps Creek. Large blocks of deciduous forest are associate with Phelps Creek, north of Phelps Road. Smaller woodlands occur in association with headwater drainage features, the rail trail corridor (west edge of study area), and as isolated features.

The woodlands shown on Figure 8a and Figure 8b are a composite of the MNRF LIO woodland layer and the woodland layer from the County of Brant Official Plan. It should be noted that the City of Brantford urban expansion lands are part of a larger landscape setting that supports less than 13% woodland cover (County of Brant Official Plan 2012). The County of Brant Official Plan (2012) considers all remaining woodlands to be constraints to development. Environment Canada (2013, *How Much Habitat is Enough? – 3rd Edition*) has reported that 30% woodland cover is the minimum requirement to support healthy habitat conditions for wildlife and plants. This observation underscores the importance of maintaining and enhancing the remaining woodland cover within the study area.

3.12 Wetlands

Wetlands within the study area are shown on Figure 9a and Figure 9b. The Cold Spring Creek PSW complex is associated with Jones Creek and its tributaries. The balance of the wetlands in the North Brantford study area are “unevaluated” wetlands. These wetlands are mainly associated with headwater drainage features, dug ponds, woodlots, or as isolated features. The main wetland types present are marsh (meadow, cattail), thicket swamp (willow/dogwood), deciduous swamp (maple, ash, elm, birch, poplar), mixed swamp (maple, ash, elm, birch, cedar), and coniferous swamp (cedar).

Wetlands within Tutela Heights are unevaluated, and are mainly associated with the main reach of Phelps Creek and associated headwater drainage features. Isolated wetlands also occur in depressions and in association with some dug ponds. The main wetland types in Tutela Heights are marsh, thicket swamp and deciduous/mixed swamp.

Naturally occurring wetlands greater than 0.5 ha are protected under GRCA wetland policies (i.e. Section 8.4.1 and 8.4.4 – *GRCA Policies for the Administration of Ontario Regulation 150/06*). Wetlands that are naturally occurring but less than 0.5 ha may be altered or removed provided they do not qualify for protection based on several evaluation criteria. Given the scope of the Comprehensive EIS, it was not possible to evaluate wetlands less than 0.5 ha in area to determine if they meet the GRCA policy test for protection.

Anthropogenic wetlands (e.g. ponds) greater than 2.0 ha are also protected under GRCA wetland policies. Given the scope of the Comprehensive EIS, it was also not possible to determine which of the anthropogenic wetlands under 2.0 ha should be protected.

Wetland assessments completed at the block plan or draft plan of subdivision stage are recommended to determine which of the smaller wetland features (natural or anthropogenic) should be protected as part of the NHS for North Brantford and Tutela Heights.

Environment Canada (2013) reports that 10% wetland cover is the <u>minimum</u> requirement to support healthy watersheds. This demonstrates the importance of protecting all remaining wetlands within the study area, as well as identifying opportunities for wetland recreation and enhancement (e.g. through low impact development stormwater management measures, creek block restoration).

4.0 Opportunities and Constraints – Natural Heritage System Framework

A natural heritage system (NHS) is defined by the Province of Ontario as: *"A system made up of natural heritage features and areas, and linkages intended to provide connectivity (at the regional or site level) and support natural processes which are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species and ecosystems. These systems can include natural heritage features and areas, federal and provincial parks and conservation reserves, other natural heritage features, lands that have been restored or have the potential to be restored to a natural state, areas that support hydrologic functions, and working landscapes that enable ecological functions to continue. The Province has a recommended approach for identifying natural heritage systems, but municipal approaches that achieve or exceed the same objectives may also be used"* (Provincial Policy Statement, MMAH 2020).

Ecosystem-based planning recognizes that natural heritage features linked by proximity or by stream and valley corridors within a properly designed NHS, are more likely to function over the *long-term* than those that are highly fragmented.

The natural environment features within the North Brantford and Tutela Heights study area were evaluated in the context of the Natural Heritage Reference Manual (MNR 2010), which is the companion document to the Provincial Policy Statement (MMAH 2020). The natural environment features within the study area were previously evaluated, as part of the County of Brant Official Plan (2012). The core components of the Natural Heritage System (NHS) within the study area, as identified in the County of Brant Official Plan, include provincially significant wetlands (PSW), woodlands and vegetation, watercourses, and hazard lands (i.e. floodplains and slope/erosion hazards).

The County of Brant NHS is shown on Figure 10a and 10b. Natural heritage features and areas that represent a constraint to development under the County Official Plan policies include: woodlands, Provincially significant woodlands and vegetation, areas of natural and scientific interest (ANSI), significant valleylands; watercourses and other surface water features, wetlands which have been evaluated by MNRF and are not considered to be Provincially significant, and fish habitat.

The County of Brant currently has 13% woodland or forest coverage (County of Brant Official Plan 2012). Environment Canada (2013) has reported that 30% woodland cover is the <u>minimum</u> requirement to support healthy habitat conditions for wildlife and plants. The limited woodland cover within the County of Brant and the study area underscores the importance of <u>protecting</u> all remaining woodlands and <u>increasing</u> woodland cover on the landscape.

Based on the above overview of existing conditions and environmental constraints, the recommended natural heritage system framework for the North Brantford and Tutela Heights study area is shown on Figure 11a and 11b. The NHS incorporates the following features:

- Growth Plan NHS;
- PSW's;
- Unevaluated (naturally occurring) wetlands 0.5 ha in area or larger[4];
- Anthropogenic wetlands 2.0 ha in area or larger[4];
- Woodlands 4.0 ha in area[5] or larger;
- Watercourses - Jones Creek, Fairchild Creek, and Phelps Creek - defined valleylands[6] and riparian corridors, including bottomland/floodplain and valley slope vegetation, fish and wildlife habitat, and corridor/linkage functions;
- Headwater drainage features to be "conserved", as defined by ERI (2019);
- Grand River – Significant Valleyland, critical habitat for species at risk, species dispersal corridor;
- Floodplains and valley slope/erosion hazards;
- Habitat for species at risk protected under the *Endangered Species Act* (2007); and,
- A minimum 30 m protective buffer from all NHS components.

The NHS was identified largely on the basis of a desktop analysis of background information sources and GIS layers provided by the GRCA, MNRF, County of Brant, and the City of Brantford. Aerial photograph interpretation, windshield surveys, and in-season wildlife surveys on selective accessible properties were used to confirm and refine the limits of the recommended NHS.

The NHS for the North Brantford and Tutela Heights study area also includes portions of the Growth Plan NHS. Refinements to the Growth Plan NHS (described below) were made in selective locations to better reflect current conditions and constraints, and to be consistent with the NHS framework for the study area.

Floodplains and slope erosion hazards are included within the NHS where they coincide with wetlands, riparian bottomlands, woodlands, and vegetated valley slopes. Portions of floodplains and slopes that occurred in cultivated agricultural land were not included as part of the NHS. The limits of the floodplain and stable top of slope in these areas will need to be reviewed in consultation with the GRCA at the block plan or draft plan of subdivision stage to determine the extent to which these areas should be included as part of the NHS.

[4] In accordance with GRCA wetland policies. Other wetlands not included in the NHS will be subject to further review at the block plan or draft plan stage to determine if they should be included as part of the NHS.
[5] For landscapes with 5-15% woodland cover, the NHRM for the PPS states that woodlands $\geq$4 ha in area should be "significant".
[6] Based on a desktop interpretation of topography, GRCA valley slope/erosion layers, ecological features/functions, and hydrologic features/functions.

It should be noted that the scope of the Comprehensive EIS did not allow for the identification, evaluation, and mapping of significant valleylands[7], significant wildlife habitat or fish habitat. Notwithstanding this, the recommended NHS for the North Brantford and Tutela Heights study area does protect existing valleyland features (i.e. Jones Creek, Fairchild Creek, Phelps Creek), wildlife habitat features/functions, and fish habitat with minimum 30 m buffers.

4.1 NHS Management Objectives

Based on the existing conditions characterization of the study area provided in Section 3.0, the following environmental management objectives are recommended to protect, restore, and enhance the North Brantford and Tutela Heights NHS for the *long-term*:

- Maintain and enhance existing woodland area;
- Maintain and enhance existing wetland area;
- Provide minimum 30 m naturalized buffers to NHS features;
- Provide minimum 30 m vegetated stream buffers;
- Maintain and enhance species dispersal corridors and linkages between NHS features;
- Maintain and enhance the overall pattern and volume of recharge to the groundwater system;
- Maintain and enhance existing surface water contributions to wetlands and floodplain habitats;
- Protect watercourses from urban pollution, sedimentation, channel/bank erosion, and thermal impacts;
- Provide opportunities for sustainable passive recreational use of the NHS through wise resource management, public education/awareness, and environmental stewardship measures;
- Protect hazard land features such as floodplains, valley slopes, and stream meander belt width;
- Protect and restore headwater drainage features identified for protection; and,
- Protect and enhance habitat for species at risk.

Recommended measures to implement the NHS management objectives are provided below in Section 4.7. The recommendations form the basis for land use policy direction, future study requirements, and environmental management considerations.

4.2 Growth Plan for the Greater Golden Horseshoe

The *Growth Plan for the Greater Golden Horseshoe* (2020) is a Provincial planning document that provides a policy framework for land use decision making in Southern Ontario. A key component of the Growth Plan is the natural heritage system (NHS), which is comprised of key hydrologic features, key hydrologic

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[7] A significant valleyland exercise was completed for the Grand River, as part of the City of Brantford Official Plan Review. The location of the significant valleyland is shown on Figure 11b.

areas, and key natural heritage features. One of the objectives of the Growth Plan is to protect, restore and enhance the natural environment of the region for the *long-term*.

The Growth Plan NHS occurs within and adjacent to the North Brantford and Tutela Heights study areas (Figure 12a and 12b). Within the North Brantford study area, the Growth Plan NHS is associated with Fairchild Creek and its tributaries, and the lower reaches of Jones Creek (east of Park Road North). For the most part, the NHS is associated with natural features such as valleylands, woodlands and wetlands, however, there are some locations where the NHS overlaps cultivated fields, existing farmsteads, roads and hedgerows. The portion of the NHS outside of a defined feature is intended to provide a buffer and/or enhancement function to adjacent natural heritage features/functions such as woodlands, wetlands and species dispersal corridors.

In the Tutela Heights study area, the Growth Plan NHS is associated with portions of the Grand River valley, Phelps Creek, and connecting linkages between the Grand River and large blocks of forest/wetland habitat to the south and north of Phelps Road. The Growth Plan NHS also encompasses hedgerows, cultivated fields, and cultural habitat features as buffers and/or enhancements to key natural heritage features.

As part of the planning exercise for North Brantford and Tutela Heights, a NHS was prepared as a "framework" for the preparation of an urban land use plan for the study area. The Growth Plan NHS is one of the components of the recommended NHS for the planning exercise, which is shown on Figure 11a and 11b. Some minor modifications were made to the Growth Plan NHS where it was unclear as to why a particular feature was included (e.g. hedgerows, cultivated fields, roads, and farmsteads). In these instances, the Growth Plan NHS boundary was "adjusted" to coincide with the recommended NHS framework for the North Brantford and Tutela Heights study area. The adjustments that were made to the Growth Plan NHS are summarized below:

- Lower Jones Creek (east of Park Road North, north of Powerline Road) - the Growth Plan NHS boundary extended marginally beyond the 30 m NHS buffer. In these locations the Growth Plan NHS boundary was modified to coincide with the 30 m NHS buffer;
- Corner of Powerline Road and Karek Road - an area of open field and farmstead not associated with a NHS feature was omitted. The Growth Plan NHS overlay in this area appears to be a function of a buffer/enhancement to Fairchild Creek, which is approximately 200+ m to the east;
- Garden Avenue extension - two small field border hedgerows, extending southerly from a tributary valley (Fairchild Creek) with no connection to another NHS feature, were omitted. An area of open cultivated land and cultural habitat to the east surrounded by NHS features was included within the Growth Plan NHS, as compensation for the recommended changes. A parcel of cultural habitat to the north of the open field was also included as part of the Growth Plan NHS. Both parcels are not currently identified as NHS in the Growth Plan;
- SW corner of Lynden Road and Adams Road – an area of cultivated fields and hedgerows was omitted as there were no NHS features in this area. The Growth Plan NHS overlay in this area appears to be a function of a buffer/enhancement to Fairchild Creek, which is approximately 100+ m to the north of Lynden Road; and,
- SW corner of Adams Road and Johnson Road – an area of cultivated fields, hedgerows and farmsteads was omitted as there were no NHS features in this area. The Growth Plan NHS overlay

in this area appears to be a function of a buffer to Fairchild Creek, which is approximately 100 m to the north of Adams Road.

Minor revisions were also made to the Growth Plan NHS in the Tutela Heights study area. The Growth Plan NHS in this portion of the study area generally coincides with "trigger lands" that are not currently being contemplated for development. Revisions to the Growth Plan NHS were made in areas where it overlapped cultivated fields, hedgerows, and existing residences along Tutela Heights Road.

The recommended revisions to the Growth Plan NHS are shown on Figure 11a/11b and Figure 12c/12d.

4.3 Other Environmental Features

Environmental features within the study area that did not meet the above-noted NHS criteria were placed into the "Other Environmental Features" category for further investigation at the block plan or draft plan of subdivision stage. Features in this category included the following:

- Woodlands less than 4.0 ha;
- Naturally occurring wetlands less than 0.5 ha;
- Anthropogenic wetlands less than 2.0;
- Field border hedgerows;
- Cultural vegetation features (i.e. old field meadows, thickets, successional woodland); and,
- Headwater drainage features.

"Other Environmental Features" to be evaluated in further detail at the block plan or draft plan of subdivision application stage are shown on Figure 13a and 13b. The results of site level environmental impact studies should determine the extent to which "Other Environmental Features" should be included as part of the NHS for the study area. Buffer requirements and linkage/corridor enhancement opportunities for "Other Environmental Features" and the NHS should also be confirmed/refined through EIS's to be completed at the block plan or draft plan of subdivision stage. A 30 m buffer is recommended for features that are to be included within the NHS.

Headwater drainage features to be "conserved" (as shown on Figures 11a and 11b) will be subject to further geomorphological assessment and floodplain analysis to confirm the dimensions of the future creek blocks. A minimum 30 m buffer is recommended for all headwater drainage features to be "conserved". Natural channel design principles should be implemented for features to be re-aligned or altered. Locally indigenous plant species are recommended for naturalization of all headwater drainage features to be conserved.

It should be noted that the study area contains several headwater drainage features with riparian wetlands that are not shown on Figures 11a, 11b, 13a and 13b. The location of these features is shown in the Headwater Drainage Feature Assessment prepared by ERI (2019). These features were initially identified as "low constraint" primarily due to agricultural related disturbances (e.g. ploughing, cropping) poorly defined channels, and ephemeral flow. Notwithstanding this, the results of the headwater drainage feature assessment prepared by ERI (2019) should be re-visited at the block plan or draft plan of subdivision stage to confirm the constraint level and management requirements for headwater drainage features with the study area.

4.4 Proposed Land Use Plan – Impact Analysis & Mitigation

The environmental criteria used to evaluate the potential impact of the proposed land uses and transportation network on the NHS were prepared by SGL Planning & Design Inc. Based on the results of the matrix evaluation, Option 1A was selected as the preferred land use alternative for the Brantford North study area (Figure 14a). Option 1 (with modifications) was identified as the “preferred” land use plan for the Tutela Heights study area (Figure 14b). An overview description of the preferred land use options for North Brantford and Tutela Heights is provided below. Potential impacts to the NHS and recommended mitigation measures are also provided.

Option 1a – North Brantford

The westerly portion of the North Brantford study area (i.e. lands west of Golf Road) are identified primarily for employment uses (general/prestige employment). The northwest corner of the study area is designated as “rural”. This portion of the study area provides an important groundwater recharge function that is critical for the maintenance of stream base flow in Jones Creek and wetland hydrology (Cold Spring Creek PSW Complex). The southwestern portion of the study area is located within a “highly vulnerable aquifer” that is connected to the Grand River (the source of drinking water for the City of Brantford). The combination of employment and rural land uses in this sensitive hydrogeological area should allow for the maintenance of the pre-development pattern and volume of recharge to the groundwater system. Various stormwater management measures (i.e. Low Impact Development) combined with open space lands and undeveloped rural areas provide opportunities for addressing the hydrogeological sensitivity of this part of the study area.

The employment land use extends east of Golf Road to the Jones Creek corridor and associated woodland and wetland features. Non-residential land uses are preferred adjacent to the NHS, as it greatly reduces the negative impacts associated with “residential” development in proximity to natural features.

Two headwater drainage features to be “conserved” are located within the proposed employment lands. The northerly watercourse provides an opportunity for wetland re-creation, and linkages between “other environmental features” and the main component of the NHS (i.e. Jones Creek Corridor). The southerly watercourse will provide a “restored” linkage connection between the Jones Creek corridor and a large block of woodland and wetland habitat located at the corner of Golf Road and Powerline Road.

Employment land use is also proposed in the extreme southeast corner of the study area (Garden Avenue and Adams Road). This portion of the study area supports a large woodlot and a riparian corridor (Fairchild Creek tributary). Non-residential land uses in proximity to these natural features will increase their sustainability in an urban setting compared to more intensive residential land uses and their associated impacts on the environment.

The lands to the north of the Jones Creek corridor will remain as “rural”. This approach provides for a high level of protection to the NHS in North Brantford, as there will be no residential development flanking the NHS on the north side of the Jones Creek corridor.

A combination of residential and commercial mixed use is proposed for the balance of North Brantford. Low density residential and neighbourhood corridors are proposed adjacent to the NHS. The NHS incorporates a minimum 30 m buffer to protect natural features from negative impacts associated with human occupancy of the landscape. Various neighbourhood and community parks, and schools are proposed within the North Brantford study area. For the most part, these types of less intrusive land uses are not located adjacent to the NHS. Where proposed parks and schools flank the NHS, they will provide additional "buffering" to the NHS from the more intensive residential areas.

Proposed roads within North Brantford include a major east-west collector north of Powerline Road with several north-south connections to the existing road grid. A future extension of Wayne Gretzky Parkway is proposed in the vicinity of the Park Road North crossing of Jones Creek.

In summary, a high level of protection has been provided to the recommended NHS for the North Brantford study area. Less intrusive land uses are proposed in sensitive groundwater recharge areas, and the headwaters of Jones Creek and associated wetlands that are sustained by groundwater discharge. A 30 m buffer has been incorporated into the NHS to provide protection from negative impacts associated with urbanization of the landscape. Road crossings of sensitive NHS features such as wetlands and valleyland has been minimized to the extent feasible. Proposed roads generally cross NHS features in the least intrusive location. Recommendations for road re-alignment in areas of potential conflict are provided below.

Option 1 – Tutela Heights

The southern half of the Tutela Heights study area is designated as "rural" and NHS with a small residential component identified near the southeast corner of Mount Pleasant Road and the future Conklin Road extension. Residential land use is proposed for the lands north of Phelps Creek, in conjunction with existing residential development. A combination of residential and institutional land use is proposed in the northwest corner of the study area. The extreme eastern portion of the study area is designated as rural. NHS is identified for the Grand River valley and the woodlands/wetlands associated with Phelps Creek and its tributaries. Four parks are proposed in Tutela Heights, two of which are proposed adjacent to the NHS. A minimum 30 m buffer is incorporated into the NHS to provide protection for natural heritage features and functions.

A headwater drainage feature (i.e. Phelps Creek tributary) to be conserved is located in the central portion of the study area. Naturalization of the watercourse will provide an enhanced linkage connection between the Phelps Creek riparian corridor and woodlands retained as part of an existing development and Municipal park.

Proposed roads within Tutela Heights include an easterly extension of Conklin Road with future connections to Phelps Road. An extension of Tutela Heights Road is proposed in the northwest corner of the study area. The easterly portion of Tutela Heights Road will be closed due to erosion of the adjacent Grand River valley slope.

In summary, the proposed land use plan for the Tutela Heights study area provides a high level of protection for the recommended NHS. Rural land uses are proposed north of Phelps Road in conjunction with a large block of forest/wetland habitat and the Phelps Creek corridor. Phelps Creek and associated wetlands/woodlands are protected with a 30 m buffer. The Grand River "significant" valleyland is also protected with a 30 m buffer. An enhanced linkage connection between NHS features will be provided in conjunction with a headwater drainage feature that will be conserved and naturalized.

The proposed Conklin Road extension and future connections to Phelps Road will fragment an existing corridor connection and create potential conflicts with wildlife movement. The potential impacts of the Conklin Road extension, including an evaluation of alternative alignments, should be completed as part of a future Class Environmental Assessment study.

Transportation

For both study areas, the number of potential road crossings of the NHS was kept to a minimum. The proposed transportation network generally avoids sensitive NHS features such as wetlands, woodlands, and valleylands. Re-alignment of the proposed road system, however, is recommended in some locations (where feasible) to avoid/minimize negative impacts to the NHS (wetlands, floodplain, and valleyland crossings). These locations include the following:

- Conklin Road Extension - wetland, floodplain, and buffer interference; corridor fragmentation;
- Future connections to Conklin Road Extension – fragmentation of Phelps Creek corridor;
- East-West Collector (north of Powerline Road) - East of Brantwood Park Road extension - wetland interference;
- East-West Collector (north of Powerline Road) – crossing of Jones Creek tributary east of Park Road North;
- Future Wayne Gretzky Parkway extension and connection to Park Road North – wetland, floodplain interference, corridor fragmentation; and,
- Proposed road connections to Garden Avenue, Adams Road and Lynden Road – fragmentation of existing linkage connections between NHS features and linkage enhancement opportunities.

The potential impacts of the proposed transportation system on the NHS should be identified and evaluated in further detail, as part of a Class Environmental Assessment process. Alternative alignments for roads and stream crossings that avoid or minimize impacts to the NHS should be identified and considered as part of the assessment.

Implementation of traffic calming measures, signage, and dry culverts (or overpass) along proposed roads and linkage corridor interfaces is recommended to facilitate safe wildlife crossing of proposed roads.

Stormwater Management

The general location of proposed centralized stormwater management (SWM) facilities is shown on Figure 15a and 15b. The proposed SWM ponds are generally located adjacent to the NHS with outlets to existing watercourses or wetlands. Six SWM ponds are proposed within the Tutela Heights study area. Seventeen SWM ponds are required to service the North Brantford study area.

Given the significance and sensitivity of the natural environment features within the study area, appropriate stormwater and groundwater management measures are recommended to maintain and enhance water quality, sustain stream baseflow/temperature, and protect wetland and stream hydrology. Low impact development (LID) measures for stormwater management such as bio-swales, at-source infiltration of runoff, wetland type storm ponds, and infiltration/cooling trench outlets, are recommended to protect the aquatic and wetland components of the natural heritage system and achieve habitat enhancement. Additional LID measures that could be considered include, greenways (treatment train approach), permeable pavers, rain barrels and cisterns, soil amendment (to re-instate pre-development infiltration and chemical properties) and tree box filters. The primary objective of LID measures is to collect, detain, polish and filter post-development runoff uniformly across the study area to maintain or enhance the pre-development hydrologic functions and inter-connections with natural heritage features/functions (e.g. wetlands, watercourses, and groundwater regime), as well as the Municipal drinking water aquifer (Source Water Protection Zones). The benefits of LID measures include, among others, improvements to surface water quality and groundwater regime, reduced demands on municipal water supply, reduced urban heat island effect, improved air quality, habitat creation, and better quality of life.

Refinements to the location of the proposed SWM ponds and outlets shown on Figure 15a and 15b are recommended in certain locations to minimize or avoid impacts to the NHS (wetlands, watercourses, and valleylands), and to achieve less disruptive connections to the receiving systems.

The potential impacts of development and future SWM on surface drainage and hydrology, groundwater regime, stream morphology and water quality are discussed in more detail by GM BluePlan et al. (2019).

Servicing

In terms of servicing, future urban development within the North Brantford and Tutela Heights study areas will involve an extension of existing Municipal water mains and sanitary sewers.

Within Tutela Heights, one sewage pumping station is proposed in the southeast corner of the study area. No sanitary sewer or force main connections are proposed or required through NHS features.

A total of five sewage pumping stations are required in the North Brantford study area. The pumping stations are located outside of the NHS and connect to existing or future sanitary sewers. Future sanitary sewer crossings of the NHS will be required in several locations, in conjunction with proposed road crossings of wetlands, watercourses and valleylands.

Future water mains within North Brantford will also require crossings of the NHS, in association with proposed roads. An elevated water tower is proposed for this area, and is located outside of the NHS.

The potential impacts of the future servicing requirements on the NHS within North Brantford and Tutela Heights should be identified and evaluated in further detail, as part of a Class Environmental Assessment process. Further detail on the potential impacts of servicing on the natural environment are provided by GM BluePlan et al. (2019).

Buffers

A minimum 30 m buffer has been provided to all NHS features within the North Brantford and Tutela Heights study areas. The recommended buffer is consistent with the policy requirements of several Provincial planning documents (e.g. Growth Plan, Greenbelt Plan), as well as the City of Brantford Official Plan. Depending on the results of an EIS at the development application stage, additional buffering may be required to protect NHS features/functions (including species at risk) from negative impacts. Reductions in the 30 m buffer, however, may be considered in certain situations, where there are no suitable alternatives, and subject to ecological off-setting (habitat compensation) on a 1:1 area removal basis.

4.5 Natural Heritage Policy Recommendations

In terms of natural heritage policies, the policy framework for the study area should comply with the Provincial Policy Statement, the Growth Plan for the Greater Golden Horseshoe, the City of Brantford Official Plan, and the regulations/policies of the GRCA. It is recommended that a specific policy be included in the land use policies requiring the completion of a Full EIS at the block plan or draft plan of subdivision stage. The purpose of the EIS will be to address the following:

- Existing conditions and constraints – aquatic, terrestrial, wetland;
- Presence/absence of species at risk;
- Significant wildlife habitat features and functions;
- NHS feature limits and buffer requirements;
- Linkage/corridor and NHS restoration/enhancement opportunities;
- Evaluation of "Other Environmental Features", including headwater drainage features, to determine the extent to which they should be included within the NHS, and their associated buffer requirements;
- Potential impacts of development on NHS features and functions;
- Mitigation strategies to avoid or minimize negative impacts to NHS features and functions, including the habitat of species at risk protected under the *Endangered Species Act*;
- An Ecological Off-setting Plan (EOP) for "Other Environmental Features" to be altered or removed for development, as determined through an agency approved EIS. The goal of the EOP is to ensure that there is a "net gain" in natural vegetation cover within the study area by compensating for reductions in buffer width and/or the alteration/removal of "Other Environmental Features" such as woodlands less than 4.0 ha, natural wetlands less than 0.5 ha or anthropogenic wetlands less than 2.0 ha, hedgerows, shrub thickets, and headwater drainage features. The Lake Simcoe Region Conservation Authority (2017) or Nottawasaga Valley Conservation Authority (2019) models for ecological off-setting are recommended approaches to follow; and,
- An Environmental Stewardship plan for NHS features and associated buffers that provides a framework for naturalization, resource management, and post-development recreational uses.

The EIS will also need to demonstrate conformity of the development application with the Provincial Policy Statement (Natural Heritage policies), the Growth Plan for the Greater Golden Horseshoe, the City of Brantford Official Plan policies, and the regulations/policies of the GRCA. A terms of reference for the EIS should be developed in consultation with the GRCA.

4.6 Future Study Requirements

Due to the presence of key natural heritage features within the study area, and the potential for these features to support habitat for species at risk, a <u>Full EIS</u>, in accordance with GRCA and City of Brantford, guidelines, should be completed at the block plan or draft plan of subdivision stage. The potential impacts of development on NHS features and functions should be fully evaluated, and appropriate mitigation measures identified to protect, restore and enhance the natural environment for the *long-term.*

Additional studies that may be required to support the EIS include:

- a fluvial geomorphology assessment to confirm meander belt width, watercourse setback requirements, and storm pond release rates;
- a valleyland assessment for Jones Creek, Fairchild Creek and Phelps Creek to identify potential "significant valleylands", based on geomorphological and ecological criteria, as outlined in the Natural Heritage Reference Manual (2010);
- a floodplain analysis to confirm the location of flood prone areas, the limits of development and setback requirements;
- a stable slope analysis to confirm hazard land limits and setback requirements;
- a hydrogeological assessment to confirm the pre-development groundwater recharge/discharge regime, and to identify appropriate Low Impact Development measures to protect/enhance groundwater dependent watercourses and wetlands;
- a natural channel design study for headwater drainage features to be restored;
- a stormwater management plan;
- a naturalization plan for NHS buffers, SWM facilities, and restored headwater drainage features;
- a tree inventory and preservation plan; and,
- a management plan for invasive plant species (e.g. phragmites, garlic mustard, dog strangling vine, Norway maple, European buckthorn).

Given the potential for species at risk to be present within the study area, a species at risk screening exercise and habitat suitability analysis is recommended as part of an EIS. Depending on the results of the screening exercise and follow-up surveys (where warranted), a mitigation plan (Avoidance Alternative Form) or an Overall Benefit Permit from MECP may be required.

The Fairchild Creek Subwatershed Characterization Study (GRCA 2016) identifies a number of data gaps that should be addressed either through subsequent phases in the subwatershed study process for North Brantford or at the block plan or draft plan of subdivision stage. These studies include the following:

- Fish community survey (Jones Creek, Fairchild Creek tributaries);
- Spawning (redd) survey (Jones Creek);
- Temperature and stream flow monitoring (Jones Creek);
- Groundwater investigation to confirm groundwater discharge areas (Jones Creek); and,
- Benthic Macro-invertebrate survey (base line water quality indicator for watercourses).

Given the apparent lack of information for Phelps Creek, a fish community and temperature survey is recommended to characterize the system, identify restoration/enhancement opportunities, and confirm stormwater management requirements.

4.7 Implementation of NHS Management Objectives

Recommended measures to implement the NHS management objectives is provided below. The recommendations form the basis for land use policy direction, future study requirements, and environmental management considerations.

NHS Management Objectives

Maintain and enhance existing woodland area

All woodlands equal to or greater than 4.0 ha in area have been identified for protection in the NHS. The provision of a 30 m buffer provides an important opportunity for increasing the overall woodland cover within the study area (i.e. 13%), which is currently well below the Environment Canada minimum guideline of 30% for healthy watersheds.

Woodlands less than 4.0 ha (i.e. Other Environmental Features) should be subject to an EIS investigation to determine the extent to which the features should be protected as part of the NHS. Given the limited amount of woodland cover on the landscape, alteration or removal of existing woodlands less than 4.0 ha in area should be discouraged. To resolve potential conflicts over woodland protection, the City of Brantford should consider "ecological off-setting" in the form of "naturalization" of NHS buffers. The Lake Simcoe Region Conservation Authority Ecological Off-setting Plan (2017) or the Nottawasaga Valley Conservation Authority (2019) model provide a useful tool that can be applied by the City of Brantford (refer to Section 4.8 below). The goal of this approach is to ensure that the pre-development woodland cover in the North Brantford and Tutela Heights study areas is not reduced as a result of future urban development, and that a "net gain" in habitat is achieved.

Maintain and enhance existing wetland area

All evaluated wetlands and unevaluated wetlands greater than 0.5 ha in area have been included within the NHS. Wetlands less than 0.5 ha (naturally occurring) or less than 2.0 ha (anthropogenic) have been identified as "Other Environmental Features" to be reviewed as part of an EIS at the block plan or draft plan of subdivision stage. The wetlands should be evaluated in the context of GRCA wetland policies to determine if they can be altered or removed. If the GRCA approves the removal of a regulated wetland, it should be compensated for through wetland re-creation elsewhere in the study area (e.g. constructed wetlands, bio-swales, floodplain wetland creation in conjunction with natural channel design of headwater drainage features to be conserved). The goal of this objective is to ensure that wetland cover within the study area is not reduced as a result of future urban development, and that a "net gain" in habitat is achieved.

Provide minimum 30 m naturalized buffers to NHS features

A 30 m buffer has been provided to all NHS features. Future naturalization of the NHS buffers, either through natural plant succession or restoration, will assist in increasing the overall woodland cover within the study area. Ecological off-setting for alteration or removal of "Other Environmental Features", where supported by an EIS, should occur within the 30 m NHS buffers.

Provide minimum 30 m vegetated stream buffers

Environment Canada (2013) recommends that a minimum 30 m buffer on each side of a watercourse, over 75% of its length, should be in natural vegetative cover to support healthy streams and rivers. Due to the extensive agricultural land use in the study area, many of the watercourses identified for protection do not fulfil this minimum criterion.

A 30 m buffer has been applied to all watercourses to be protected as part of the NHS. Stream reaches wherein the buffer is not vegetated (i.e. cultivated land) should be allowed to regenerate naturally and/or be restored with locally indigenous plant species.

Maintain and enhance species dispersal corridors and linkages between NHS features

Existing species dispersal corridors and linkages have been protected as part of the NHS (e.g. Jones Creek corridor). The provision of a 30 m buffer that will ultimately be naturalized will enhance the overall corridor/linkage function of the NHS. Headwater drainage features to be “conserved” will also be naturalized, which will re-instate former linkage connections between NHS features. Opportunities for improving the linkages between existing NHS components has also been identified (refer to Figure A and Figure B in Appendix D).

Maintain and enhance the overall pattern and volume of recharge to the groundwater system

The study area supports coldwater fish habitat (Jones Creek) and wetlands that are primarily sustained by groundwater discharge. Groundwater recharge in areas with high infiltration rates should be protected and enhanced to the extent feasible using Low Impact Development (LID) measures. A detailed hydrogeological investigation of the study area is recommended to confirm the groundwater regime, identify potential impacts, and develop an appropriate mitigation strategy. The study should be developed in consultation with the GRCA.

Maintain and enhance existing surface water contributions to wetlands and floodplain habitats

The preliminary SWM plan for the study area identifies the location of several centralized SWM facilities that are designed to maintain the hydrology of receiving watercourses, floodplains, and wetlands. Additional SWM measures may be required to fully protect watercourses, wetlands and floodplain habitat. Further studies are required to confirm the pre-development surface drainage regime, and refine the SWM plan for the study area. This work should be completed as part of a subsequent phase in the subwatershed study process or through individual EIS’s at the block plan or draft plan of subdivision stage.

Protect watercourses from urban pollution, sedimentation, channel/bank erosion, and thermal impacts

Given the sensitivity and significance of watercourses within the study area, “enhanced” stormwater management measures are recommended to protect aquatic habitat, stream morphology, and the thermal regime. Temperature mitigation measures will need to be incorporated into the design of SWM ponds and outlets to protect coldwater fish habitat. A comprehensive SWM plan should be prepared for the study area as part of the subwatershed study process that provides direction for the preparation of SWM plans for individual development applications at the block plan or draft plan of subdivision stage. The SWM plan should be developed in consultation with the GRCA.

Provide opportunities for sustainable passive recreational use of the NHS through wise resource management, public education/awareness, and environmental stewardship measures

Further work is required to address this objective. It is recommended that when the City of Brantford assumes full ownership of the Open Space lands (i.e. NHS), they should partner with the GRCA to complete a detailed bio-physical inventory of the study area to confirm existing conditions (baseline), constraints, and sensitive habitat locations. This information should be used to identify resource management issues and targets, restoration/enhancement opportunities, suitable locations for trails and bridge crossings, sensitive areas to avoid and rehabilitate, and public education opportunities. The City of Brantford should consider preparing an environmental stewardship and education program that promotes public awareness and appropriate practices to safeguard the natural environment.

Protect hazard land features such as floodplains, valley slopes, and stream meander belt width

Floodplains and valley slopes are included within the NHS. Some portions of floodplains and valley slopes (i.e. in cultivated fields) however were not included in the NHS. Further analysis is required in these areas to confirm the limits of the floodplain and stable top of slope. In addition, the meander belt width for all watercourses to be protected will need to be calculated to confirm the limits of development and allowances (setbacks). This work can either be completed as part of the subwatershed study process or at the block plan or draft plan of subdivision stage.

Revisions to the NHS will be required to accommodate floodplains and meander belt widths. Where these areas coincide with cultivated fields, it will provide an opportunity for naturalization and restoration to augment and reinforce the resiliency of the NHS.

Protect and restore headwater drainage features identified for protection

Headwater drainage features identified for protection are shown on the NHS mapping. The features in question should be restored using natural channel principles, and should be naturalized using locally indigenous plant species. Restoration of the headwater drainage features will provide enhanced linkage connections between NHS components.

Protect and enhance habitat for species at risk

Habitat for the majority of species at risk previously recorded from the study area and observed as part of the Comprehensive EIS is protected in the NHS with 30 m buffers. The study area, however, does provide potential habitat for species at risk in areas proposed for development or within Other Environmental Features. Comprehensive species at risk surveys are therefore recommended at the block plan or draft plan of subdivision stage to confirm the presence/absence of endangered and threatened species, and to identify appropriate mitigation measures, including habitat avoidance, where required. Consultation with MECP will be required for matters related to species at risk.

4.8 Ecological Off-setting

Ecological off-setting is a management tool that the City of Brantford can use to resolve land use planning conflicts related to the natural heritage system, “Other Environmental Features”, and the application of 30 m buffers. The intent of an ecological off-setting plan is to ensure that the pre-development woodland and wetland cover within the study area is not further reduced as a result of future urban growth within North Brantford and Tutela Heights. Woodland, wetland, NHS and “Other Environmental Feature” area calculations are provided below in Table 4.

Table 4 – Area Calculations

Feature	**North Brantford (NB) Area (ha)**	**Tutela Heights (TH) Area (ha)**	**% of Total Area NB/TH**
Woodland	279	83	13/14
Wetland	327	53	15/9
NHS	507	87	24/15
30 m Buffer	230	45	11/8
Other Environmental Feature – Woodland/Hedgerow	37	20	2/3
Other Environmental Feature – Wetland	9.8	3.6	0.5/0.6
Study Area	2128	587	

The total area of buffer lands within North Brantford and Tutela Heights is 230 ha and 45 ha, respectively. This represents a potential increase in woodland cover of 11% for North Brantford and 8% for Tutela Heights. The post-development woodland cover within the study area however would still be below the Environment Canada (2013) minimum 30% cover target (i.e. 24% for North Brantford and 22% for Tutela Heights). The percentage of wetland cover within North Brantford (i.e. 15%) and Tutela Heights (i.e. 9%) generally meets the Environment Canada (2013) minimum target of 10%. The total area of "Other Environmental Features, inclusive of woodland/hedgerow and wetland, is 47 ha for North Brantford and 24 ha for Tutela Heights.

The above area calculations underscore the importance of maintaining the existing woodland and wetland cover within the study area, and achieving an overall "net gain" in habitat to meet or exceed the Environment Canada (2013) targets for healthy, sustainable ecosystems.

The Importance of Other Environmental Features

"Other Environmental Features" within the North Brantford and Tutela Heights study area have the potential to provide a wide range of important ecosystem services such as:

- Habitat for species at risk or rare species;
- Linkage/corridor function between NHS features;
- Buffer function to NHS features;
- Shelterbelt or windbreak functions;
- Temperature moderation - reducing the urban heat island effect;

- Reducing soil erosion;
- Significant wildlife habitat functions;
- Groundwater recharge/discharge function;
- Flood moderation;
- Air quality moderation;
- Pollination services;
- Visual/acoustic buffer; and,
- Maintaining native species richness and diversity.

The above ecosystem services of “Other Environmental Features” should be taken into account in future land use decision making. Other factors to consider in determining whether “Other Environmental Features” can be altered or removed for development include the age of the feature (e.g. early-successional, mid-successional, late-successional), tree size class (e.g. <15 cm diameter, >30 cm diameter), the level of disturbance, presence/absence of invasive species, the ability to re-create the feature and its ecological functions in a timely manner, and location (i.e. isolated, in proximity to the NHS).

Should the Municipality determine through an EIS that an “Other Environmental Feature” can be partially or entirely removed for development, ecological off-setting (i.e. habitat compensation) is recommended to maintain/enhance the overall habitat cover within the study area (i.e. woodland, wetland). Ecological off-setting can take many forms, including planting plans for NHS buffers, specific habitat recreation within the NHS or 30 m buffer, or cash-in-lieu that would be applied to an overall NHS restoration and enhancement plan within the study area.

Ecological off-setting is currently practiced by the Nottawasaga Valley Conservation Authority (2019) and the Lake Simcoe Region Conservation Authority (2017). Examples of ecological off-setting approaches applied by the NVCA (2019) are provided below in Table 5. It is recommended that the City of Brantford take the lead and administration of the ecological off-setting model.

Table 5 – Ecological Off-setting Ratios (Source: NVCA 2019)

Environmental Feature – Woodland/Wetland	**Ecological Off-setting Ratio (area basis)**
Factor 1 – Woodland Successional Type/Age	
Plantation, Non-native Woodland	1:1
Early-successional Forest	1:1.5
Mid-successional Forest	1:2
Late-successional Forest	1:3
Factor 2 – Size Class of Woodland Canopy Cover	
Native Woodland Tree Size Class <15cm DBH	1:1.5

Native Woodland Tree Size Class 15-30 cm DBH	1:2
Native Woodland Tree Size Class >30cm DBH	1:3
Factor 1 – Wetland Type	
Non-native Wetland	1:1
Marsh	1:1.5
Thicket Swamp	1:2
Swamp	1:3
Factor 2 – Size Class of Wetland Canopy Cover	
Treed Wetland (swamp) Tree Size Class <15cm DBH	1:1.5
Treed Wetland (swamp) Tree Size Class 15cm-30cm DBH	1:2
Treed Wetland (swamp) Tree Size Class >30cm DBH	1:3
Factor 3 – Groundwater Influence	
Groundwater Influence – High reliance on groundwater discharge (seeps, springs, upwellings)	1:1.5
Factor 4 – Wetland Soil Type	
Organic Soil	1:15

The NVCA off-setting ratio for woodlands and wetlands is equal to a base off-setting ratio of 1:1 plus the sum of all applicable "factors" outlined in Table 5 above. In terms of buffers, a 1:1 off-setting ratio is recommended for reductions in the 30 m NHS buffer, where supported by the results of an EIS.

The ecological off-setting can occur in several locations within the study area, including the following:

- 30 m NHS buffers (cultivated field portion);
- Riparian corridors (cultivated field portion);
- Cultivated fields identified as a NHS "enhancement opportunity"; and,
- Linkage enhancement opportunities.

The ecological off-setting should take the form of natural planting plans and landscaping utilizing locally indigenous plant species. The naturalization plans should be developed in consultation with the City of

Brantford and the GRCA. In certain circumstances, cash-in-lieu may be an acceptable alternative approach to a proponent/developer led off-setting undertaking. The funds should be used by the City of Brantford for NHS restoration/enhancement projects within the North Brantford and Tutela Heights study areas.

4.9 Enhancement Opportunities

Enhancement opportunities describe above are shown on Figure 16a and Figure 16b. The key enhancement opportunity associated with the study area is the "naturalization" of the 30 m NHS buffer through a combination of natural plant succession and landscaping with locally indigenous plant species. Additional enhancement opportunities include long-term naturalization of agricultural fields that are surrounded by NHS features (e.g. Jones Creek valleyland). The long-term rehabilitation of these lands would greatly increase the resiliency and robustness of the NHS, and improve its chances of sustainability in a settled, urban landscape.

Linkage enhancement opportunities have also been identified in certain areas to maintain and enhance existing linkage connections between NHS components in the study area, and with the Growth Plan NHS. Additional linkage enhancement opportunities exist with headwater drainage features to be “conserved”. The naturalization of these features over time will re-establish linkages across the study area landscape, as well as strengthen existing connections between habitat patches.

4.10 Comprehensive Monitoring Program

Development and implementation of a comprehensive monitoring program (pre-development, during-development and post-development) is recommended to measure the effectiveness and performance of mitigation strategies to be developed in subsequent phases of the subwatershed study process or at the block plan or draft plan of subdivision stage. Data on groundwater and surface water quality and quantity, as well as ecological features/functions, should be collected to establish baseline conditions for subsequent comparison during the monitoring period. The monitoring program should be developed in consultation with the GRCA and the City of Brantford. Impact contingency measures should also be developed as part of the monitoring program. The monitoring program should be included as part of a Full EIS or an Environmental Implementation Report (EIR) prepared as a condition of block plan or draft plan of subdivision approval.

5.0 Summary & Conclusions

A Comprehensive EIS exercise was completed for the North Brantford and Tutela Heights study area as part of the Municipal Comprehensive Review for the City of Brantford. The study area is mainly comprised of agricultural land and existing residential development.

The key components of the natural heritage system for the study area include the following:

- Growth Plan NHS;
- PSW’s;
- Unevaluated (naturally occurring) wetlands 0.5 ha in area or larger;
- Anthropogenic wetlands 2.0 ha in area or larger;

- Woodlands 4.0 ha in area[8] or larger;
- Watercourses - Jones Creek, Fairchild Creek, and Phelps Creek – defined valleylands and riparian corridors, including bottomland/floodplain and valley slope vegetation, fish/wildlife habitat, and corridor/linkage functions;
- Headwater drainage features to be "conserved", as defined by ERI (2019);
- Grand River – Significant Valleyland, critical habitat for species at risk, species dispersal corridor;
- Floodplains and valley slope/erosion hazards;
- Habitat for species at risk protected under the *Endangered Species Act* (2007); and,
- A 30 m protective buffer from all NHS components.

Environmental management and mitigation recommendations to protect, restore and enhance the natural heritage system for the *long-term* have been provided for implementation through subsequent stages in the planning process (i.e. Subwatershed Study or Full EIS at block plan or draft plan of subdivision stage). Ecological off-setting is recommended to address potential land use planning conflicts, and to achieve an overall "net gain" in woodland and wetland cover within the North Brantford and Tutela Heights study areas. Naturalization of the 30 m NHS buffer provides an excellent opportunity to achieve this environmental management objective.

The recommended natural heritage system framework described above was used in the development of land use concept plans for the study area, and the subsequent evaluation of alternatives, and selection of a preferred option. An analysis of potential impacts associated with the preferred land use option for North Brantford and Tutela Heights has been provided.

In conclusion, a high level of environmental protection and enhancement can be achieved with the preferred land use concept for the North Brantford and Tutela Heights study areas. Environmental management and mitigation measures have been provided to protect the NHS from irreversible, negative impacts to key ecological and key hydrologic features and functions. It is recommended that these measures be developed in more detail, as part of subsequent phases in the Subwatershed Study process, or as a Full EIS to be completed in conjunction with future development applications (i.e. block plan or draft plan of subdivision). Land use policies for North Brantford and Tutela Heights should address the recommendations of the Comprehensive EIS, and ensure conformity with the Provincial Policy Statement (2020), the Growth Plan for the Greater Golden Horseshoe (2020), the City of Brantford Official Plan, and the regulations/policies of the GRCA.

Respectfully submitted by,

PLAN B Natural Heritage

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[8] For landscapes with 5-15% woodland cover, the NHRM for the PPS states that woodlands ≥4 ha in area should be considered as "significant".

References

Acton, C.J. 1989. The Soils of Brant County – Soil Survey Report No. 55 of the Ontario Institute of Pedology.

Bird Studies Canada. 1995. Great Lakes Marsh Monitoring Program.

Cadman, M. D., D.A. Sutherland, G.G. Beck, D. Lepage, and A.R. Courturier. 2007. *Atlas of the Breeding Birds of Ontario, 2001-2005*. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature.

County of Brant. 2012. County of Brant Official Plan.

Chapman, L.J. and D.F. Putnam. 1984. The Physiography of Southern Ontario, 3rd Edition.

Environment Canada. 2013. How Much Habitat is Enough? 3rd Edition. Environment Canada.

Ecosystem Recovery Inc. 2019. Settlement Area Boundary Expansion: Geomorphic Assessment.

Ecosystem Recovery Inc. 2019. Headwater Drainage Feature Assessment.

GM BluePlan, Ecosystem Recovery Inc. and PLAN B Natural Heritage. 2019. North Brantford and Tutela Heights Subwatershed Study – Phase 1.

Grand River Conservation Authority. 2017. Lower Middle Grand River Watershed. Natural Heritage Characterization Report.

Grand River Conservation Authority. 2016. Fairchild Creek Subwatershed Characterization Study.

Grand River Conservation Authority. 2015. Policies for the Administration of the Development, Interference with Wetlands and Alterations to Shorelines and Watercourses Regulation Ontario Regulation 150/06.

Grand River Conservation Authority. 2008. Grand River Watershed Characterization Report.

Lake Simcoe Region Conservation Authority. 2017. Ecological Offsetting Plan.

Lee, H.T., W.D. Bakowsky, J. Riley, J. Bowles, M. Puddister, P. Uhlig and S. McMurray. 1998. Ecological Land Classification for Southern Ontario: First Approximation and Its Application. Ontario Ministry of Natural Resources, Southcentral Science Section Field Guide FG-02. 225 pp.

Nottawasaga Valley Conservation Authority. 2019. Achieving Net Gains Through Ecological Offsetting. Guidelines for Preparing a Site-specific ecological Offsetting Plan. Draft for Discussion.

Ontario Ministry of Municipal Affairs and Housing. 2020. Provincial Policy Statement.

Ontario Ministry of Municipal Affairs and Housing. 2020. Growth Plan for the Greater Golden Horseshoe.

Ontario Ministry of Natural Resources and Forestry. 2019. Land Information Ontario.

Ontario Ministry of Natural Resources. 2019. Natural Heritage Information Centre.

Ontario Ministry of Natural Resources. 2010. Natural Heritage Reference Manual for Natural Heritage Policies of the Provincial Policy Statement, 2005. Second Edition. Toronto: Queen's Printer for Ontario. 248 pp.

Ontario Ministry of Energy, Northern Development and Mines. 2019. Surficial Geology Mapping.

SGL Planning & Design Inc. 2019. Envisioning Brantford – Municipal Comprehensive Review – Part 3: Preferred Settlement Area Boundary Expansion and Draft Preferred Land Use and Transportation Plan.

Toronto and Region Conservation Authority and Credit Valley Conservation. 2014. Evaluation, Classification and Management of Headwater Drainage Features Guideline.

Appendices

Appendix A	*Amphibian Observations*
Appendix B	*Bird Observations*
Appendix C	*Bird Point Count Data*
Appendix D	*Species Dispersal Corridors (Figure A & Figure B)*

Appendix A - 2018 Amphibian Point Count Survey

Visit 1

Day	April 27 2018
Temperature	8-9 Celsius

Station 1	Count levels	
Species	<100	>100
Spring Peeper		1_1

Station 2	Count levels	
Species	<100	>100
Spring Peeper	1_1	3

Station 3	Count levels	
Species	<100	>100
Spring Peeper	3	
American Toad	2_4	

Station 4	Count levels	
Species	<100	>100
Spring Peeper		3

Station 5	Count levels	
Species	<100	>100
Spring Peeper		1_1

Station 6	Count levels	
Species	<100	>100
Spring Peeper	1_1	1_2
American Toad	2_2	

Station 7	Count levels	
Species	<100	>100
Spring Peeper		2_5
American Toad		2_3

Visit 2

Day	May 29 2018
Temperature	17-19 Celsius

Station 3	Count levels	
Species	<100	>100
Gray Tree Frog	1_1	
Green Frog	1_1	

Station 7	Count levels	
Species	<100	>100
Gray Tree Frog		2_3
Green Frog		1_2

Station 9	Count levels	
Species	<100	>100
Gray Tree Frog	1_1	2_4
Spring Peeper		1_1

Station 12	Count levels	
Species	<100	>100
Gray Tree Frog		1_2
Green Frog		2_2

Station 13	Count levels	
Species	<100	>100
Green Frog		1_1

Station 16	Count levels	
Species	<100	>100
Green Frog		1_1

Station 17	Count levels	
Species	<100	>100
Green Frog	1_1	

Visit 3

Day	June 26 2018
Temperature	17 Celsius

Station 3	Count levels	
Species	<100	>100
Green Frog	1_2	

Station 7	Count levels	
Species	<100	>100
Green Frog		1_1

Station 9	Count levels	
Species	<100	>100
Green Frog		1_1

Station 12	Count levels	
Species	<100	>100
Green Frog		2_3

Station 16	Count levels	
Species	<100	>100
Green Frog		1_2

Station 17	Count levels	
Species	<100	>100
Green Frog	2_3	

Station 19	Count levels	
Species	<100	>100
Green Frog		1_1

Station 8	Count levels	
Species	<100	>100
Spring Peeper	1_1	
American toad	2_2	

Station 9	Count levels	
Species	<100	>100
Spring Peeper	3	3
American Toad		2_4

Station 10	Count levels	
Species	<100	>100
Spring Peeper		1_1

Station 11	Count levels	
Species	<100	>100
Spring Peeper		2_6

Station 12	Count levels	
Species	<100	>100
Spring Peeper		3

Station 13	Count levels	
Species	<100	>100
Spring Peeper		3

Station 14	Count levels	
Species	<100	>100
Spring Peeper		1_1

Station 15	Count levels	
Species	<100	>100
Spring Peeper		3

Station 16	Count levels	
Species	<100	>100
Spring Peeper		2_5

Station 17	Count levels	
Species	<100	>100
Spring Peeper	2_6	3

Spring Peeper	1_1	

Station 19	Count levels	
Species	<100	>100
Gray Tree Frog		1_2
Green Frog		1_1

Station 18	Count levels	
Species	<100	>100
Spring Peeper		3

Station 19	Count levels	
Species	<100	>100
Spring Peeper	1_1	3

Appendix B - 2017 and 2018 Breeding Bird Observations

Common Name	Breeding Evidence	
	North Brantford	Tutela Heights
AMERICAN CROW	confirmed	confirmed
AMERICAN GOLDFINCH	probable	probable
AMERICAN REDSTART		possible
AMERICAN ROBIN	confirmed	confirmed
BALTIMORE ORIOLE	probable	confirmed
BARN SWALLOW	probable	possible
BELTED KINGFISHER	possible	
BLACK-BILLED CUCKOO	possible	probable
BLACK-CAPPED CHICKADEE	probable	probable
BLUE GRAY GNATCATCHER	possible	possible
BLUE JAY	confirmed	confirmed
BLUE-WINGED WARBLER	possible	
BOBOLINK	possible	
BROWN THRASHER	possible	possible
BROWN-HEADED COWBIRD	probable	probable
CANADA GOOSE	possible	
CAROLINA WREN	possible	probable
CEDAR WAXWING	probable	probable
CHIPPING SPARROW	confirmed	confirmed
CLAY-COLOURED SPARROW	probable	
COMMON GRACKLE	confirmed	confirmed
COMMON YELLOWTHROAT	confirmed	probable
DOWNY WOODPECKER	probable	possible
EASTERN KINGBIRD	confirmed	possible
EASTERN MEADOWLARK	probable	
EASTERN PHOEBE	probable	confirmed
EASTERN WOOD PEWEE	probable	possible
EUROPEAN STARLING	confirmed	confirmed
FIELD SPARROW	probable	probable
GRAY CATBIRD	probable	confirmed
GREAT BLUE HERON	possible	
GREAT CRESTED FLYCATCHER	possible	probable
HAIRY WOODPECKER	possible	
HORNED LARK	possible	
HOUSE FINCH	possible	probable
HOUSE SPARROW	confirmed	confirmed
HOUSE WREN	confirmed	probable
INDIGO BUNTING	probable	probable
KILLDEER	probable	possible
LEAST FLYCATCHER		possible
MALLARD	possible	
MOURNING DOVE	confirmed	confirmed

Appendix B - 2017 and 2018 Breeding Bird Observations

MOURNING WARBLER		probable
NORTHERN CARDINAL	probable	confirmed
NORTHERN FLICKER	possible	probable
NORTHERN ROUGH-WINGED SWALLOW	possible	
ORCHARD ORIOLE	possible	
OSPREY	confirmed	
PILEATED WOODPECKER		possible
RED-BELLIED WOODPECKER	probable	confirmed
RED-EYED VIREO	confirmed	probable
RED-TAILED HAWK	possible	
RED-WINGED BLACKBIRD	confirmed	confirmed
RING-BILLED GULL	visitor	
ROCK PIGEON	confirmed	possible
ROSE-BREASTED GROSBEAK		possible
RUBY-THROATED HUMMINGBIRD		possible
SAVANNAH SPARROW	possible	
SONG SPARROW	confirmed	confirmed
SPOTTED SANDPIPER	possible	
TREE SWALLOW	possible	possible
TURKEY VULTURE		possible
WARBLING VIREO	confirmed	probable
WHITE-BREASTED NUTHATCH		probable
WILD TURKEY	possible	
WILLOW FLYCATCHER	possible	possible
WOOD THRUSH		possible
YELLOW WARBLER	probable	probable
YELLOW-BILLED CUCKOO	possible	

Appendix B - 2017 and 2018 Breeding Bird Observations

SPECIES	Tutela Heights		North Brantford	
	Number of point counts species recorded in	Total number of individuals	Number of point counts species recorded in	Total number of individuals
AMERICAN CROW	15	31	34	55
AMERICAN GOLDFINCH	18	42	40	69
AMERICAN REDSTART	1	1	0	0
AMERICAN ROBIN	35	112	69	164
BALTIMORE ORIOLE	18	27	18	21
BARN SWALLOW	3	5	10	16
BELTED KINGFISHER	0	0	1	1
BLACK-BILLED CUCKOO	3	4	1	1
BLACK-CAPPED CHICKADEE	5	6	10	13
BLUE GRAY GNATCATCHER	2	2	2	2
BLUE JAY	12	18	8	9
BLUE-WINGED WARBLER	0	0	1	1
BOBOLINK	0	0	2	3
BROWN THRASHER	1	1	1	1
BROWN-HEADED COWBIRD	5	6	22	27
CANADA GOOSE	0	0	1	1
CAROLINA WREN	6	8	1	1
CEDAR WAXWING	10	18	19	27
CHIPPING SPARROW	15	22	33	44
CLAY-COLOURED SPARROW	0	0	2	3
COMMON GRACKLE	16	42	46	140
COMMON YELLOWTHROAT	7	10	19	26
DOWNY WOODPECKER	3	3	5	5
EASTERN KINGBIRD	3	3	17	26
EASTERN MEADOWLARK	0	0	4	5
EASTERN PHOEBE	3	3	4	4
EASTERN WOOD PEWEE	3	3	3	3
EUROPEAN STARLING	17	40	49	195
FIELD SPARROW	6	7	8	9
GRAY CATBIRD	11	25	23	26
GREAT BLUE HERON	1	1	2	2
GREAT CRESTED FLYCATCHER	3	3	3	3
HAIRY WOODPECKER	0	0	1	1
HORNED LARK	0	0	1	1
HOUSE FINCH	6	9	5	8
HOUSE SPARROW	15	37	30	90
HOUSE WREN	16	25	24	31
INDIGO BUNTING	10	15	14	19
KILLDEER	6	6	12	16

Appendix B - 2017 and 2018 Breeding Bird Observations

LEAST FLYCATCHER	1	1	0	0
MALLARD	0	0	3	4
MOURNING DOVE	24	42	44	88
MOURNING WARBLER	2	2	1	1
NORTHERN CARDINAL	29	55	44	71
NORTHERN FLICKER	9	9	11	11
NORTHERN ROUGH-WINGED SWALLOW	0	0	1	1
ORCHARD ORIOLE	0	0	2	2
OSPREY	0	0	1	1
PILEATED WOODPECKER	2	2	0	0
RED-BELLIED WOODPECKER	9	14	3	3
RED-EYED VIREO	9	14	16	24
RED-TAILED HAWK	0	0	1	1
RED-WINGED BLACKBIRD	14	35	60	202
RING-BILLED GULL	0	0	4	8
ROCK PIGEON	1	1	7	14
ROSE-BREASTED GROSBEAK	4	6	0	0
RUBY-THROATED HUMMINGBIRD	1	1	0	0
SAVANNAH SPARROW	0	0	4	4
SONG SPARROW	21	38	73	146
SPOTTED SANDPIPER	1	1	1	1
TREE SWALLOW	3	3	1	1
TURKEY VULTURE	1	1	0	0
WARBLING VIREO	7	9	17	19
WHITE-BREASTED NUTHATCH	2	2	0	0
WILD TURKEY	0	0	1	1
WILLOW FLYCATCHER	2	3	2	2
WOOD THRUSH	1	4	0	0
YELLOW WARBLER	5	12	9	17
YELLOW-BILLED CUCKOO	0	0	1	1

Appendix C - 2017 and 2018 Breeding Bird Point Count Survey

June 16 2017

Station 1	<100	>100
RED-WINGED BLACKBIRD	2	2
HOUSE SPARROW	1	1
COMMON GRACKLE	1	
AMERICAN ROBIN	1	
EUROPEAN STARLING	1	16
AMERICAN CROW	1	
SONG SPARROW	1	1
KILLDEER		1

July 9 2017

Station 1	<100	>100
COMMON GRACKLE	7	2
HOUSE SPARROW		3
SONG SPARROW	1	1
RED-WINGED BLACKBIRD	1	3
MOURNING DOVE	1	
EUROPEAN STARLING	1	
RING-BILLED GULL	1	

June 16 2017

Station 2	<100	>100
RED-WINGED BLACKBIRD	5	2
SAVANNAH SPARROW	1	
KILLDEER	1	2
CHIPPING SPARROW	1	
BALTIMORE ORIOLE		1
SONG SPARROW		2
COMMON GRACKLE	1	
AMERICAN ROBIN	1	
AMERICAN CROW		1
EUROPEAN STARLING	1	

July 9 2017

Station 2	<100	>100
SONG SPARROW	1	1
COMMON GRACKLE		4
RED-WINGED BLACKBIRD	2	
BROWN-HEADED COWBIRD	2	
CEDAR WAXWING	1	
AMERICAN ROBIN		2
NORTHERN CARDINAL		1

June 16 2017

Station 3	<100	>100
HOUSE WREN	1	
AMERICAN GOLDFINCH	2	
RED-EYED VIREO	1	
AMERICAN ROBIN	2	
RED-WINGED BLACKBIRD	1	2
BROWN-HEADED COWBIRD		1
COMMON GRACKLE		1
CHIPPING SPARROW	1	
CANADA GOOSE	2	
GRAY CATBIRD	1	1
COMMON YELLOWTHROAT		1
BLACK-CAPPED CHICKADEE		1

July 9 2017

Station 3	<100	>100
NORTHERN CARDINAL	1	
AMERICAN CROW	3	4
BALTIMORE ORIOLE	1	
SONG SPARROW	1	2
AMERICAN GOLDFINCH	2	
GREAT CRESTED FLYCATCHER		1
GRAY CATBIRD	1	
HOUSE WREN		1

June 16 2017

Station 4	<100	>100
AMERICAN CROW	2	
WARBLING VIREO	1	
BALTIMORE ORIOLE	1	1
RING-BILLED GULL	5	
AMERICAN ROBIN	2	1
CHIPPING SPARROW	2	
SONG SPARROW		1

July 9 2017

Station 4	<100	>100
HOUSE SPARROW	4	
SONG SPARROW	1	
CHIPPING SPARROW	1	2
AMERICAN ROBIN	1	1
HOUSE WREN		1
RED-WINGED BLACKBIRD		2
COMMON GRACKLE	1	
EUROPEAN STARLING	2	
RED-BELLIED WOODPECKER		1
AMERICAN GOLDFINCH	1	

June 16 2017

Station 5	<100	>100
AMERICAN GOLDFINCH	3	
SONG SPARROW	1	2
FIELD SPARROW		1
EUROPEAN STARLING	1	
BROWN-HEADED COWBIRD	2	
BALTIMORE ORIOLE		1
RED-WINGED BLACKBIRD	1	
NORTHERN CARDINAL		1
M0URNING DOVE	1	
COMMON GRACKLE	1	
INDIGO BUNTING		1

July 9 2017

Station 5	<100	>100
WARBLING VIREO	1	
CEDAR WAXWING	1	
HOUSE WREN	1	1
SONG SPARROW		1
AMERICAN ROBIN	1	1
RED-EYED VIREO		1
CHIPPING SPARROW	2	
MALLARD	1	

June 16 2017

Station 6	<100	>100
SONG SPARROW	1	1
EASTERN PHOEBE		1
HOUSE WREN		2
CHIPPING SPARROW	1	
AMERICAN ROBIN	3	1
MOURNING DOVE	1	1
RED-WINGED BLACKBIRD	1	3
CEDAR WAXWING	1	
AMERICAN GOLDFINCH	1	2
NORTHERN CARDINAL		2
BARN SWALLOW	1	
EASTERN MEADOWLARK		1
INDIGO BUNTING	2	
BALTIMORE ORIOLE	1	
EUROPEAN STARLING	1	

July 9 2017

Station 6	<100	>100
EUROPEAN STARLING	4	
BLUEJAY		2
GRAY CATBIRD	1	
MOURNING DOVE	1	1
CEDAR WAXWING	3	
SONG SPARROW	2	1
BLACK-CAPPED CHICKADEE	1	1
NORTHERN CARDINAL		1
AMERICAN ROBIN	1	
AMERICAN GOLDFINCH	2	
AMERICAN CROW		2
COMMON YELLOWTHROAT	1	
BROWN-HEADED COWBIRD	1	

June 16 2017

Station 7	<100	>100
HOUSE WREN		1
NORTHERN CARDINAL	2	1
WARBLING VIREO	1	
SONG SPARROW	1	1
YELLOW WARBLER	1	
RED-WINGED BLACKBIRD		1
RED-BELLIED WOODPECKER	1	
COMMON GRACKLE		1

July 9 2017

Station 7	<100	>100
NORTHERN CARDINAL	1	1
EASTERN KINGBIRD	1	
WARBLING VIREO	1	
EUROPEAN STARLING	7	10
AMERICAN GOLDFINCH	1	
INDIGO BUNTING	1	
CHIPPING SPARROW	1	
MOURNING DOVE	1	1
COMMON GRACKLE		1
SONG SPARROW		2
AMERICAN CROW		1
NORTHERN FLICKER		1

June 16 2017

Station 8	<100	>100
AMERICAN GOLDFINCH	3	1
YELLOW WARBLER	3	1
AMERICAN ROBIN	2	2
MALLARD		2
BROWN THRASHER	1	
HOUSE WREN		1
MOURNING DOVE		1
BROWN-HEADED COWBIRD	1	
NORTHERN CARDINAL		1
CEDAR WAXWING	1	
EUROPEAN STARLING	2	
BALTIMORE ORIOLE	1	
GRAY CATBIRD	1	
CHIPPING SPARROW		1

July 9 2017

Station 8	<100	>100
COMMON GRACKLE	2	3
SONG SPARROW	1	2
AMERICAN GOLDFINCH	1	1
WARBLING VIREO		1
MOURNING DOVE	1	5
BALTIMORE ORIOLE		1
BROWN-HEADED COWBIRD	1	
GRAY CATBIRD		1
AMERICAN ROBIN	2	3
COMMON YELLOWTHROAT	1	2
RED-WINGED BLACKBIRD	2	7
EUROPEAN STARLING	1	3
NORTHERN CARDINAL		1
HOUSE WREN		1

June 16 2017

Station 9	<100	>100
RED-WINGED BLACKBIRD	2	2
HOUSE SPARROW	6	
KILLDEER	1	
AMERICAN ROBIN	1	1
CHIPPING SPARROW	1	1
EUROPEAN STARLING	5	1
COMMON GRACKLE	2	
MOURNING DOVE	3	

July 9 2017

Station 9	<100	>100
MOURNING DOVE	3	
NORTHERN CARDINAL	1	1
RED-WINGED BLACKBIRD		1
HOUSE SPARROW	3	3
AMERICAN ROBIN	1	
HOUSE WREN		1
AMERICAN GOLDFINCH	2	
EUROPEAN STARLING	1	
COMMON GRACKLE		2
CAROLINA WREN	1	

June 16 2017

Station 10	<100	>100
HOUSE SPARROW	3	
BALTIMORE ORIOLE	1	
AMERICAN ROBIN	1	
MOURNING DOVE	1	1
GRAY CATBIRD	1	
EUROPEAN STARLING	2	
HOUSE WREN		1
SONG SPARROW		1
COMMON GRACKLE	1	1
AMERICAN GOLDFINCH		1
RED-WINGED BLACKBIRD	2	

July 9 2017

Station 10	<100	>100
RED-WINGED BLACKBIRD	3	3
HOUSE SPARROW	5	
HOUSE FINCH		1
COMMON GRACKLE		2
AMERICAN CROW	1	1
EUROPEAN STARLING	1	
MOURNING DOVE		1
BLACK-CAPPED CHICKADEE		1

June 16 2017

Station 11	<100	>100
SONG SPARROW	1	1
AMERICAN CROW		3
COMMON GRACKLE	2	
GREAT BLUE HERON		1
HOUSE SPARROW	3	3
NORTHERN CARDINAL		1
AMERICAN ROBIN	1	
HOUSE WREN	1	
BLUE GRAY GNATCATCHER	1	
ROCK PIGEON		3

July 9 2017

Station 11	<100	>100
NORTHERN CARDINAL	2	1
SONG SPARROW	1	
RED-WINGED BLACKBIRD	1	1
HOUSE WREN		1
COMMON GRACKLE	3	2
AMERICAN ROBIN		2
COMMON YELLOWTHROAT		1
EUROPEAN STARLING	4	
GRAY CATBIRD		1
MOURNING DOVE		1
AMERICAN GOLDFINCH	1	
BROWN-HEADED COWBIRD		1

June 16 2017

Station 12	<100	>100
AMERICAN ROBIN	1	
RED-WINGED BLACKBIRD	5	2
COMMON GRACKLE	5	
EUROPEAN STARLING		3
SONG SPARROW	1	1
AMERICAN GOLDFINCH		2
DOWNY WOODPECKER	1	
HOUSE WREN	1	
BLACK-CAPPED CHICKADEE	1	
NORTHERN CARDINAL		2

July 9 2017

Station 12	<100	>100
MOURNING DOVE		1
SONG SPARROW	1	1
EUROPEAN STARLING	6	
CHIPPING SPARROW	1	1
AMERICAN CROW		1
RED-WINGED BLACKBIRD	2	
BARN SWALLOW		2
COMMON GRACKLE		1
AMERICAN ROBIN		1
OSPREY	1	

June 16 2017

Station 13	<100	>100
CHIPPING SPARROW		1
AMERICAN GOLDFINCH	1	
BROWN-HEADED COWBIRD	1	
HOUSE SPARROW	2	
MOURNING DOVE	1	
YELLOW WARBLER		1
RED-WINGED BLACKBIRD		1
BLACK-CAPPED CHICKADEE		1
HOUSE WREN		1
AMERICAN CROW	3	1
AMERICAN ROBIN		1
NORTHERN CARDINAL	1	
CEDAR WAXWING	1	
ROCK PIGEON		2
INDIGO BUNTING		1
SONG SPARROW	1	1

July 9 2017

Station 13	<100	>100
AMERICAN CROW		1
SONG SPARROW	1	2
EASTERN KINGBIRD		1
AMERICAN ROBIN	1	
INDIGO BUNTING		1
AMERICAN GOLDFINCH		1

June 16 2017

Station 14	<100	>100
AMERICAN ROBIN	2	1
RED-EYED VIREO	2	2
INDIGO BUNTING	1	1
GREAT CRESTED FLYCATCHER	1	
NORTHERN CARDINAL	2	1
EASTERN WOOD PEWEE		1
HOUSE WREN		2
SONG SPARROW	1	
WILD TURKEY		1
COMMON GRACKLE		1

July 9 2017

Station 14	<100	>100
AMERICAN ROBIN	1	2
RED-EYED VIREO	2	2
AMERICAN GOLDFINCH	3	
BLACK-CAPPED CHICKADEE	2	1
SONG SPARROW	1	
NORTHERN CARDINAL	1	2
AMERICAN CROW		1

June 16 2017

Station 15	<100	>100
NORTHERN CARDINAL	1	1
GRAY CATBIRD	1	
SONG SPARROW	1	1
RED-WINGED BLACKBIRD	2	2
RED-EYED VIREO		1
AMERICAN ROBIN	1	
AMERICAN GOLDFINCH	1	
YELLOW WARBLER	1	2
ORCHARD ORIOLE	1	

July 9 2017

Station 15	<100	>100
AMERICAN GOLDFINCH	1	1
INDIGO BUNTING		1
AMERICAN ROBIN	3	
GREAT CRESTED FLYCATCHER		1
CHIPPING SPARROW		1
EUROPEAN STARLING		1
BALTIMORE ORIOLE		1
RED-WINGED BLACKBIRD		1
CEDAR WAXWING	1	
SONG SPARROW	1	
MOURNING DOVE		3
NORTHERN CARDINAL		1

June 16 2017

Station 16	<100	>100
COMMON GRACKLE	2	1
ROCK PIGEON	2	
NORTHERN CARDINAL		1
AMERICAN ROBIN		1
RED-EYED VIREO		1
SONG SPARROW	1	
EUROPEAN STARLING	1	
HOUSE SPARROW		2
BALTIMORE ORIOLE	1	
YELLOW WARBLER		1

July 9 2017

Station 16	<100	>100
AMERICAN ROBIN	2	1
SONG SPARROW	1	
GRAY CATBIRD		1
TREE SWALLOW	1	
EASTERN PHOEBE		1
EUROPEAN STARLING		2
HOUSE SPARROW	2	
MOURNING DOVE		1

June 16 2017

Station 17	<100	>100
CLAY-COLOURED SPARROW	1	
SONG SPARROW	2	2
AMERICAN ROBIN	1	
YELLOW WARBLER	2	
RED-WINGED BLACKBIRD	2	1
EASTERN MEADOWLARK		2
COMMON YELLOWTHROAT		1
FIELD SPARROW		1
NORTHERN ROUGH-WINGED SWALLOW	1	
EASTERN KINGBIRD		1
GREAT BLUE HERON		1
BROWN-HEADED COWBIRD	1	2
MOURNING DOVE	1	
SAVANNAH SPARROW	1	

July 9 2017

Station 17	<100	>100
CLAY-COLOURED SPARROW	2	
AMERICAN ROBIN	3	
EUROPEAN STARLING	3	3
GRAY CATBIRD	1	
RED-TAILED HAWK	1	
RED-WINGED BLACKBIRD	1	2
EASTERN MEADOWLARK	1	
SONG SPARROW	1	1
BLUE GRAY GNATCATCHER	1	

June 16 2017

Station 18	<100	>100
EUROPEAN STARLING	2	10
MOURNING DOVE	3	
AMERICAN ROBIN	2	1
SONG SPARROW	1	1
RED-WINGED BLACKBIRD	1	
FIELD SPARROW		1
KILLDEER		1
CEDAR WAXWING	1	
SAVANNAH SPARROW	1	

July 9 2017

Station 18	<100	>100
EUROPEAN STARLING	1	
HOUSE WREN		1
HOUSE SPARROW	5	
RED-WINGED BLACKBIRD		1
COMMON GRACKLE	1	
MOURNING DOVE	1	1
NORTHERN CARDINAL		1
SONG SPARROW		1
BROWN-HEADED COWBIRD	1	
AMERICAN CROW		1
AMERICAN ROBIN		1

June 16 2017

Station 19	<100	>100
AMERICAN GOLDFINCH	2	
AMERICAN CROW		1
MOURNING DOVE		1
AMERICAN ROBIN		2
GRAY CATBIRD		1
SONG SPARROW	1	
WARBLING VIREO		1
RED-WINGED BLACKBIRD		1

July 9 2017

Station 19	<100	>100
AMERICAN ROBIN	1	2
SONG SPARROW	2	2
CHIPPING SPARROW	1	
AMERICAN CROW		2
DOWNY WOODPECKER		1
MOURNING DOVE		3
NORTHERN CARDINAL		1

June 16 2017

Station 20	<100	>100
SONG SPARROW	2	1
YELLOW WARBLER	2	
RED-WINGED BLACKBIRD	1	1
COMMON YELLOWTHROAT	1	
EUROPEAN STARLING		1
AMERICAN GOLDFINCH	1	
NORTHERN CARDINAL	1	1
EASTERN KINGBIRD	1	
WARBLING VIREO		1
BROWN-HEADED COWBIRD	1	
AMERICAN ROBIN	1	
COMMON GRACKLE	1	
RING-BILLED GULL		1

July 9 2017

Station 20	<100	>100
WARBLING VIREO	1	
SONG SPARROW	1	1
NORTHERN FLICKER		1
AMERICAN ROBIN	2	
EASTERN KINGBIRD	4	
GRAY CATBIRD	1	
NORTHERN CARDINAL	1	
MOURNING DOVE		1
AMERICAN CROW		1
RED-WINGED BLACKBIRD	1	1
ROCK PIGEON		1
AMERICAN GOLDFINCH	2	
BLUEJAY		1
EUROPEAN STARLING		2
BALTIMORE ORIOLE	1	
YELLOW-BILLED CUCKOO	1	

June 16 2017

Station 21	<100	>100
EASTERN WOOD PEWEE	1	
AMERICAN ROBIN	5	1
RED-WINGED BLACKBIRD	1	1
WILLOW FLYCATCHER		1
COMMON YELLOWTHROAT		2
MOURNING DOVE		1
WARBLING VIREO		1
SONG SPARROW	1	1
EUROPEAN STARLING		3
BROWN-HEADED COWBIRD		1
HOUSE WREN		2
CHIPPING SPARROW	1	

July 9 2017

Station 21	<100	>100
EASTERN WOOD PEWEE	1	
WARBLING VIREO		1
HOUSE WREN	1	1
GRAY CATBIRD	1	
AMERICAN ROBIN	1	3
MOURNING DOVE		1
AMERICAN GOLDFINCH	1	
EASTERN MEADOWLARK		1
BOBOLINK		2
EASTERN KINGBIRD	1	
CHIPPING SPARROW	1	
EUROPEAN STARLING		1
MOURNING DOVE		3
NORTHERN FLICKER		1
BLUEJAY		1
RED-WINGED BLACKBIRD	1	2
SONG SPARROW		1
COMMON GRACKLE	3	
BALTIMORE ORIOLE		1

June 16 2017

Station 22	<100	>100
EUROPEAN STARLING	4	
SONG SPARROW	1	
BARN SWALLOW	1	
ROCK PIGEON	2	
CHIPPING SPARROW		1
EASTERN PHOEBE		1
AMERICAN ROBIN		2

July 9 2017

Station 22	<100	>100
SONG SPARROW	1	1
HOUSE SPARROW		1
RED-EYED VIREO		1
EUROPEAN STARLING	2	
MOURNING DOVE	1	
ROCK PIGEON		2
BARN SWALLOW		2
BROWN-HEADED COWBIRD		1
AMERICAN GOLDFINCH		1
KILLDEER		1
EASTERN KINGBIRD		1
RED-WINGED BLACKBIRD		3

June 16 2017

Station 23	<100	>100
SPOTTED SANDPIPER	1	
RED-WINGED BLACKBIRD	4	1
AMERICAN ROBIN	3	1
COMMON GRACKLE	1	
BARN SWALLOW	1	1
COMMON YELLOWTHROAT	1	1
NORTHERN CARDINAL		1
EASTERN KINGBIRD		1
EUROPEAN STARLING	1	1
SONG SPARROW		1
RED-EYED VIREO		1

July 9 2017

Station 23	<100	>100
NORTHERN CARDINAL		1
SONG SPARROW	1	2
AMERICAN CROW		1
RED-WINGED BLACKBIRD	5	1
AMERICAN ROBIN		2
COMMON YELLOWTHROAT	1	
MOURNING DOVE	1	1
RED-EYED VIREO		1
GRAY CATBIRD	1	1
BLACK-BILLED CUCKOO		1
NORTHERN FLICKER	1	
BOBOLINK		1
BARN SWALLOW	1	
DOWNY WOODPECKER	1	

June 16 2017

Station 24	<100	>100
COMMON YELLOWTHROAT	1	
BROWN-HEADED COWBIRD	1	
AMERICAN ROBIN	1	
RED-WINGED BLACKBIRD	1	1
BARN SWALLOW		1
EUROPEAN STARLING		2
MOURNING DOVE		1
SONG SPARROW	1	

July 9 2017

Station 24	<100	>100
HOUSE SPARROW	3	
CHIPPING SPARROW	2	
KILLDEER	2	
WARBLING VIREO		1
BROWN-HEADED COWBIRD	1	
AMERICAN GOLDFINCH		2
SONG SPARROW	1	1
RED-WINGED BLACKBIRD	2	1
AMERICAN CROW	2	
MOURNING DOVE	1	
EASTERN KINGBIRD		1
NORTHERN CARDINAL		1
BARN SWALLOW		3
CEDAR WAXWING	1	
BLACK-CAPPED CHICKADEE	1	
BLUEJAY		1
EUROPEAN STARLING		3

June 16 2017

Station 25	<100	>100
GRAY CATBIRD	1	
BROWN-HEADED COWBIRD		1
EUROPEAN STARLING	10	3
HOUSE SPARROW	2	
COMMON GRACKLE		1
AMERICAN ROBIN	1	

July 9 2017

Station 25	<100	>100
AMERICAN GOLDFINCH	1	1
AMERICAN ROBIN		1
RED-WINGED BLACKBIRD	2	2
SONG SPARROW	1	
GRAY CATBIRD		1
COMMON YELLOWTHROAT	1	
BROWN-HEADED COWBIRD		2
AMERICAN CROW		1
EUROPEAN STARLING	2	
EASTERN KINGBIRD	1	
HOUSE SPARROW	1	
HAIRY WOODPECKER	1	
COMMON GRACKLE		1

June 16 2017

Station 26	<100	>100
AMERICAN CROW		1
SONG SPARROW	1	2
EUROPEAN STARLING	1	3
NORTHERN CARDINAL		1
YELLOW WARBLER	1	1
BALTIMORE ORIOLE		1
COMMON YELLOWTHROAT		1

July 9 2017

Station 26	<100	>100
EASTERN KINGBIRD	4	
HOUSE WREN	1	1
SONG SPARROW	1	1
GRAY CATBIRD	1	1
AMERICAN ROBIN		1
AMERICAN CROW		1
RED-EYED VIREO		1
BARN SWALLOW	1	
MOURNING DOVE	3	
CHIPPING SPARROW	1	
RED-WINGED BLACKBIRD	1	
EUROPEAN STARLING		3

June 16 2017

Station 27	<100	>100
AMERICAN ROBIN	5	3
HOUSE WREN	1	1
CHIPPING SPARROW	1	
RED-WINGED BLACKBIRD	2	2
MOURNING DOVE	1	
SONG SPARROW	1	2
FIELD SPARROW		2
NORTHERN FLICKER		1
EASTERN KINGBIRD		1
AMERICAN GOLDFINCH	2	
BLUE-WINGED WARBLER	1	
NORTHERN CARDINAL	1	1
YELLOW WARBLER		1

July 9 2017

Station 27	<100	>100
SONG SPARROW	2	2
AMERICAN CROW		2
BLACK-CAPPED CHICKADEE	1	
CHIPPING SPARROW	2	
HOUSE SPARROW	4	
NORTHERN CARDINAL	1	1
AMERICAN ROBIN		4
AMERICAN GOLDFINCH	2	
COMMON GRACKLE	2	1
RED-EYED VIREO		1
EUROPEAN STARLING	3	
RED-WINGED BLACKBIRD	2	2
EASTERN KINGBIRD	2	
HOUSE WREN		1
FIELD SPARROW		1

June 16 2017

Station 28	<100	>100
RED-WINGED BLACKBIRD	4	2
GRAY CATBIRD	1	
EUROPEAN STARLING	2	
COMMON GRACKLE	3	
CEDAR WAXWING		1
CHIPPING SPARROW		1
MOURNING DOVE	1	1
ORCHARD ORIOLE	1	
AMERICAN CROW		1
HOUSE SPARROW		3
NORTHERN CARDINAL		1
AMERICAN GOLDFINCH		1

July 9 2017

Station 28	<100	>100
AMERICAN GOLDFINCH	3	
SONG SPARROW	6	
EUROPEAN STARLING	7	
COMMON GRACKLE	5	
CHIPPING SPARROW		1
BLUEJAY		1
RED-WINGED BLACKBIRD	4	3
AMERICAN ROBIN	2	2
NORTHERN FLICKER	1	
GRAY CATBIRD		1
MOURNING DOVE	3	
HOUSE SPARROW	2	2

June 16 2017

Station 29	<100	>100
MOURNING DOVE	1	8
SONG SPARROW	1	1
NORTHERN CARDINAL	2	2
NORTHERN FLICKER		1
EUROPEAN STARLING	2	6
AMERICAN ROBIN	3	1
COMMON GRACKLE	3	
BLUEJAY	1	
RED-EYED VIREO		1
COMMON YELLOWTHROAT		1
BALTIMORE ORIOLE	2	
AMERICAN GOLDFINCH		2
RED-BELLIED WOODPECKER	1	
BROWN-HEADED COWBIRD		1
EASTERN PHOEBE		1

July 9 2017

Station 29	<100	>100
AMERICAN ROBIN	5	3
HOUSE WREN	1	1
CHIPPING SPARROW	1	
RED-WINGED BLACKBIRD	2	2
MOURNING DOVE	1	
SONG SPARROW	1	2
FIELD SPARROW		2
NORTHERN FLICKER		1
EASTERN KINGBIRD		1
AMERICAN GOLDFINCH	2	
BLUE-WINGED WARBLER	1	
NORTHERN CARDINAL	1	1
YELLOW WARBLER		1
EUROPEAN STARLING	1	

2018 Observations

JUNE 23 2018

Station A	<100	>100
Northern Cardinal	2	1
Indigo Bunting	1	1
American Crow		1
Brown-headed Cowbird	1	
Red-winged Blackbird		1
Common Grackle	1	
Cedar Waxwing	2	
Common Yellowthroat		1
Mourning Warbler		1

JULY 5 2018

Station A	<100	>100
Red-eyed Vireo	2	1
Northern Flicker		1
American Goldfinch	1	1
Indigo Bunting	1	1
Chipping Sparrow		1
Northern Cardinal		2
American Robin		1
Downy Woodpecker	1	
Song Sparrow		1

JUNE 23 2018

Station B	<100	>100
Song Sparrow	1	
Indigo Bunting	1	
American Crow		1
American Robin		2
Rock Pigeon	2	
American Goldfinch	1	
Common Grackle	1	
Red-winged Blackbird	1	
Northern Cardinal		1

JULY 5 2018

Station B	<100	>100
European Starling		2
Eastern Kingbird	1	2
Red-winged Blackbird		2
Indigo Bunting	1	
Chipping Sparrow		1
American Crow	2	
Song Sparrow	1	1
Black-capped Chickadee	1	
Northern Flicker		1
American Goldfinch	2	
American Robin		1

JUNE 23 2018

Station C	<100	>100
Song Sparrow	1	2
American Crow		2
Common Grackle	9	6
Killdeer	1	
Red-winged Blackbird	5	2
Cedar Waxwing	2	
American Goldfinch	1	
European Starling	2	4
Baltimore Oriole	1	

JULY 5 2018

Station C	<100	>100
Mourning Dove	1	
American Goldfinch	1	1
Chipping Sparrow	1	1
Eastern Kingbird	1	
Common Grackle	1	2
House Sparrow	2	1
Killdeer		1
Red-winged Blackbird	3	
American crow		1
Northern Flicker		1
Baltimore Oriole		2
Song Sparrow		1

JUNE 23 2018

Station D	<100	>100
species	<100	>100
American Robin	1	2
Common Grackle	3	4
House Sparrow		1
Northern Cardinal	1	
European Starling		8
Mourning Dove	2	1
Chipping Sparrow	2	
American Goldfinch	2	
Song Sparrow		1
American crow		1

JULY 5 2018

Station D	<100	>100
House Wren		1
Chipping Sparrow	1	
House Sparrow	1	
Red-winged Blackbird	3	2
American Robin	3	1
Killdeer	1	1
Common Grackle	2	6
Warbling Vireo	1	1
European Starling	3	1
Song Sparrow		1
Gray Catbird	1	
Cedar Waxwing		1
Mallard		1
Mourning Dove		1

JUNE 23 2018

Station E	<100	>100
Chipping Sparrow		2
Red-winged Blackbird	3	4
Common Grackle	3	
American Robin	2	2
American Crow		1
Song Sparrow		1
Northern Cardinal		1
Mourning Dove		1
Common Yellowthroat	1	1
Killdeer	1	
American Goldfinch	1	

JULY 5 2018

Station E	<100	>100
Song Sparrow	1	1
Warbling Vireo	1	
Red-winged Blackbird	3	2
House Sparrow	2	
Northern Cardinal		1
American Robin	2	1
Cedar Waxwing	2	
Killdeer		1
Common Grackle	3	

JUNE 23 2018

Station F	<100	>100
House Sparrow	1	
Red-winged Blackbird	5	2
Song Sparrow	1	1
Willow Flycatcher	1	
Gray Catbird	1	
Warbling Vireo	1	
American Robin	2	1
Mourning Dove		1
House Finch		1

JULY 5 2018

Station F	<100	>100
Killdeer	1	
American Robin	3	2
Chipping Sparrow	1	
Red-winged Blackbird	2	1
Song Sparrow	1	1
American Goldfinch	1	1
Red-eyed Vireo		1
Brown-headed Cowbird	1	
Warbling Vireo		2
Common Grackle		2
Gray Catbird	1	

JUNE 23 2018

Station G	<100	>100
Song Sparrow	1	1
Northern Cardinal	2	
Red-winged Blackbird	1	4
Indigo Bunting	1	
House Finch	1	
House Sparrow	3	
American Robin	1	
Chipping Sparrow	1	
Red-eyed Vireo		1
Mourning Dove		1

JULY 5 2018

Station G	<100	>100
Indigo Bunting	1	1
Field Sparrow		1
American Robin	1	2
House Sparrow		2
Red-eyed Vireo		1
Warbling Vireo		1
Brown-headed Cowbird	1	
Song Sparrow	2	1

JUNE 23 2018

Station H	<100	>100
Downy Woodpecker	1	
Red-winged Blackbird	1	2
House Sparrow	2	
Northern Cardinal	1	1
American Robin	1	1
Song Sparrow	1	1

JULY 5 2018

Station H	<100	>100
Red-winged Blackbird	1	1
House Sparrow	1	3
Northern Cardinal		1
American Robin		2
Song Sparrow	1	1
Blue Jay		1
American crow	3	

JUNE 23 2018

Station I	<100	>100
Cedar Waxwing	2	
American Robin	1	2
Red-winged Blackbird	2	3
European Starling	1	3
Northern Cardinal		2
Mourning Dove	3	1
Baltimore Oriole	1	
Chipping Sparrow	1	
Common Grackle	1	3

JULY 5 2018

Station I	<100	>100
Indigo Bunting	1	
American Robin	1	2
Red-winged Blackbird	2	1
Common Grackle		3
Mourning Dove	1	1
Baltimore Oriole		1
Song Sparrow		1
Chipping Sparrow	1	

JUNE 23 2018

Station J	<100	>100
Common Yellowthroat	1	2
Song Sparrow	1	
Red-winged Blackbird	1	1
Barn Swallow	2	
Cedar Waxwing	1	

JULY 5 2018

Station J	<100	>100
Ring-billed Gull		1
Common Yellowthroat	1	
Song Sparrow	1	1
Red-winged Blackbird		1
Mourning Dove		2
European Starling	2	1

JUNE 23 2018

Station K	<100	>100
species	<100	>100
Field Sparrow		1
American Robin		2
Song Sparrow	1	1
Common Grackle		1
Chipping Sparrow		1
Cedar Waxwing	2	
Eastern Kingbird	1	

JULY 5 2018

Station K	<100	>100
Song Sparrow	2	1
Cedar Waxwing		1
Eastern Kingbird	1	
American Robin	1	1
Common Yellowthroat		1
Red-winged Blackbird	2	
House Wren		1
Black-capped Chickadee	1	
House Finch		4
American Goldfinch	1	

JUNE 23 2018

Station L	<100	>100
Red-winged Blackbird	1	2
American Goldfinch	5	1
Song Sparrow		1
Common Yellowthroat	1	
Northern Cardinal		2
American Robin		1

JULY 5 2018

Station L	<100	>100
American Goldfinch	2	2
Northern Cardinal		1
American Robin	2	1
Killdeer		1
American Crow		1
House Sparrow	2	

JUNE 23 2018

Station M	<100	>100
Song Sparrow	2	2
Red-winged Blackbird	2	1
Willow Flycatcher	1	
Northern Cardinal		1
American Goldfinch		1
Common Yellowthroat	1	1
Red-bellied Woodpecker		1
Spotted Sandpiper	1	
Mourning Dove		2
Chipping Sparrow	1	
Common Grackle	1	
American Robin		1

JULY 5 2018

Station M	<100	>100
American Goldfinch	3	1
Red-winged Blackbird	4	
Northern Cardinal		3
Rose-breasted Grosbeak		1
Barn Swallow	2	
Song Sparrow		1
Killdeer	1	
House Wren		1
Red-bellied Woodpecker		1
Blue Jay		1
American Robin		1
Northern Flicker	1	
Tree Swallow	1	
Baltimore Oriole	1	

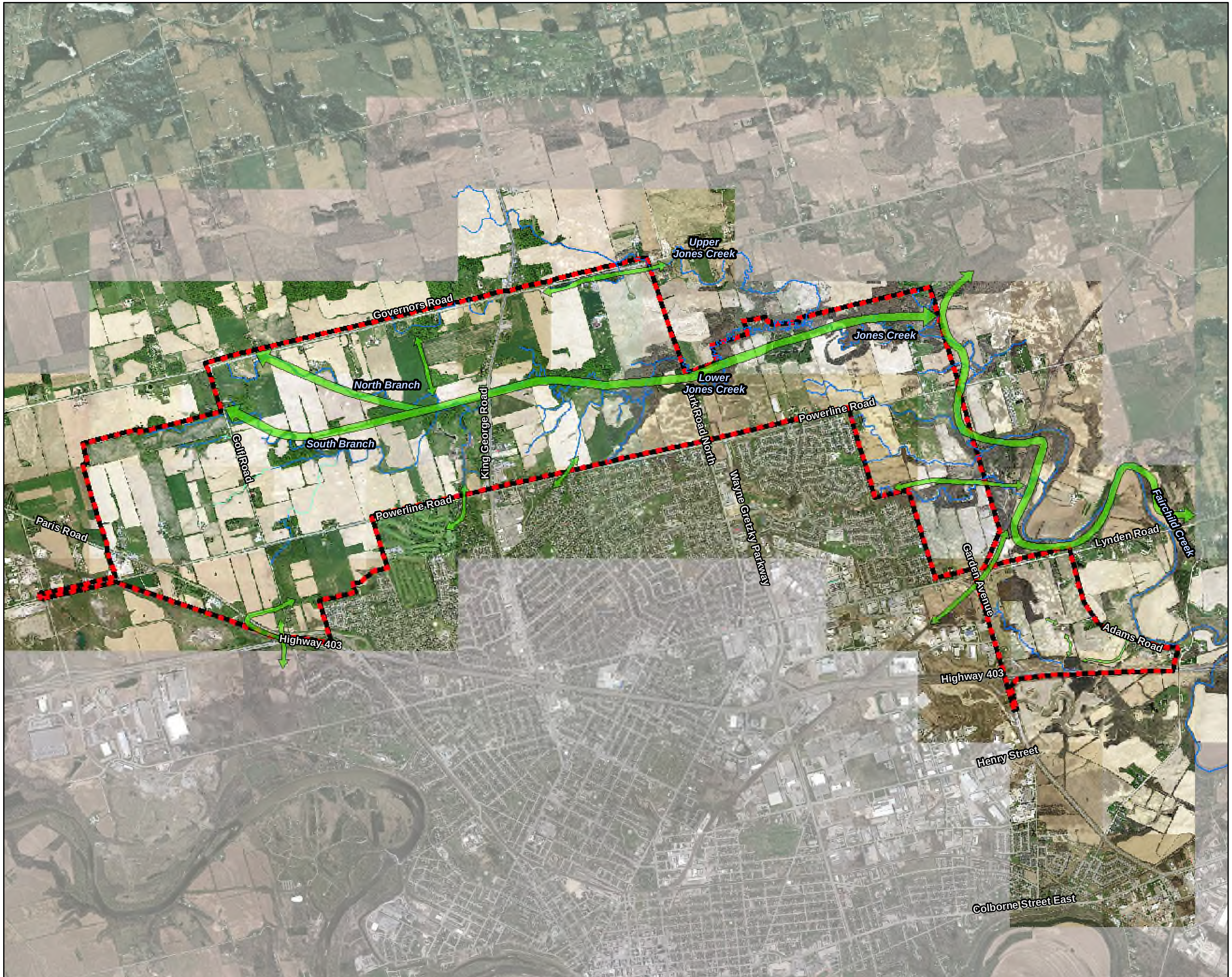
JUNE 23 2018

Station N	<100	>100
Killdeer	1	
Chipping Sparrow		1
American Robin	1	
Red-winged Blackbird	3	
Common Grackle		2
American Goldfinch	2	
Northern Cardinal		2
Great Blue Heron	1	
Mourning Dove		1
Song Sparrow		1

JULY 5 2018

Station N	<100	>100
American crow		1
American Robin	2	2
Song Sparrow	1	1
Red-winged Blackbird	3	1
American Goldfinch	1	1
Baltimore Oriole	1	

Appendix D Species Dispersal Corridors (Figure A & Figure B)



Legend

- Study Area
- Watercourse to be Protected
- Watercourse to be Conserved – channel form and location may vary
- Species Dispersal Corridors

N

0 250 500 1,000 1,500 2,000 Meters

*Minor adjustments were made to the Growth Plan NHS to better reflect existing conditions and constraints.

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Corridors and Linkages

Project #	2017-146	Figure #	A
Date	July 2020		
Scale	1 : 40,000		
Prepared By: JJJ	Verified By: BDB		

Legend

- Study Area
- Watercourse to be Protected
- Watercourse to be Conserved – channel form and location may vary
- Species Dispersal Corridors

N

0 125 250 500 750 Meters

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Corridors and Linkages

Project #	2017-146	Figure # B
Date	July 2020	
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	

Figures

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Figure 14a	North Brantford - Preliminary Land Use and Transportation Plan
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Figure 15a-15b	Proposed SWM Pond Locations
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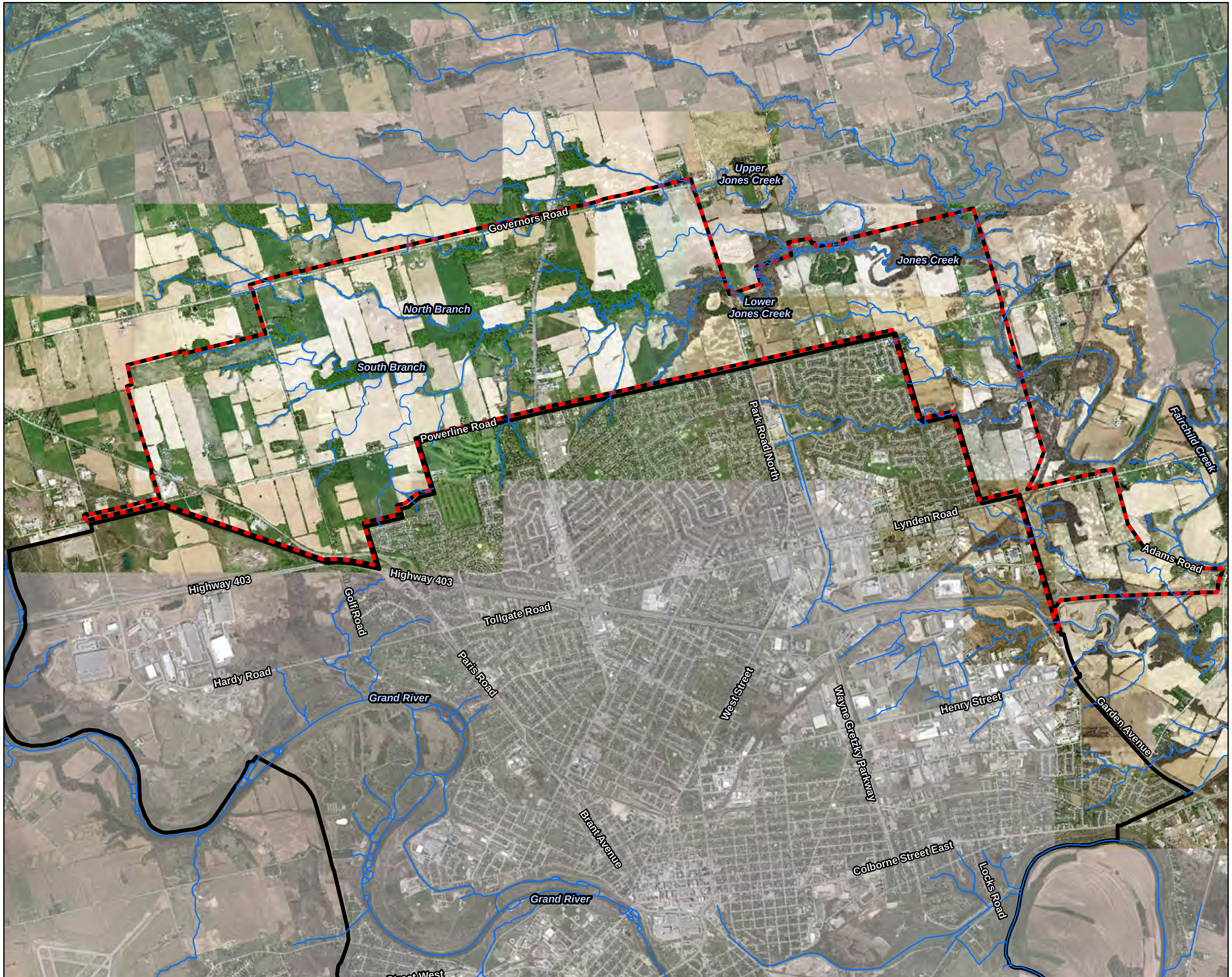


Legend

- Study Area
- Municipal Boundary
- Watercourse

Data Source (with Plan B NH modifications)
- City of Brantford
- GRCA
- Airphoto: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Study Area

Project #	2017-146	Figure # 1a
Date	July 2020	
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	

Legend

- Study Area
- Municipal Boundary
- Watercourse

N

0 125 250 500 750 Meters

Data Source (with Plan B NH modifications)
- City of Brantford
- GRCA
- Airphoto: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Study Area

Project #	2017-146	Figure # 1b
Date	July 2020	
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	

Legend

- Study Area
- Contour Line (5 m interval)
- Watercourse

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

Topography

Project #	2017-146	Figure # 2a
Date	July 2020	
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	

Legend

- Study Area
- Contour Line (5 m interval)
- Watercourse

N

0 125 250 500 750 Meters

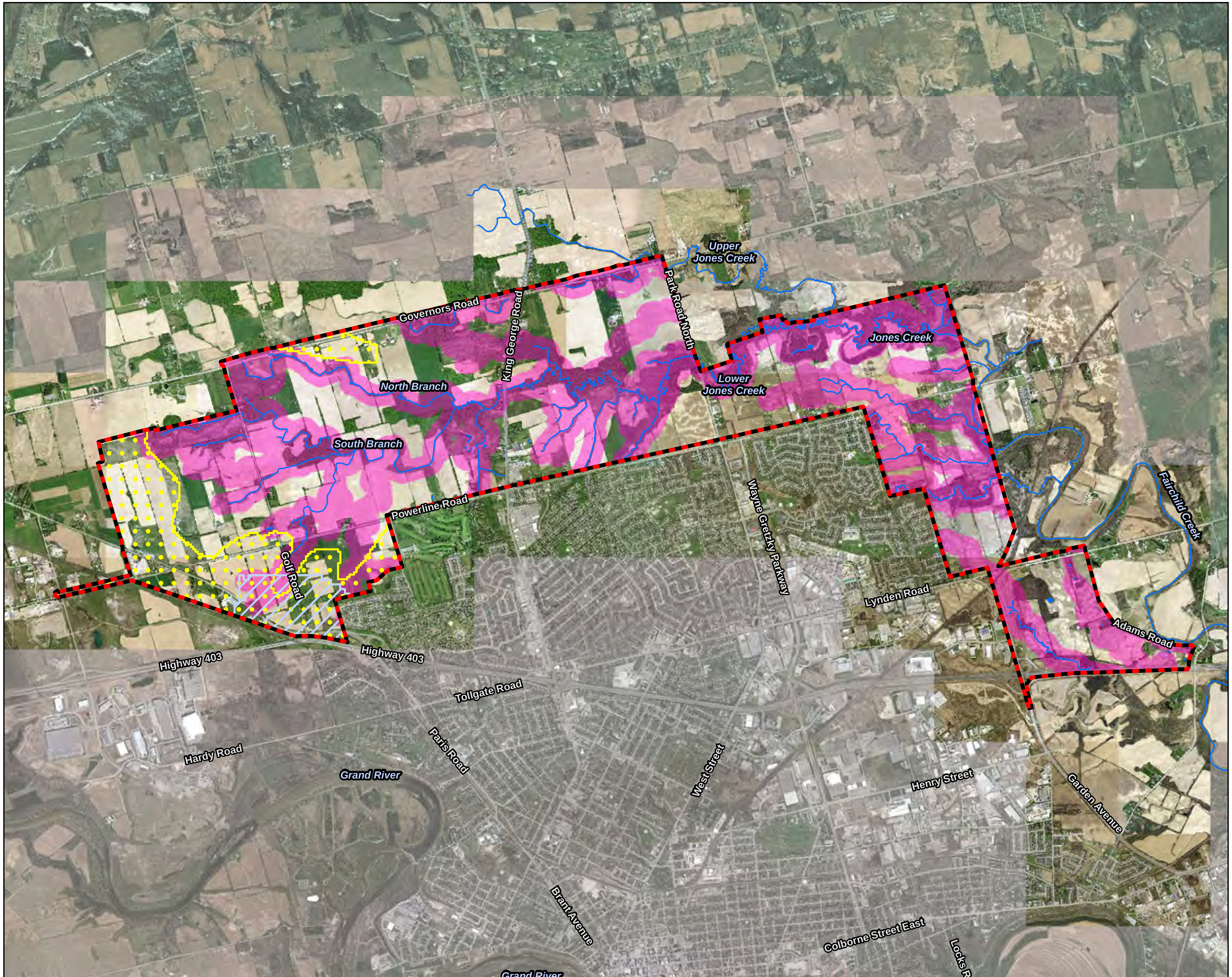
Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

Topography

Project #	2017-146	Figure #
Date	July 2020	2b
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse
- Waterbody
- Surface Water Intake Protection Zone
- Significant Groundwater Recharge Area
- Highly Vulnerable Aquifer

N

0 250 500 1,000 1,500 2,000 Meters

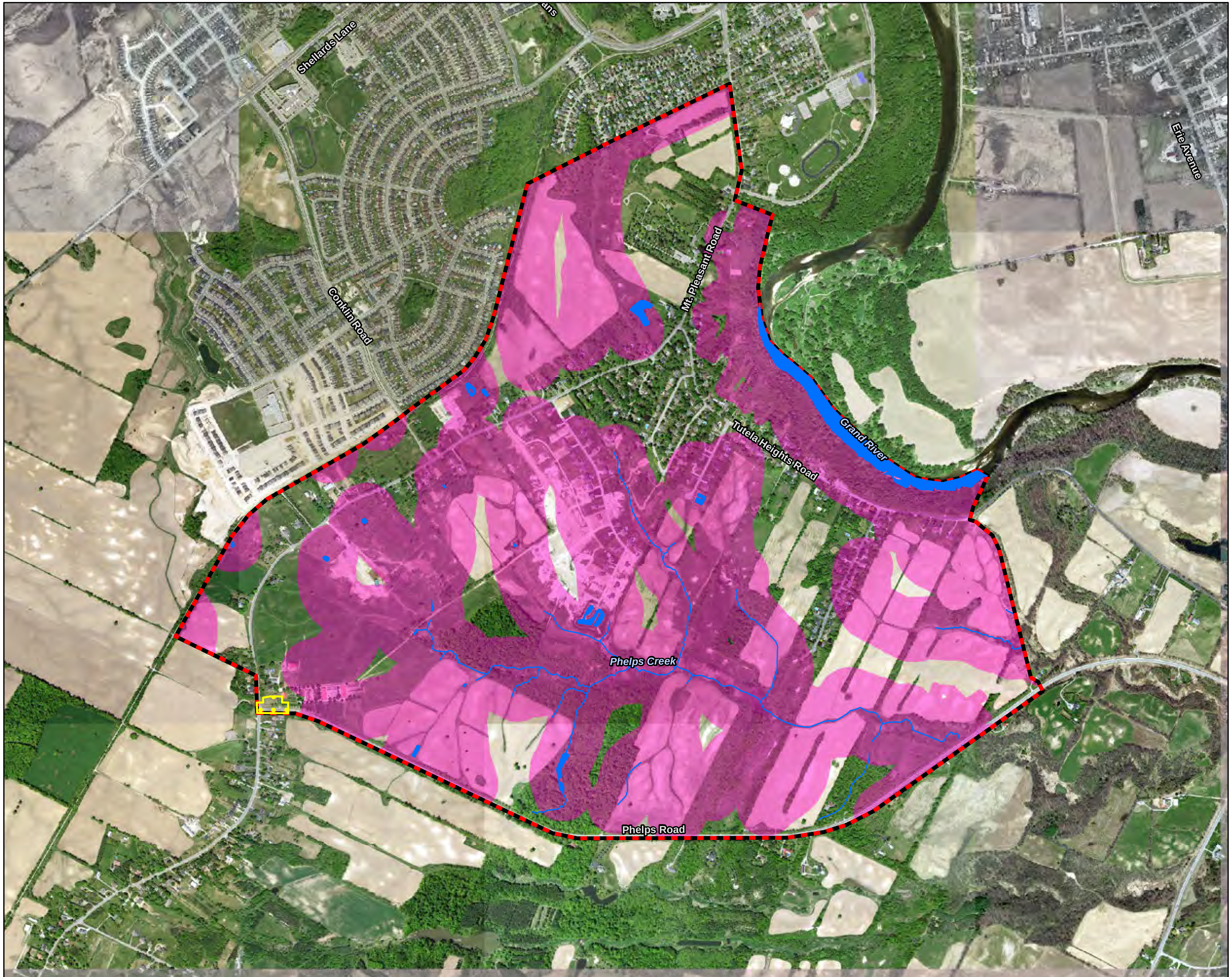
Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

Surface and Groundwater Features

Project #	2017-146	Figure # 3a
Date	July 2020	
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse
- Waterbody
- Surface Water Intake Protection Zone
- Significant Groundwater Recharge Area

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

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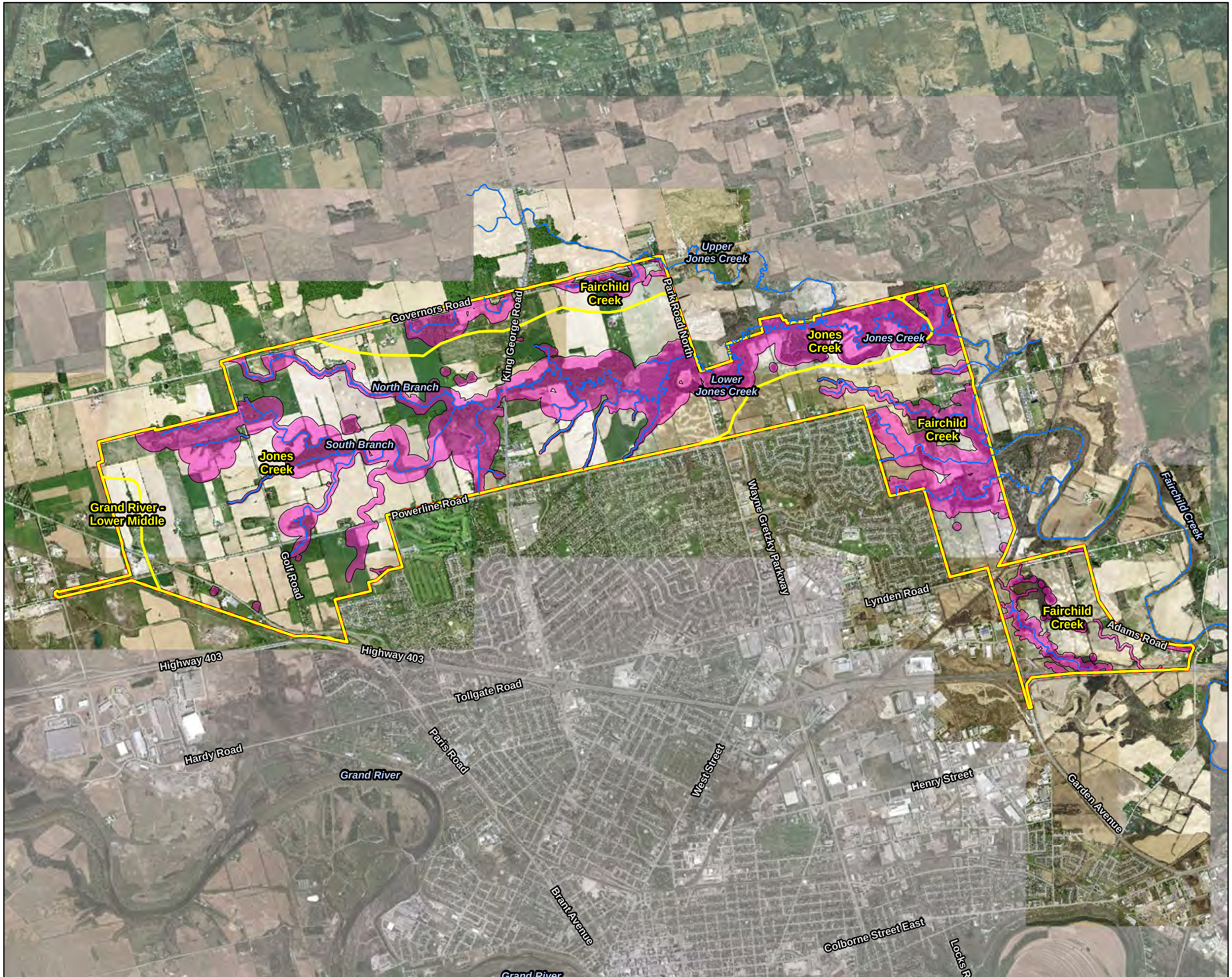
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

Surface and Groundwater Features

Project #	2017-146	Figure #
Date	July 2020	3b
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Subcatchments
- Watercourse
- Regulation Limit

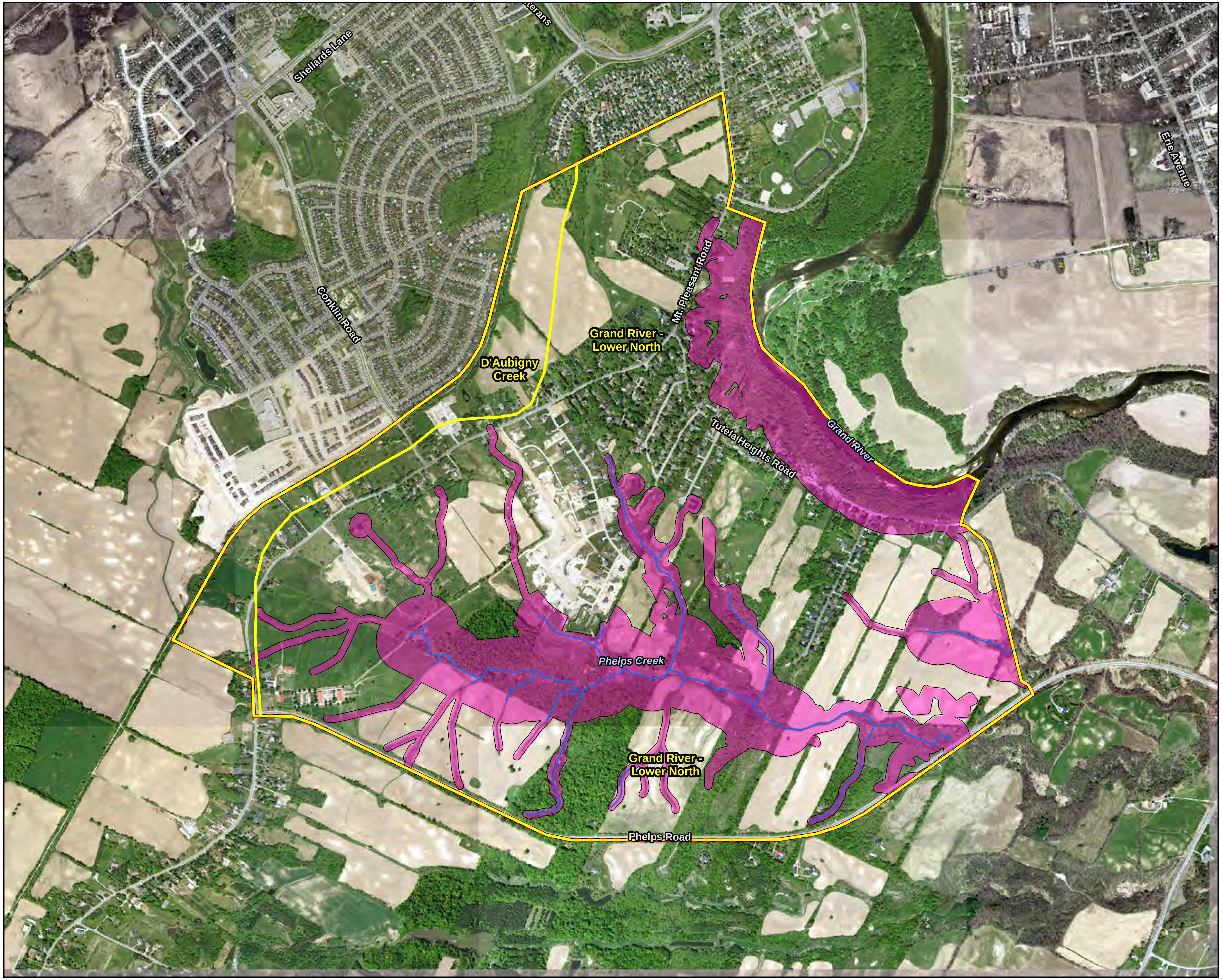
Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

GRCA Regulated Areas and Sub-catchments

Project #	2017-146	Figure # 4a
Date	November 2020	
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Subcatchments
- Watercourse
- Regulation Limit

N

0 125 250 500 750 Meters

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- Airphoto Date: 2015

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Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
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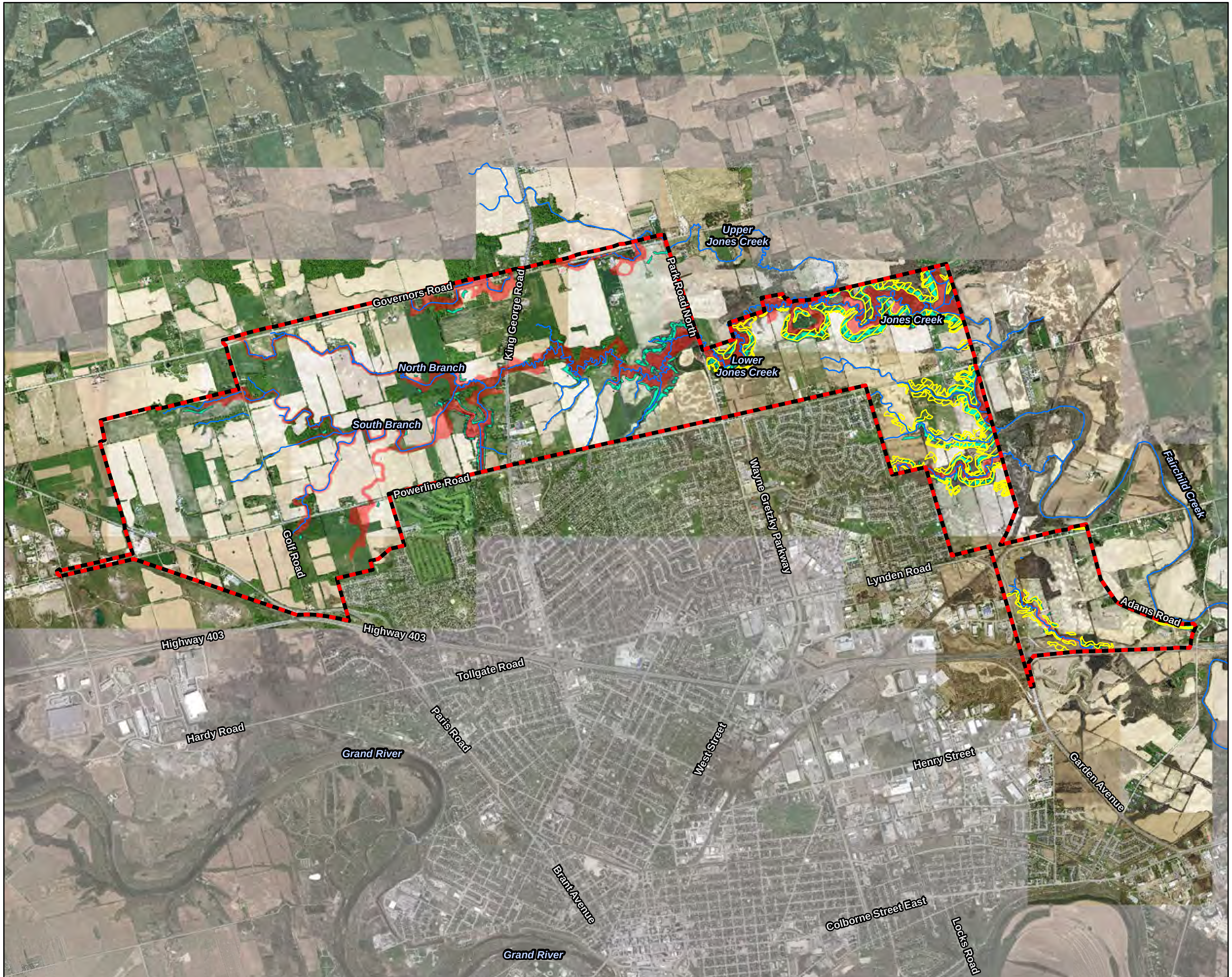
North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

GRCA Regulated Areas and Sub-catchments

Project #	2017-146	Figure # 4b
Date	July 2020	
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse
- River Slope Erosion Allowance
- River Valley Slopes
- Floodplain

N

0 245 490 980 1,470 1,960 Meters

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

Valley Slope/Erosion Hazards and Floodplains

Project #	2017-146	Figure #
Date	July 2020	5a
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
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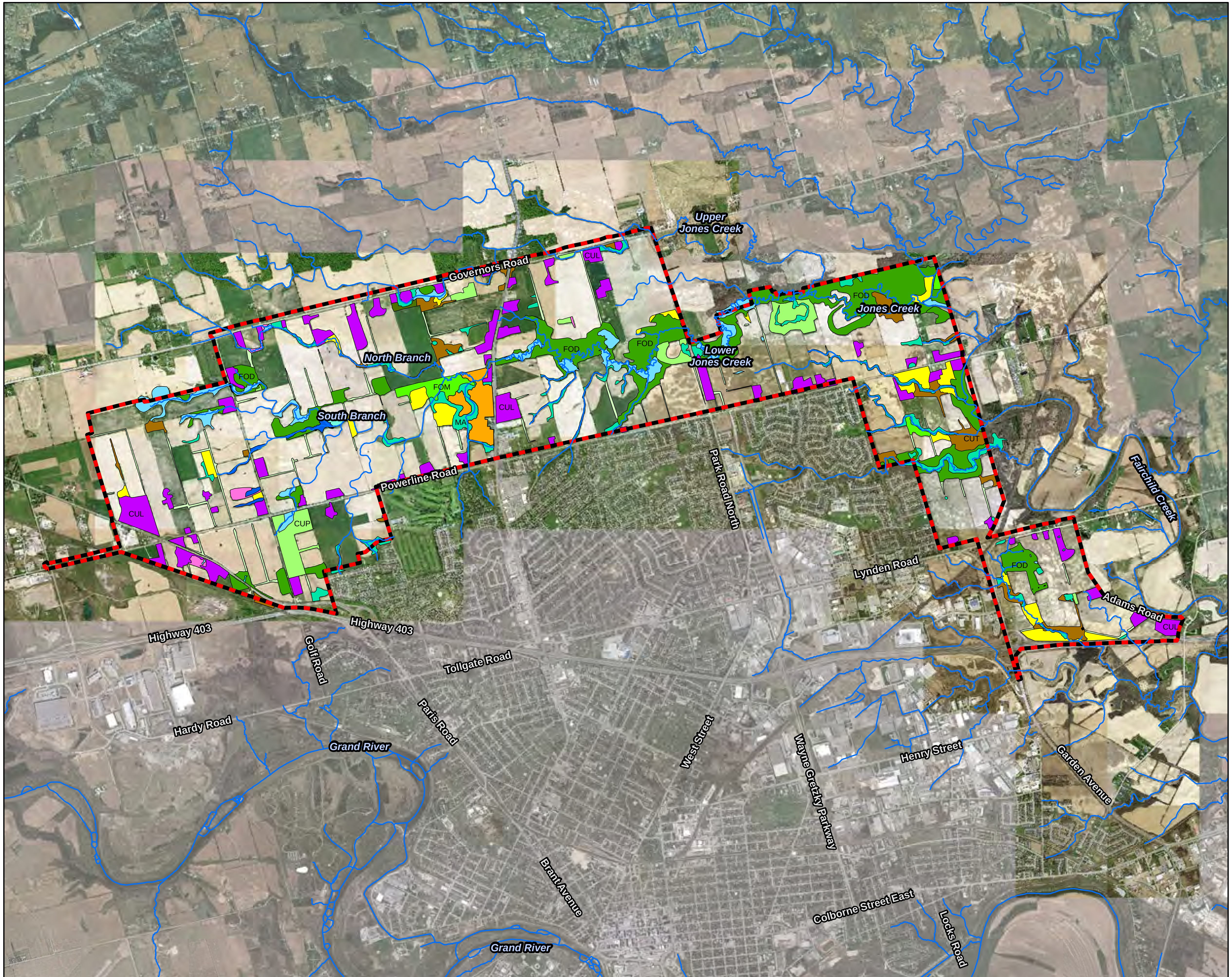
North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Valley Slope/Erosion Hazards and Floodplains

Project #	2017-146	Figure # 5b
Date	July 2020	
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse
- CUL/RES - Cultural Vegetation & Ornamental Plantings (Residential/Farmsteads)
- CUM - Cultural Old Field Meadow
- CUM/CUT - Cultural Old Field Meadow and Shrub Thicket Mosaic
- CUT - Cultural Shrub Thicket
- CUW - Cultural Woodland
- FOC - Coniferous Forest
- FOD - Deciduous Forest
- FOM - Mixed Forest
- CUP - Conifer Plantation
- HR - Hedgerow
- MA - Marsh (Meadow, Cattail)
- MA/SWT - Marsh/Thicket Swamp Mosaic
- SWD - Deciduous Swamp
- SWT - Thicket Swamp

Data Source (with Plan B NH modifications)
- City of Brantford
- GRCA
- Airphoto: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
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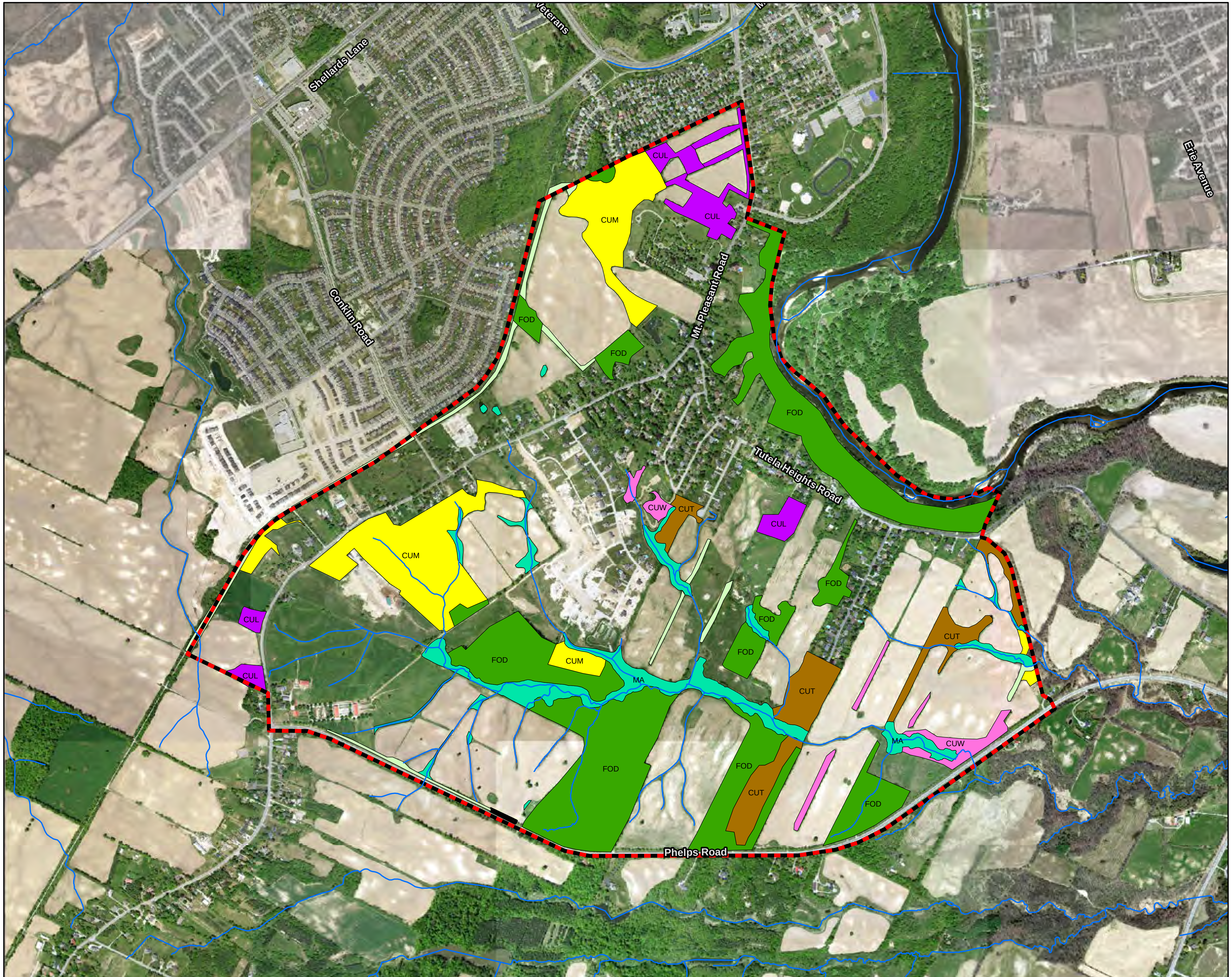
North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Vegetation

Project #	2017-146	Figure #
Date	July 2020	6a
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse
- CUL/RES - Cultural Vegetation & Ornamental Plantings (Residential/Farmsteads)
- CUM - Cultural Old Field Meadow
- CUM/CUT - Cultural Old Field Meadow and Shrub Thicket Mosaic
- CUT - Cultural Shrub Thicket
- CUW - Cultural Woodland
- FOC - Coniferous Forest
- FOD - Deciduous Forest
- FOM - Mixed Forest
- CUP - Conifer Plantation
- HR - Hedgerow
- MA - Marsh (Meadow, Cattail)
- MA/SWT - Marsh/Thicket Swamp Mosaic
- SWD - Deciduous Swamp
- SWT - Thicket Swamp

N

0 125 250 500 750 Meters

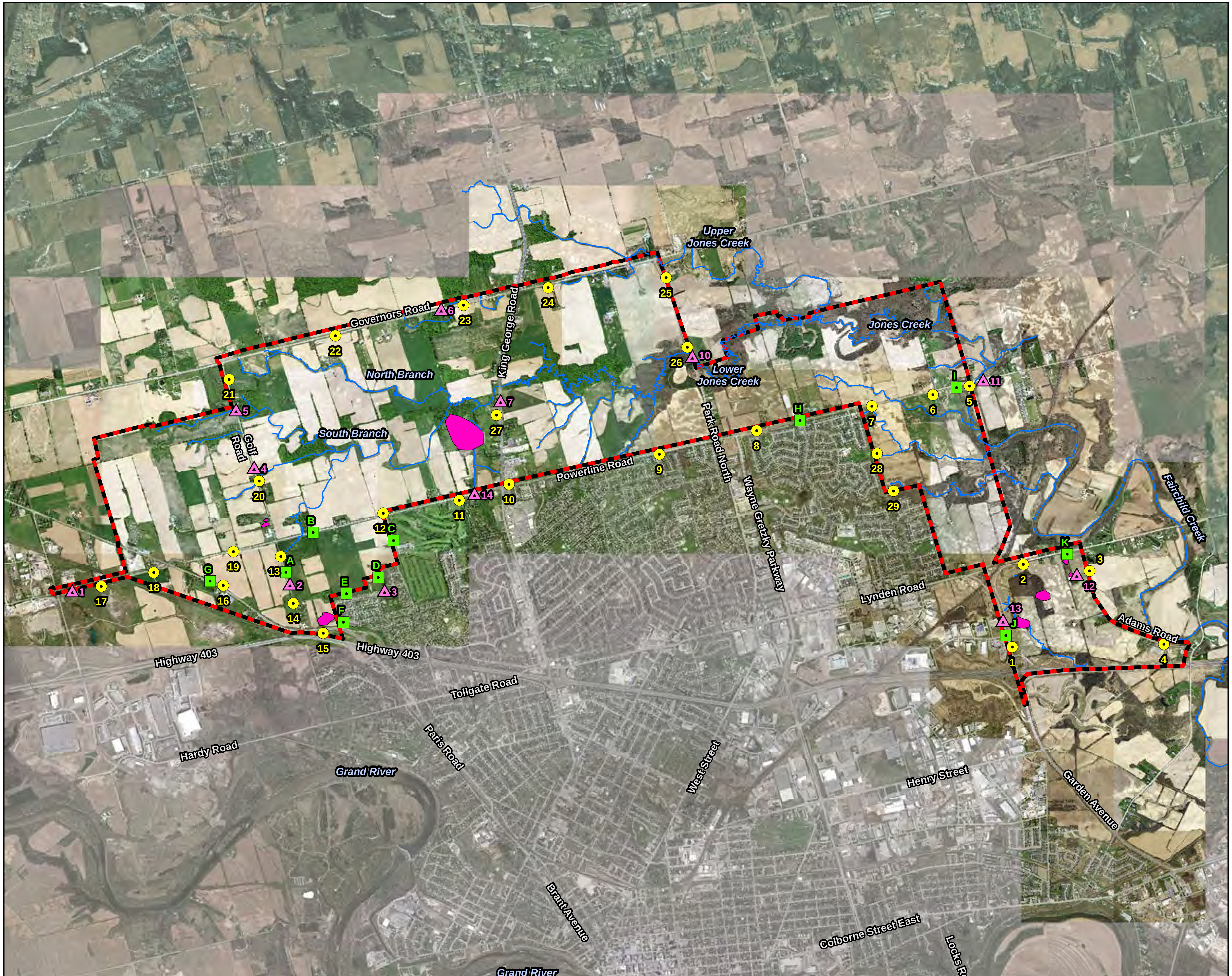
Data Source (with Plan B NH modifications)
- City of Brantford
- GRCA
- Airphoto: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

Vegetation

Project #	2017-146	Figure # 6b
Date	July 2020	
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse (GRCA)
- Bird Point Count Station 2017
- Bird Point Count Station 2018
- Frog Call Monitoring Station 2018
- Frog Call Concentration Area

N

0 250 500 1,000 1,500 2,000 Meters

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Wildlife Monitoring

Project #	2017-146	Figure # 7a
Date	July 2020	
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	

Legend

- Study Area
- Watercourse (GRCA)
- Bird Point Count Station 2017
- Bird Point Count Station 2018
- Frog Call Monitoring Station 2018
- Frog Call Concentration Area

N

Meters: 0, 125, 250, 500, 750

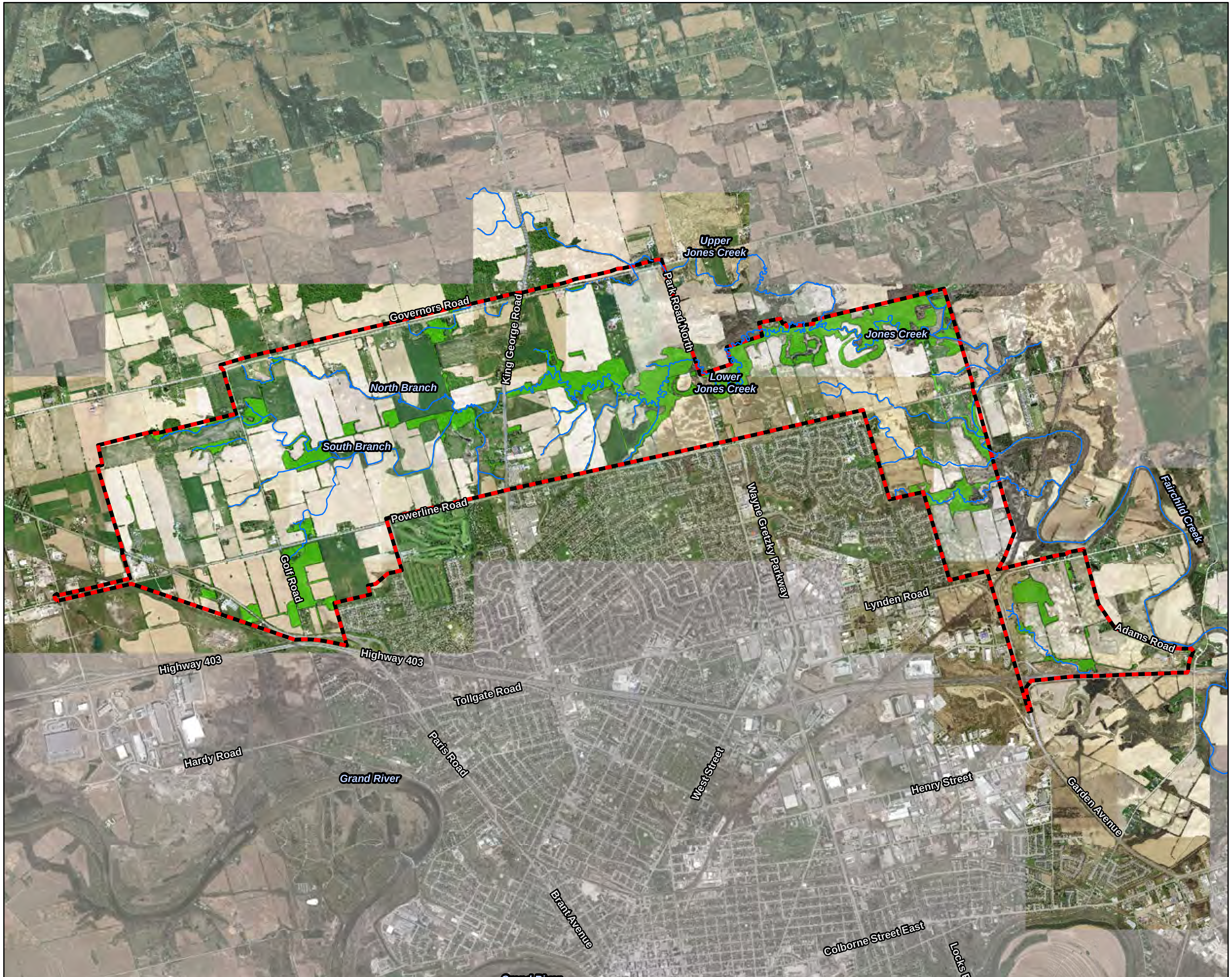
Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019

Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Wildlife Monitoring

Project #	2017-146	Figure #	7b
Date	July 2020		
Scale	1 : 15,000		
Prepared By: JJJ	Verified By: BDB		



Legend

- Study Area
- Watercourse
- Woodland

Data Source (with Plan B NH modifications)

- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Woodlands

Project #	2017-146	Figure # 8a
Date	July 2020	
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	

Legend

- Study Area
- Watercourse
- Woodland

N

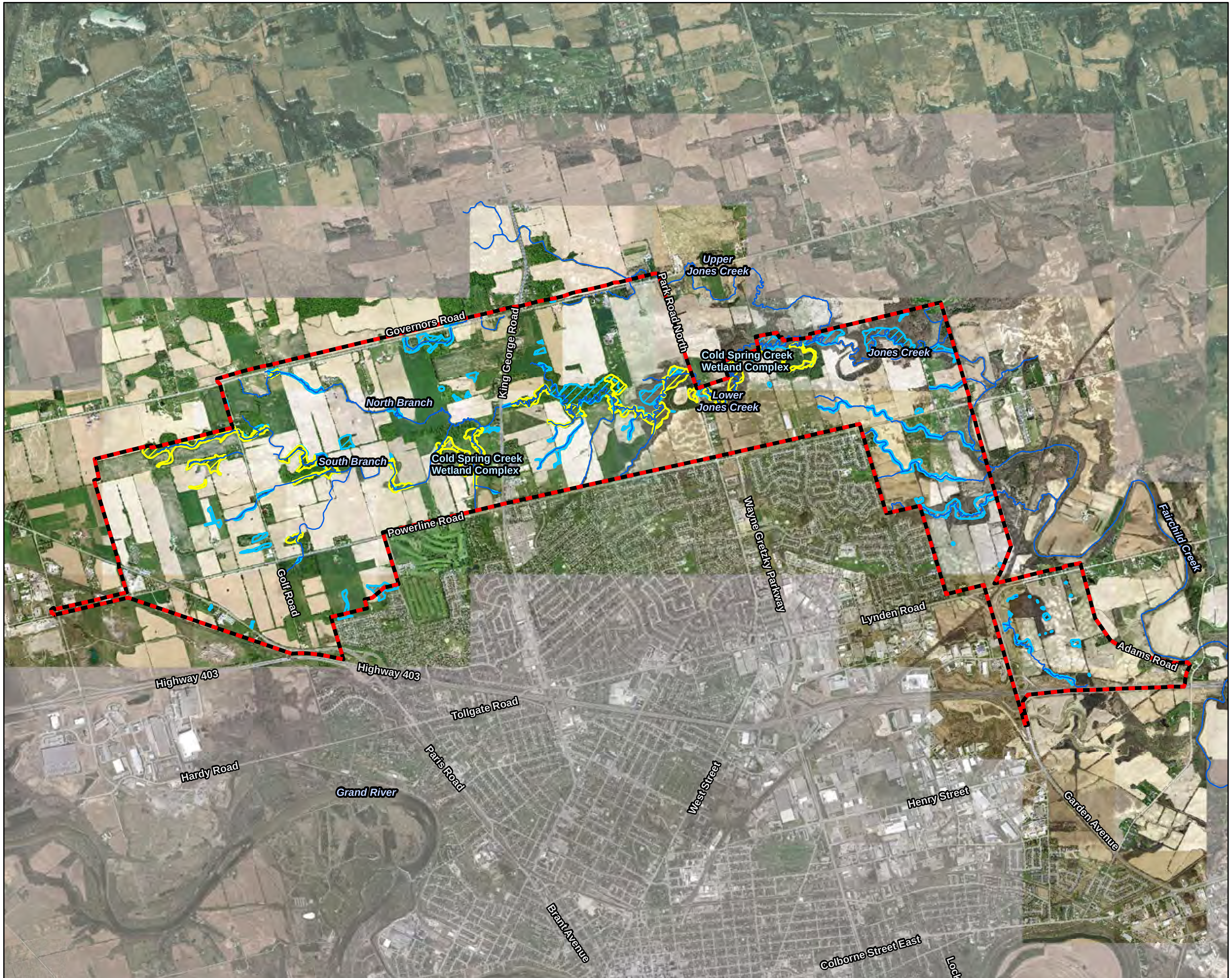
0 125 250 500 750 Meters

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Woodlands

Project #	2017-146	Figure # 8b
Date	July 2020	
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse
- Evaluated Wetland (PSW)
- Unevaluated Wetland

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Wetlands

Project #	2017-146	Figure # 9a
Date	July 2020	
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	

Legend

- Study Area
- Watercourse
- Wetland - Not Evaluated

N

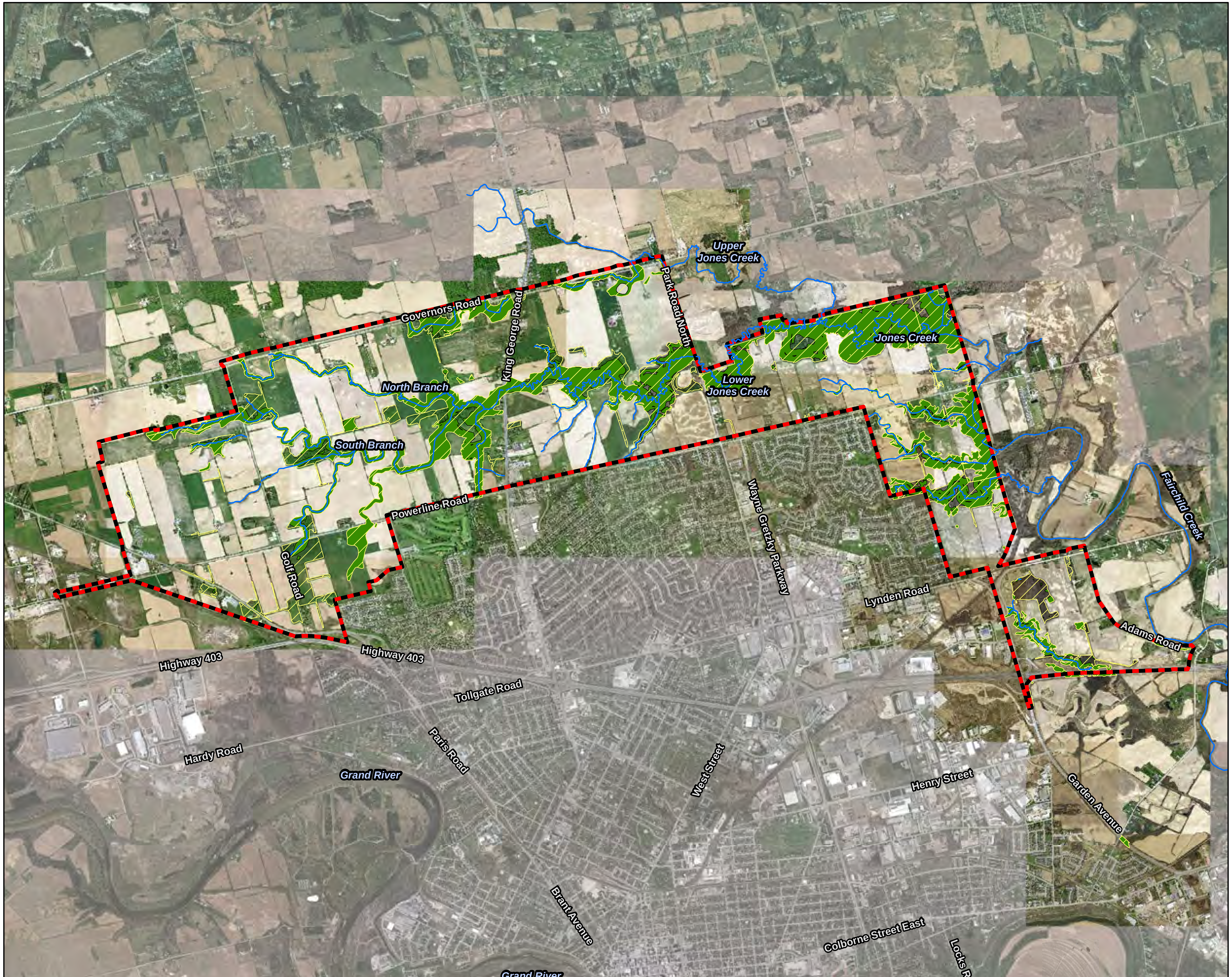
0 125 250 500 750 Meters

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Wetlands

Project #	2017-146	Figure # 9b
Date	July 2020	
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse
- Woodot
- County NHS (floodplain, valley slope/erosion hazard, PSW's)

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
County of Brant NHS

Project #	2017-146	Figure # 10a
Date	July 2020	
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	

Legend

- Study Area
- Watercourse
- Woodot
- County NHS (floodplain, valley slope/erosion hazard, PSW's)

N

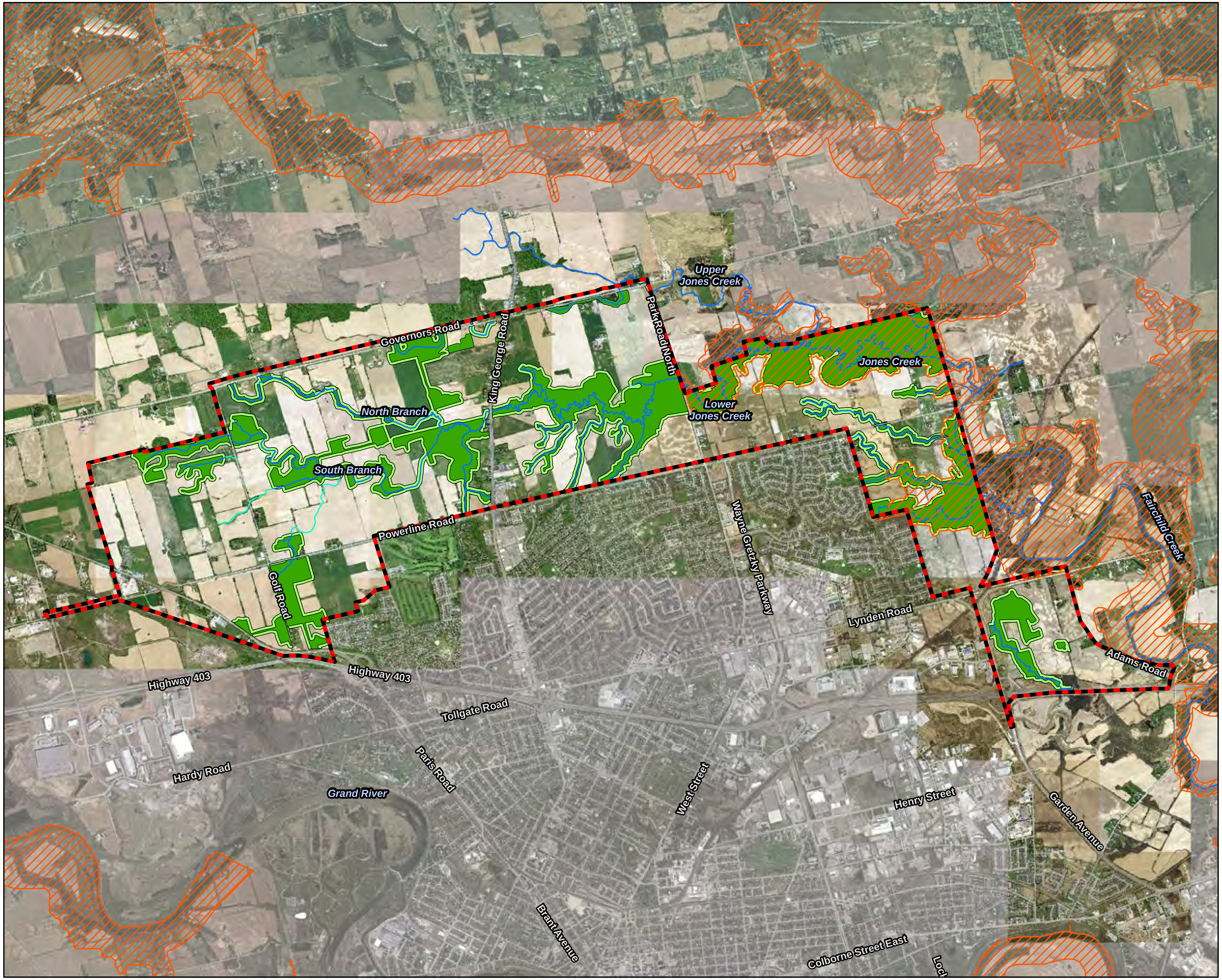
0 125 250 500 750 Meters

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
County of Brant NHS

Project #	2017-146	Figure #
Date	July 2020	10b
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse to be Protected
- Watercourse to be Conserved - channel form and location may vary
- Natural Heritage System
- 30 m Protective Buffer
- Growth Plan NHS*

N

0 250 500 1,000 1,500 2,000 Meters

*Minor adjustments were made to the Growth Plan NHS to better reflect existing conditions and constraints.

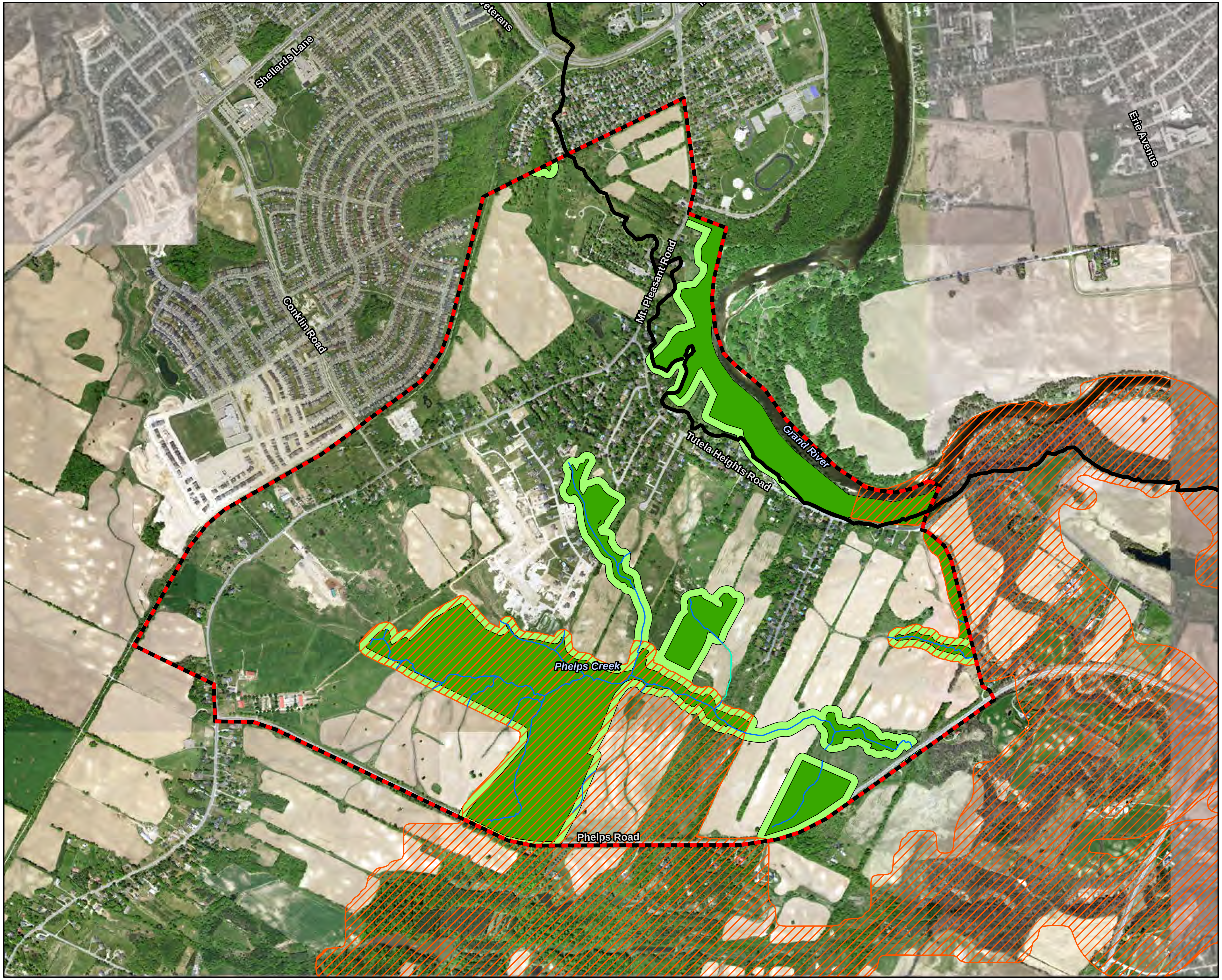
Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

Recommended NHS

Project #	2017-146	Figure # 11a
Date	July 2020	
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse to be Protected
- Watercourse to be Conserved - channel form and location may vary
- Grand River Significant Valley Line
- Natural Heritage System
- 30 m Protective Buffer
- Growth Plan NHS

N

0 125 250 500 750 Meters

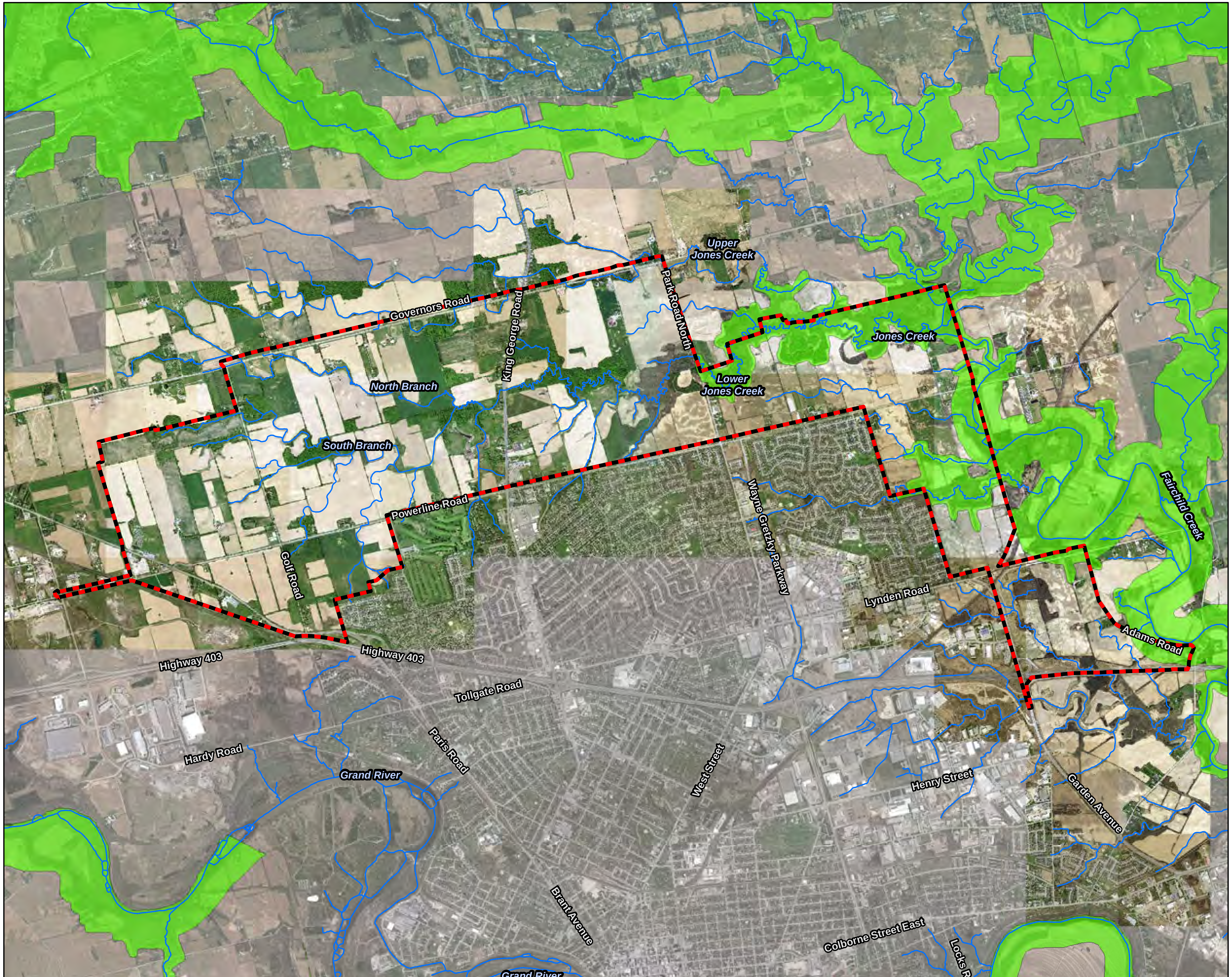
Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

Recommended NHS

Project #	2017-146	Figure # 11b
Date	July 2020	
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Growth Plan NHS
- Watercourse

Data Source (with Plan B NH modifications)
- City of Brantford
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Growth Plan NHS

Project #	2017-146	Figure # 12a
Date	July 2020	
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	

Legend

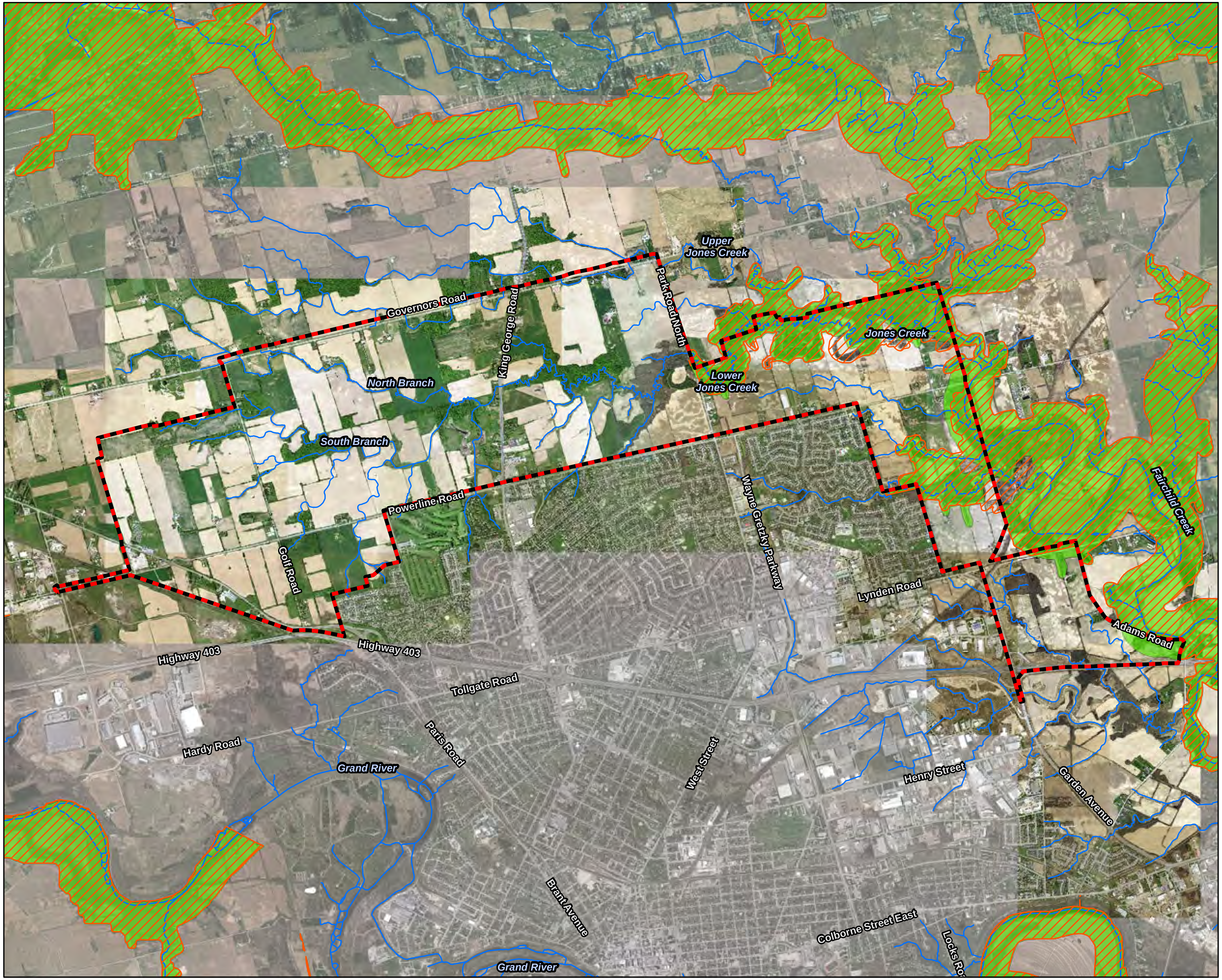
- Study Area
- Growth Plan NHS
- Watercourse

Data Source (with Plan B NH modifications)
- City of Brantford
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Growth Plan NHS

Project #	2017-146	Figure #
Date	July 2020	12b
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse
- Growth Plan NHS
- Growth Plan NHS as modified by Plan B Natural Heritage

N

0 245 490 980 1,470 1,960 Meters

Data Source (with Plan B NH modifications)
- City of Brantford
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

Recommended Adjustments to Growth Plan NHS

Project #	2017-146	Figure #
Date	July 2020	12c
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	

Legend

- Study Area
- Watercourse
- Growth Plan NHS
- Growth Plan NHS as modified by Plan B Natural Heritage

N

0 125 250 500 750 Meters

Data Source (with Plan B NH modifications)
- City of Brantford
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
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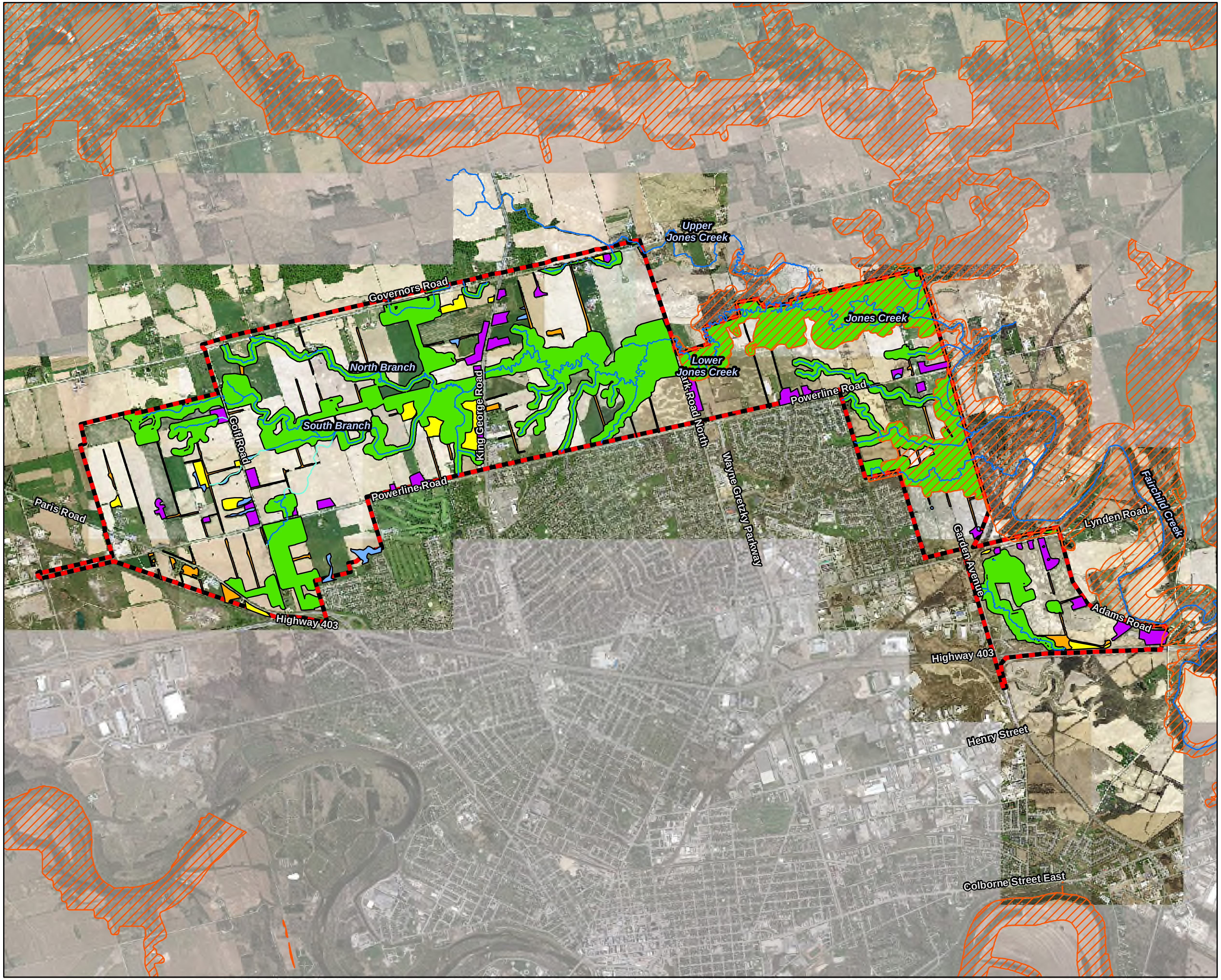
North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Recommended Adjustments to Growth Plan NHS

Project #	2017-146	Figure # 12d
Date	July 2020	
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse to be Protected
- Watercourse to be Conserved – channel form and location may vary
- Natural Heritage System
- Growth Plan NHS*

Other Environmental Features

- Residential (ornamental plantings, cultural vegetation)
- Cultural (meadow, thicket, early-successional woodland)
- Wetland
- Woodland/Hedgerow

N

0 250 500 1,000 1,500 2,000 Meters

*Minor adjustments were made to the Growth Plan NHS to better reflect existing conditions and constraints.

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

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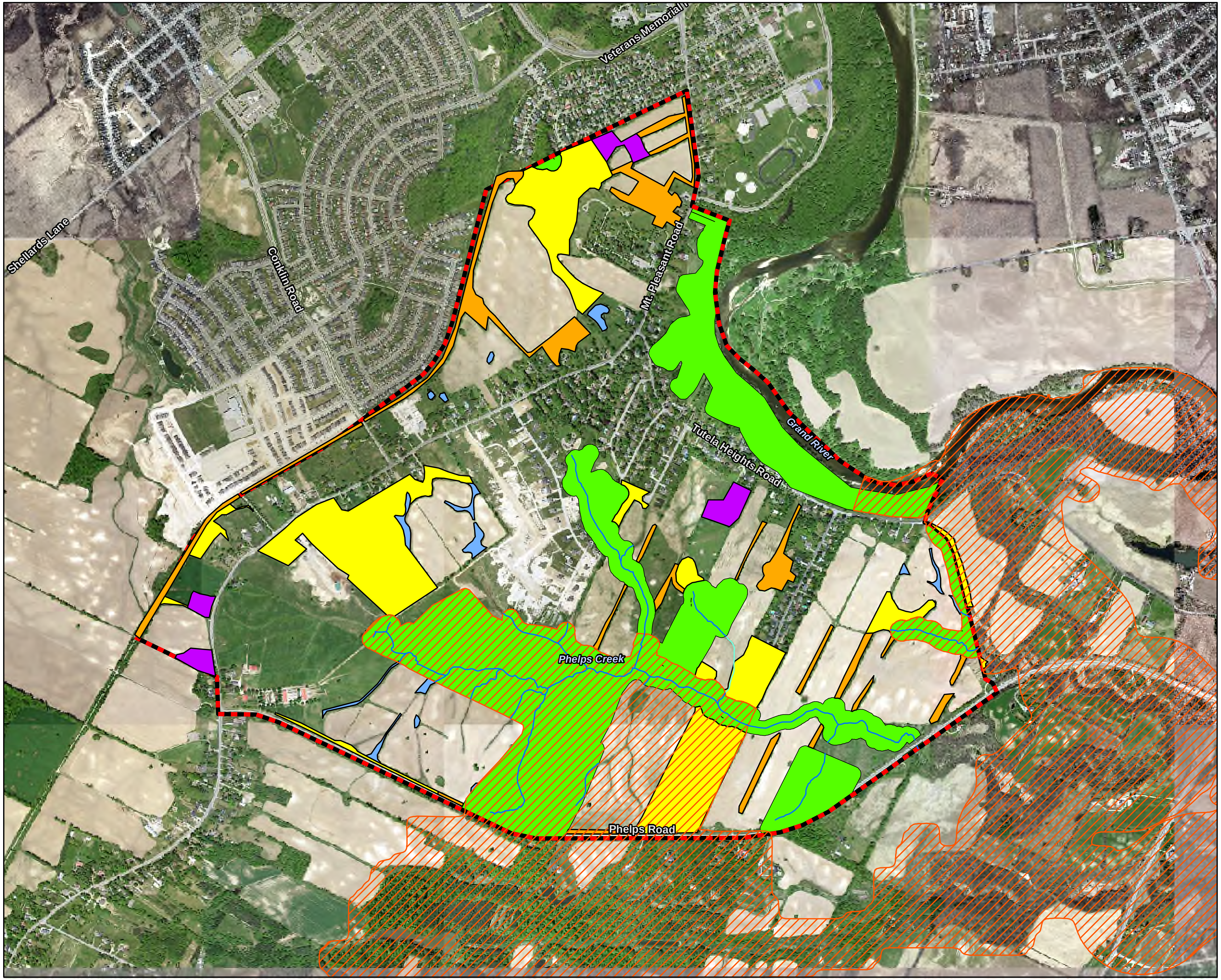
North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

Other Environmental Features

Project #	2017-146	Figure #
Date	July 2020	13a
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse to be Protected
- Watercourse to be Conserved – channel form and location may vary
- Natural Heritage System
- Growth Plan NHS

Other Environmental Features

- Residential (ornamental plantings, cultural vegetation)
- Cultural (meadow, thicket, early-successional woodland)
- Wetland
- Woodland/Hedgerow

N

0 125 250 500 750 Meters

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

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Landscape Ecology & Natural Heritage Planning
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L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

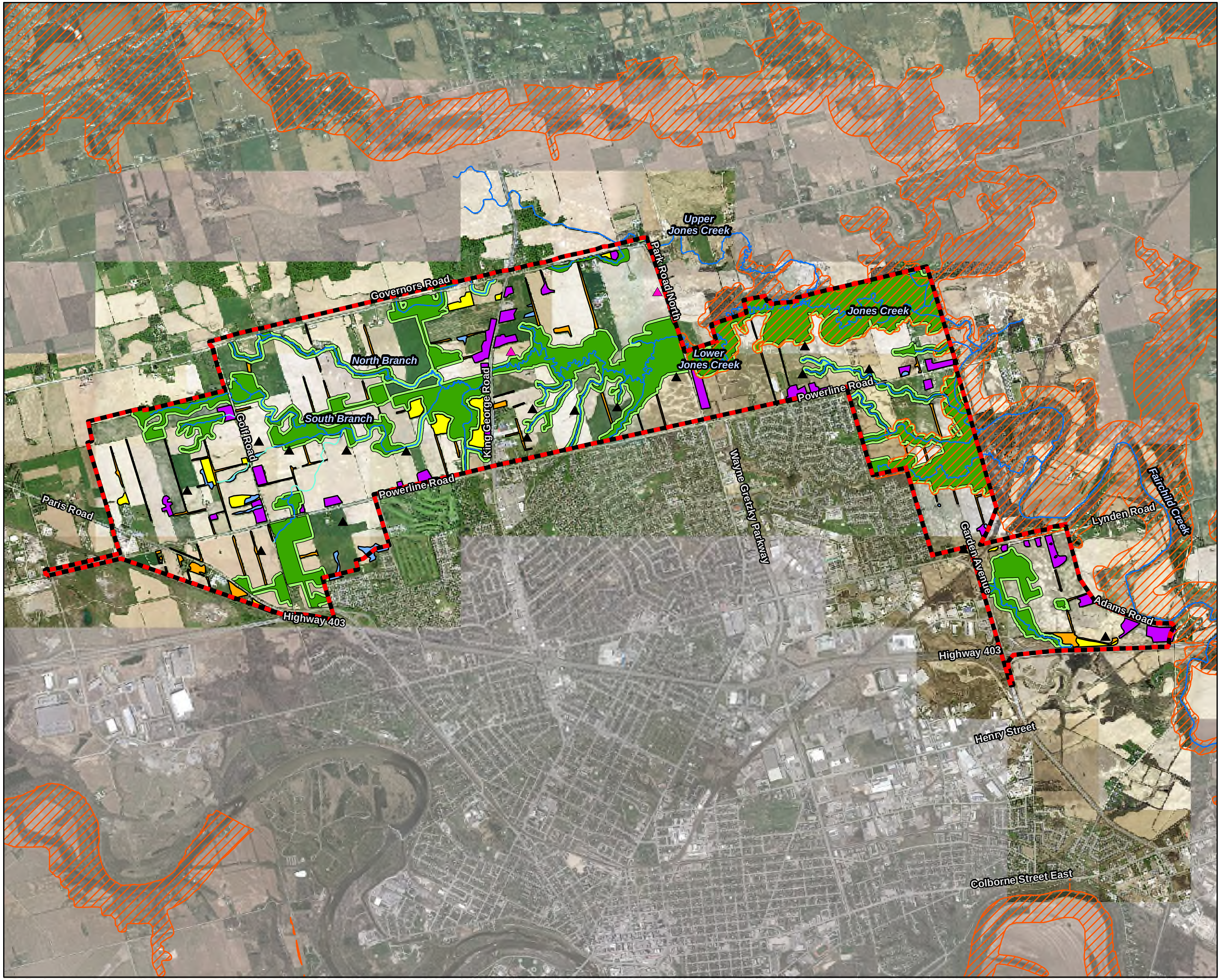
Other Environmental Features

Project #	2017-146	Figure # 13b
Date	July 2020	
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	


Figure 14a
Preliminary Land Use and Transportation Plan – North
0 0.275 0.55 1.1 Kilometers
N
Legend
Neighbourhood Residential
Neighbourhood Corridor
Neighbourhood Centre
Greenfield Intensification Corridor
Community Commercial Mixed Use
Employment Supportive
General Employment
Prestige Employment
Natural Heritage System
Growth Plan Natural Heritage System
Floodplain
Rural
Trigger Lands
SWM Pond
CP Community Park
NP Neighbourhood Park
HS High School
ES Elementary School
Municipal Boundary
Current Settlement Boundary
Roads
Controlled Access Major Arterial
Major Arterial Road
Minor Arterial Road
Collector Road
Local Road
Proposed Controlled Access Major Arterial
Proposed Major Arterial Road
Proposed Collector Road
Governor's Rd E
Golf Rd
King George Rd
Powerline Rd
Paris Rd
Oak Park Rd
Hardy Rd
Toll Gate Rd
Fairview Dr
Memorial Dr
Dunsdon St
Brantwood Park Rd
Wayne Gretzky Pky
Lynden Rd
Hwy 403
Adams Rd
West St
North Park St
St Paul Ave
Brant Ave
Dundas St
Dundas St E
Bedford St
Morton Ave E
Adams Blvd
Henry St
Garden Ave

Fig. 14b - Preliminary Land Use and Transportation Plan - Tutela Heights

*In Accordance with the Tutela Heights Road Slope Stability Municipal Class Environmental Assessment



Legend

- Study Area
- Watercourse to be Protected
- Watercourse to be Conserved – channel form and location may vary
- Natural Heritage System
- 30 m Protective Buffer
- NHS Area - Undifferentiated (Growth Plan)
- Proposed Storm Water Management Pond Location

Other Environmental Features

- Residential (ornamental plantings, cultural vegetation)
- Cultural (meadow, thicket, early-successional woodland)
- Wetland
- Woodland/Hedgerow

N

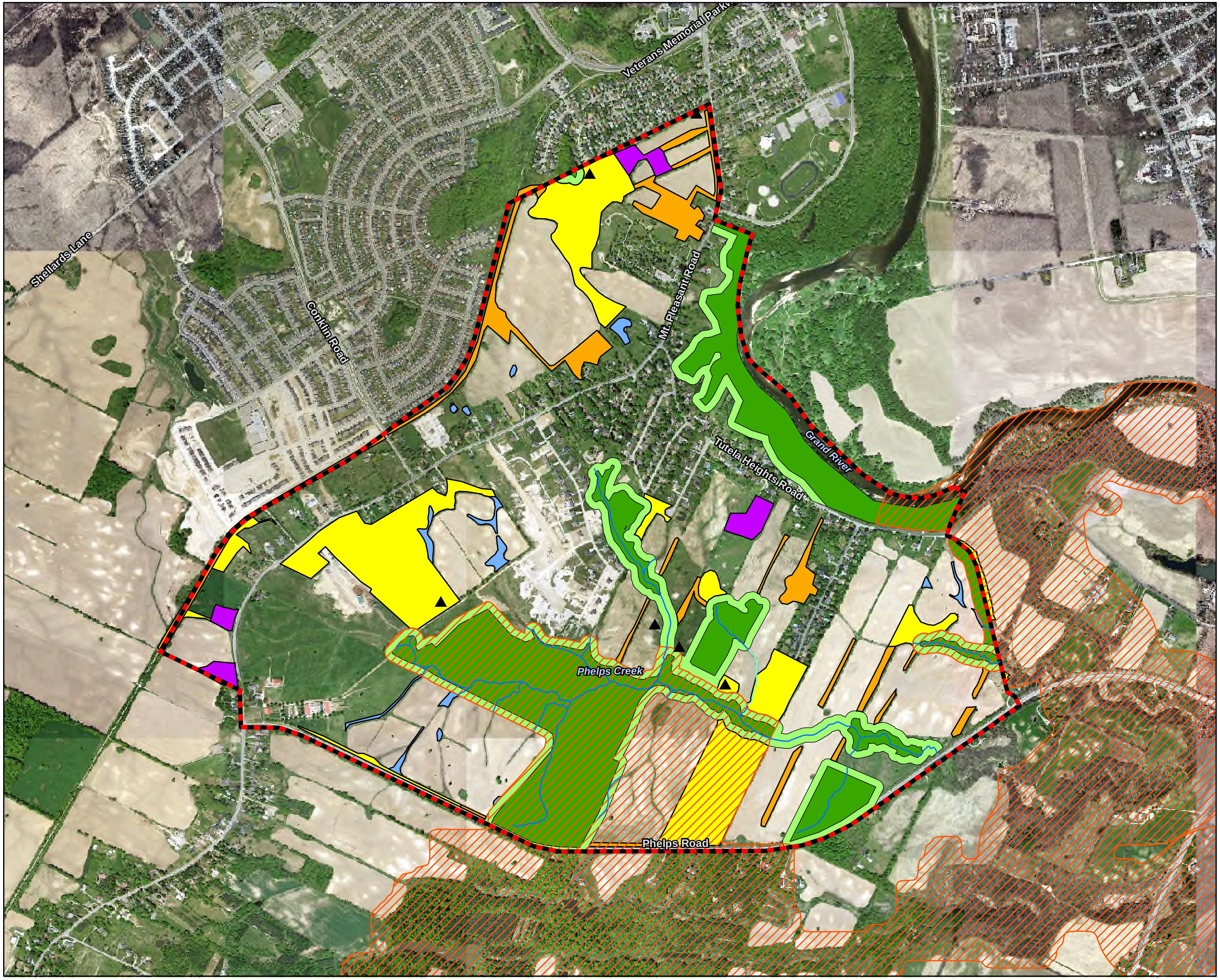
Meters
0 250 500 1,000 1,500 2,000

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS
Proposed SWM Pond Locations

Project #	2017-146	Figure # 15a
Date	July 2020	
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse to be Protected
- Watercourse to be Conserved – channel form and location may vary
- Natural Heritage System
- 30 m Protective Buffer
- NHS Area - Undifferentiated (Growth Plan)
- Proposed Storm Water Management Pond Location

Other Environmental Features

- Residential (ornamental plantings, cultural vegetation)
- Cultural (meadow, thicket, early-successional woodland)
- Wetland
- Woodland/Hedgerow

N

0 125 250 500 750 Meters

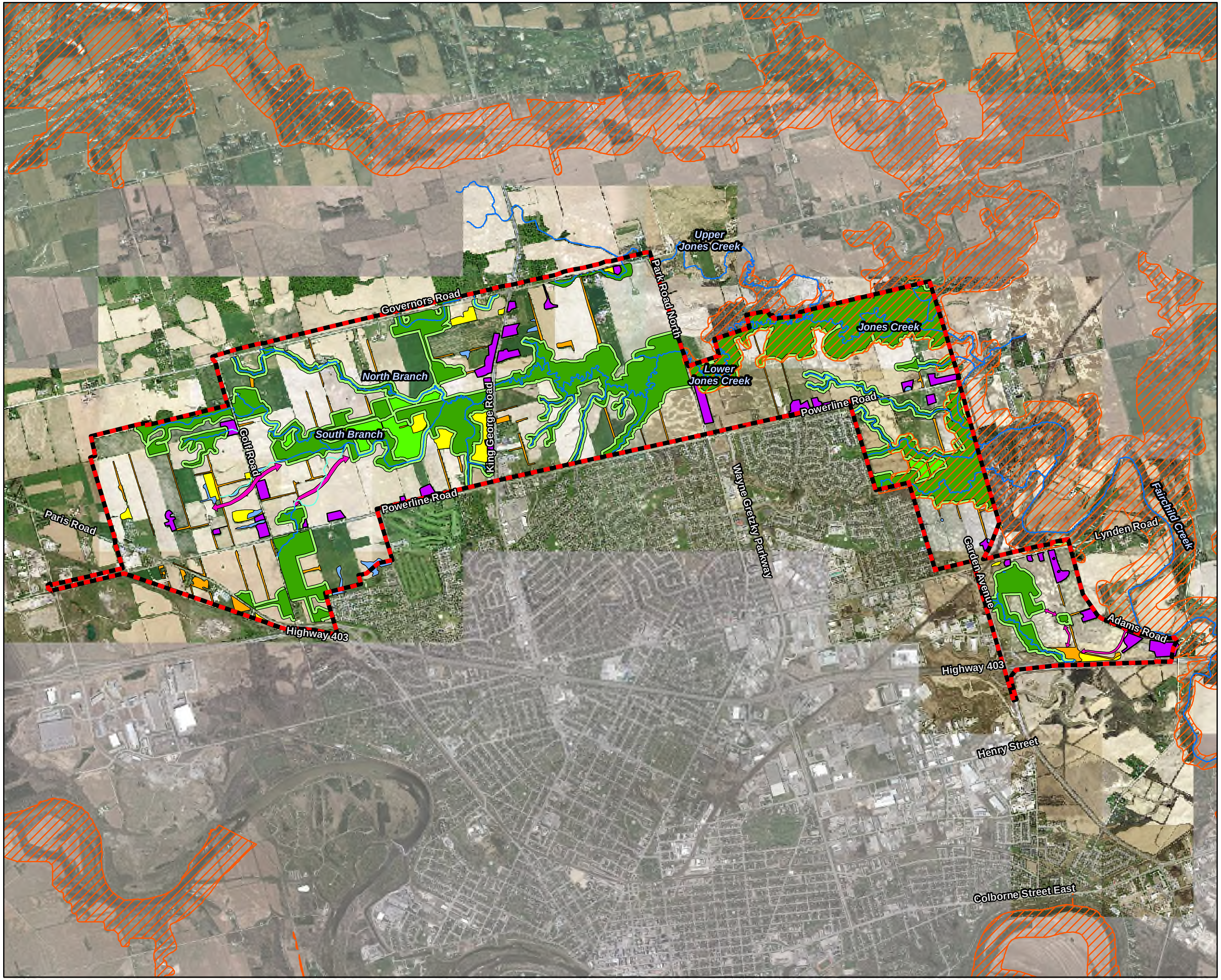
Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

PLAN B Natural Heritage
Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

Proposed SWM Pond Locations

Project #	2017-146	Figure # 15b
Date	July 2020	
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse to be Protected
- Natural Heritage System
- Growth Plan NHS

Other Environmental Features

- Residential (ornamental plantings, cultural vegetation)
- Cultural (meadow, thicket, early-successional woodland)
- Wetland
- Woodland/Hedgerow

NHS and Linkage Enhancement Opportunities

- 30 m Protective Buffer
- Headwater Drainage Features
- NHS Linkage
- Cultivated Field

N

Meters
0 250 500 1,000 1,500 2,000

Data Source (with Plan B NH modifications)
- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

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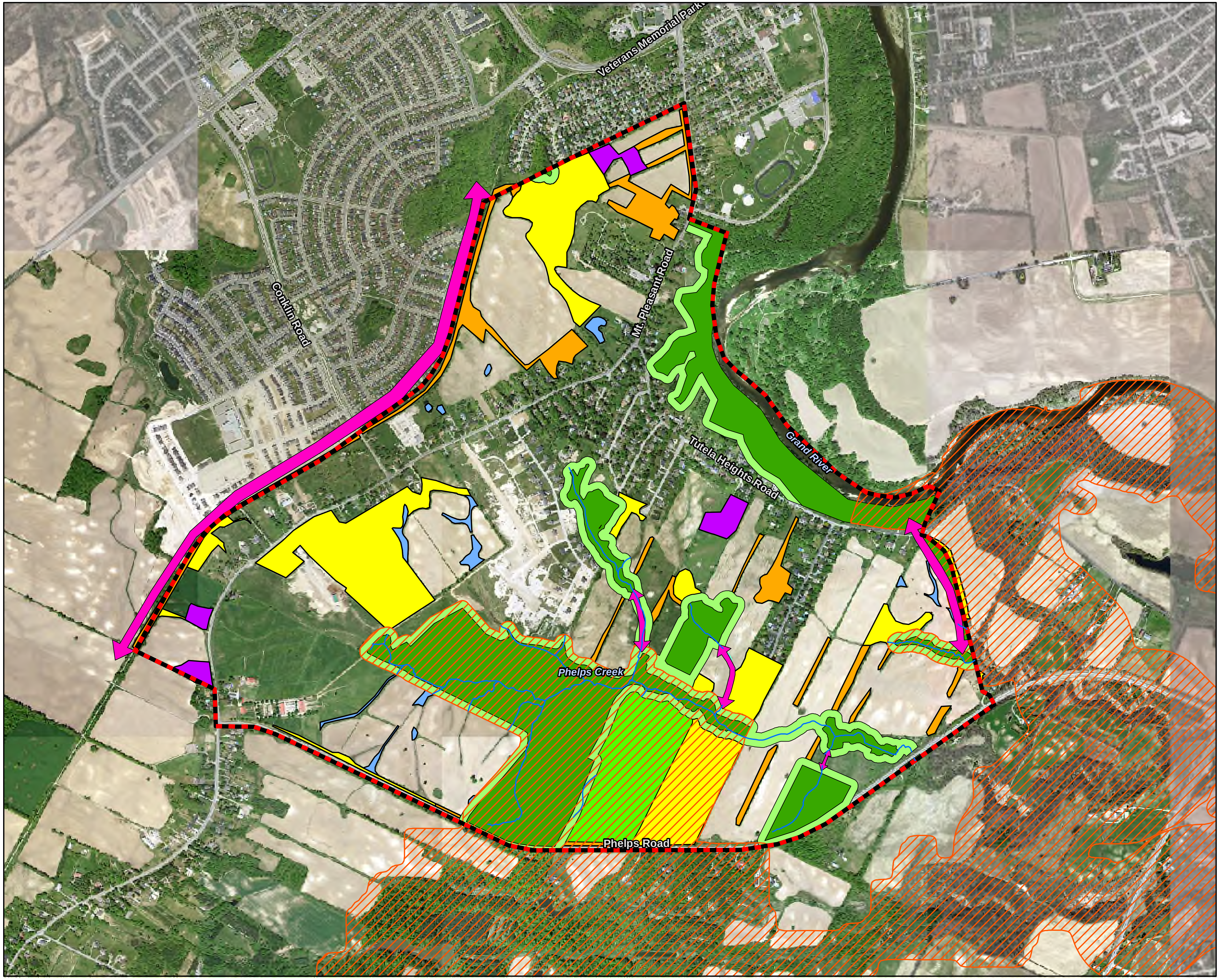
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

NHS Enhancement Opportunities

Project #	2017-146	Figure # 16a
Date	July 2020	
Scale	1 : 40,000	
Prepared By: JJJ	Verified By: BDB	



Legend

- Study Area
- Watercourse to be Protected
- Natural Heritage System
- Growth Plan NHS

Other Environmental Features

- Residential (ornamental plantings, cultural vegetation)
- Cultural (meadow, thicket, early-successional woodland)
- Wetland
- Woodland/Hedgerow

NHS and Linkage Enhancement Opportunities

- 30 m Protective Buffer
- Headwater Drainage Features
- NHS Linkage
- Cultivated Field

Data Source (with Plan B NH modifications)

- City of Brantford
- Ecosystem Recovery
- GRCA
- © Queen's Printer for Ontario, 2019
- Airphoto Date: 2015

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Landscape Ecology & Natural Heritage Planning
176 Fellowes Crescent
Waterdown, ON
L0R 2H3

North Brantford and Tutela Heights
City of Brantford
Comprehensive EIS

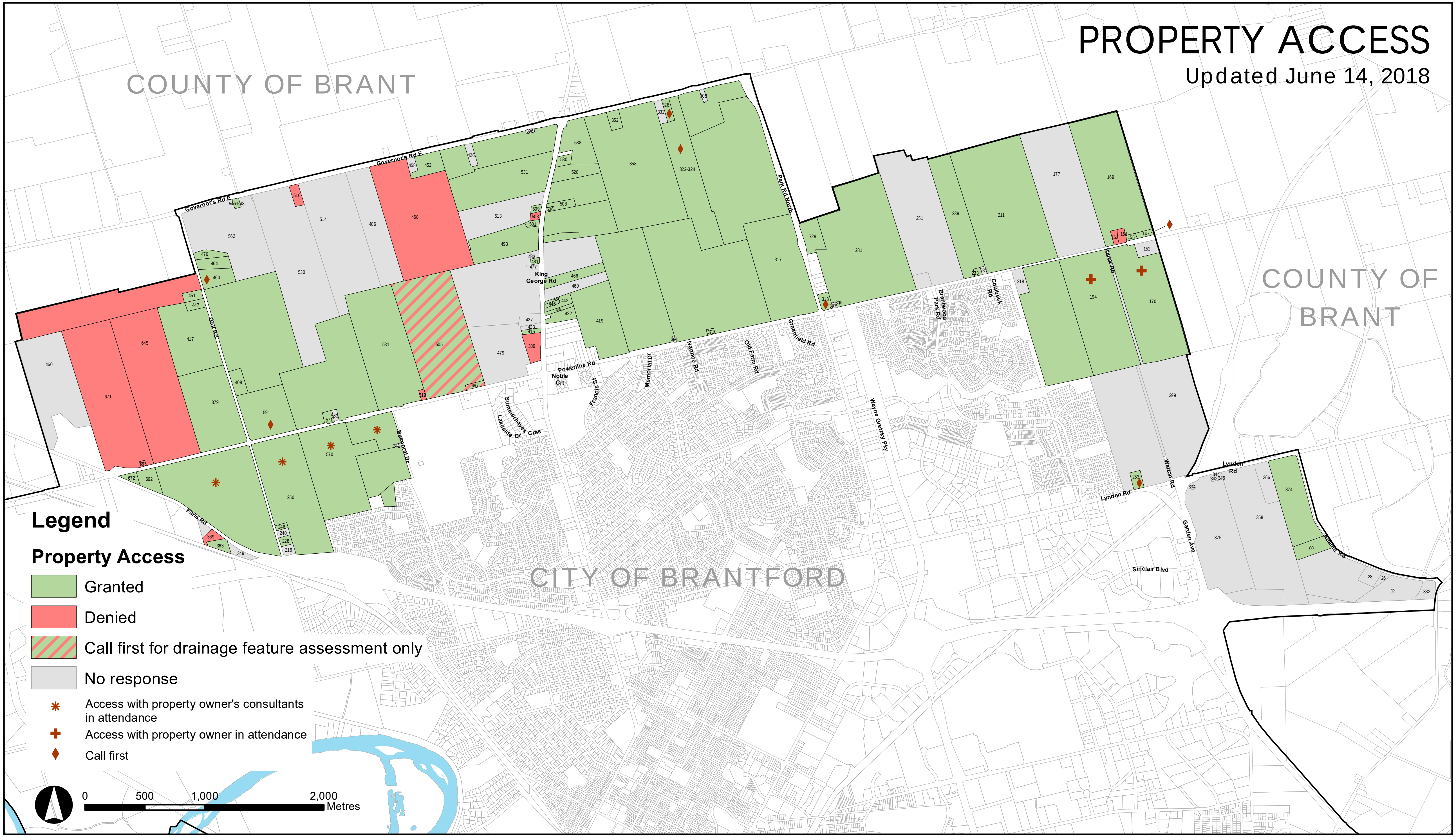
NHS Enhancement Opportunities

Project #	2017-146	Figure #
Date	July 2020	16b
Scale	1 : 15,000	
Prepared By: JJJ	Verified By: BDB	

APPENDIX C:
RECORD OF LANDOWNER CONSULTATION

PROPERTY ACCESS

Updated June 14, 2018



Project No: .... Date: ....

Project: ....

Name: .... Sheet: ....

SIGN IN SHEET

NAME	ADDRESS	PHONE /EMAIL
[redacted]	[redacted]	[redacted]
Juli Laudadio - Dg group.	30 FLORAL PKWY	jlaudadio@dggroup.ca
JORDAN ARCHER - DG GROUP	30 FLORAL PKWY	jarcher@dggroup.ca
DOUGLAS STEWART IBI GROUP	410 ALBERT ST. WATERLOO	douglas.stewart@ibigroup.com
KEVIN FERGIN STANTEC		kevin.fergin@stantec.com
[redacted]	[redacted]	[redacted]
MATT NINOMIYA (STANTEC)		matt.ninomiya@stantec.com
[redacted]		[redacted]
Alan Waterfield		awaterfield@brantford.ca
[redacted]	[redacted]	[redacted]
Janet Ivey, GRCA		jivey@grandriver.ca
[redacted]	[redacted]	[redacted]

North Brantford Subwatershed Study

Landowners' Meeting
July 17, 2018
Branlyn Community Centre

AGENDA

1. Introduction
2. Meeting Objectives
3. Need for Subwatershed Study
4. What is Involved
5. Process and Timing
6. Progress Updates
7. Feedback and Information Exchange

PURPOSE

1. Outline Subwatershed Study process and anticipated timing
2. Provide update regarding ongoing drainage feature and ecological assessments
3. Exchange information related to environmental conditions, natural heritage features and species, and drainage

NW1

2017 City Boundary Expansion

Today's meeting

1. **North Area** = 1,966 hectares
2. **East Area** = 174 hectares
3. **Tutela Heights** = 580 hectares

Planning Framework

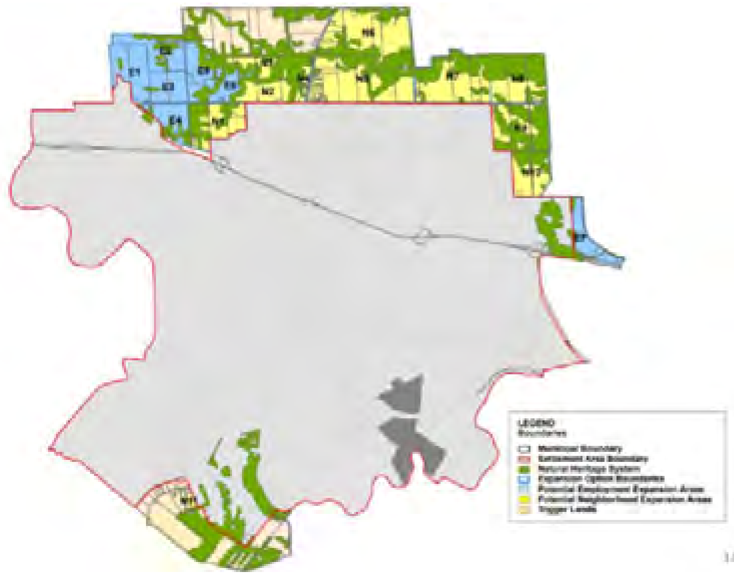
What needs to be done to support development of lands?

- **Official Plan Update**
  - Municipal Comprehensive Review (MCR) and associated studies
- **Secondary Plan**
- **Subwatershed Plans**
- **Master Plans**
  - Master Servicing Plan (MSP)
  - Transportation Master Plan (TMP)

What will this tell us/let us do

- Define the New Urban Settlement Area (where you can and can't develop)
- Map proposed land uses
- Define long-term Infrastructure Plan
- Provide guidelines and policies to frame growth & mitigate impacts

Potential Urban Settlement Expansion Areas



Why are we here?

- To outline Subwatershed Study process and anticipated timing
- To provide updates regarding ongoing drainage feature and ecological assessments
- *Exchange information* related to environmental conditions, natural heritage features and species, and drainage

Why Do We Need a Subwatershed Study?

Urban Settlement Area Expansion

- City of Brantford requires additional lands to be brought into its urban settlement area in order to meet 2041 growth targets
- Majority of land acquired from County of Brant was not designated for urban development and therefore did not automatically fall within the City's urban settlement area when it was acquired – settlement area must be expanded and Secondary Plan prepared for the area

Provincial Policy

Policies such as the Growth Plan have specific requirements in order to expand an urban settlement area and prepare a Secondary Plan, including the requirement for Subwatershed Planning

Environmental Planning and Protection

Study allows environmental protection/enhancement to be assessed and planned comprehensively, on a subwatershed basis rather than piecemeal

What is Involved in a Subwatershed Study?

Identify hydrologic features, areas, linkages, and functions as well as natural features, areas, and related hydrological functions

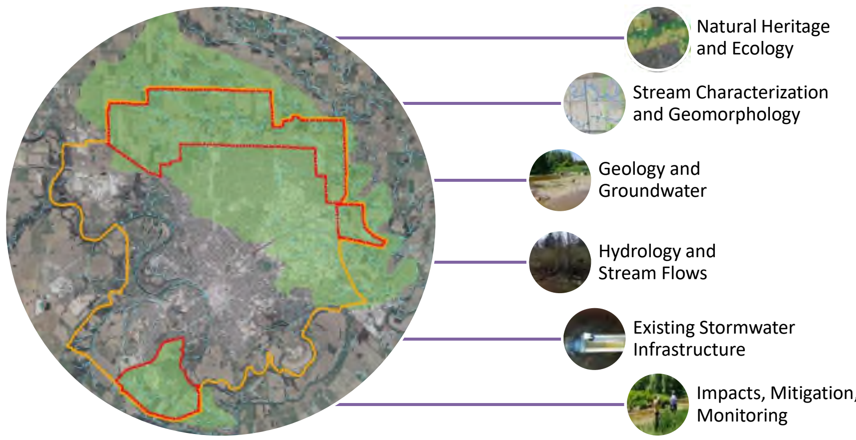
Provide for protecting, improving, and/or restoring the quality and quantity of water

Long-Term Management Plan for the Water Resource and Natural Heritage Systems

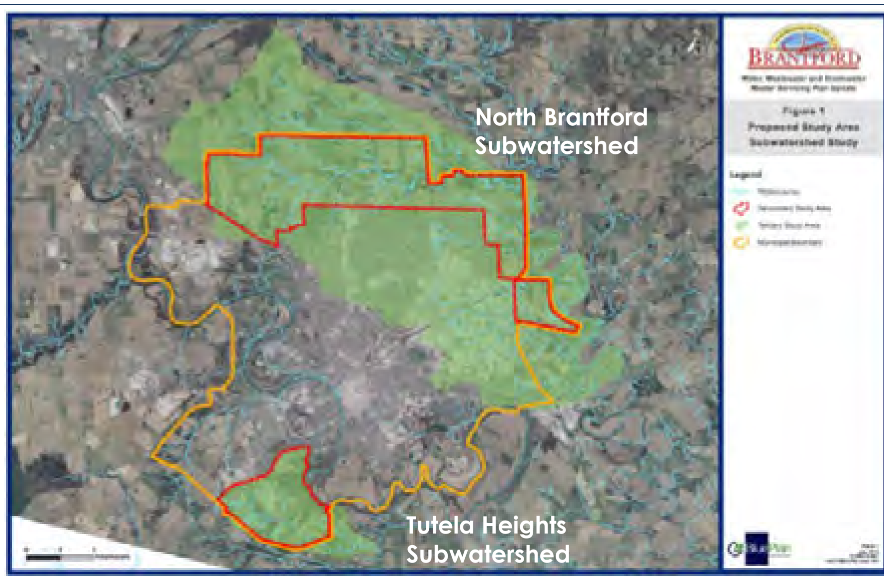
Consider existing development and evaluate impacts of proposed land uses and development, and provide guidance as to how, and when urban development can occur within the subwatersheds to ensure that impacts related to severe weather events are minimized and ecological needs are supported

Provide a clear implementation and monitoring plan that will be used to help guide/direct development while ensuring that potential impacts to the natural heritage and water resource systems are appropriately mitigated

What is Involved in a Subwatershed Study?

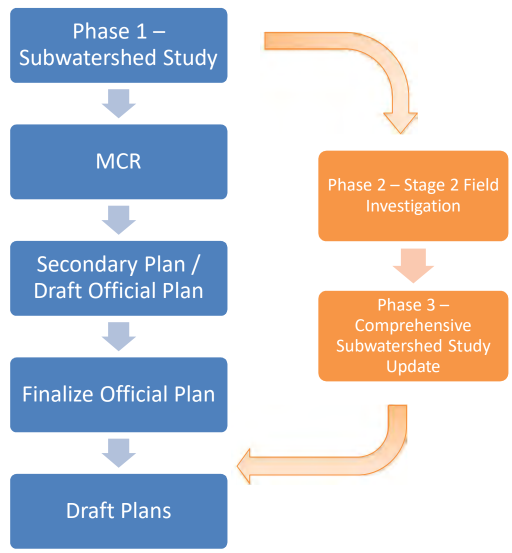


Subwatershed Study Area



NW3 CC-GB1

Process and Timing– Phased Approach



Post Official Plan Planning and Approval Framework

New City of Brantford Official Plan will establish a new Settlement Area Boundary and land use designations

- Will identify supporting studies required to be completed before new urban land use designations will come into effect in the new Settlement Area (e.g. Comprehensive Subwatershed Study Update; other studies)
- Will require new development to comply with the requirements of the Subwatershed Study, as part of a complete application

Proposed Subwatershed Study – Phased Approach Objectives

Phase 1: Subwatershed Study

- Complete Preliminary Characterization of the study area utilizing best available information and limited field investigation.
- Complete baseline desktop analysis utilizing best available information, of key hydrologic and hydrogeological impacts and mitigations.

Phase 2: Field Investigation

- Complete 2 years of data collection to verify assumptions, fill data gaps and support subwatershed study update.

Phase 3: Subwatershed Study Update

- Complete detailed analysis and model development utilizing the field investigation to update characterization, confirm impacts and mitigations, and provide more quantitative stormwater management targets for individual development areas.
- Outline appropriate implementation and monitoring plan.

GM BluePlan 13

Proposed Subwatershed Study – Implementation and Next Steps

Phase 1
Ongoing as part of MCR, Secondary Plan, OP Update
To be completed December 2018

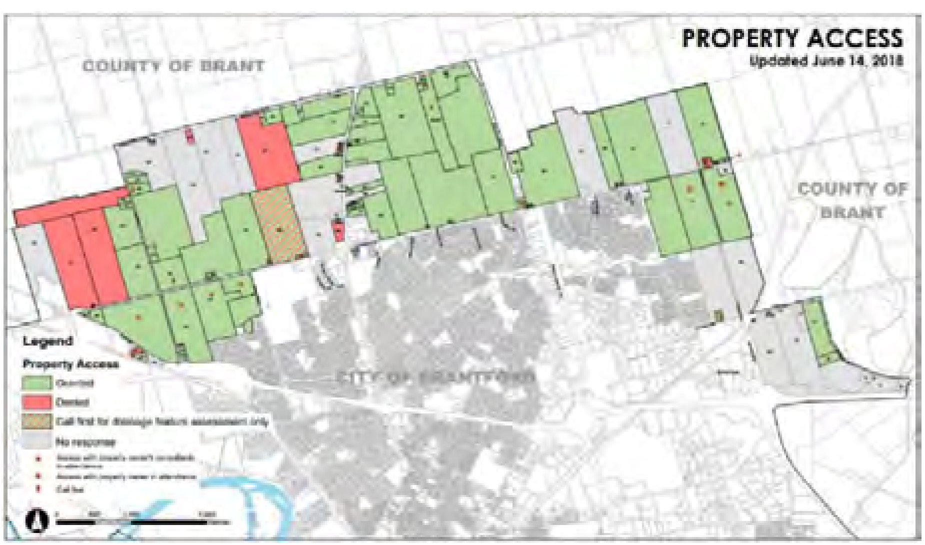
Phase 2
To begin Spring 2019 (pending Council approval of funding requirements)

Phase 3
- Work alongside and following Phase 2 investigations
- Complete by end of 2021

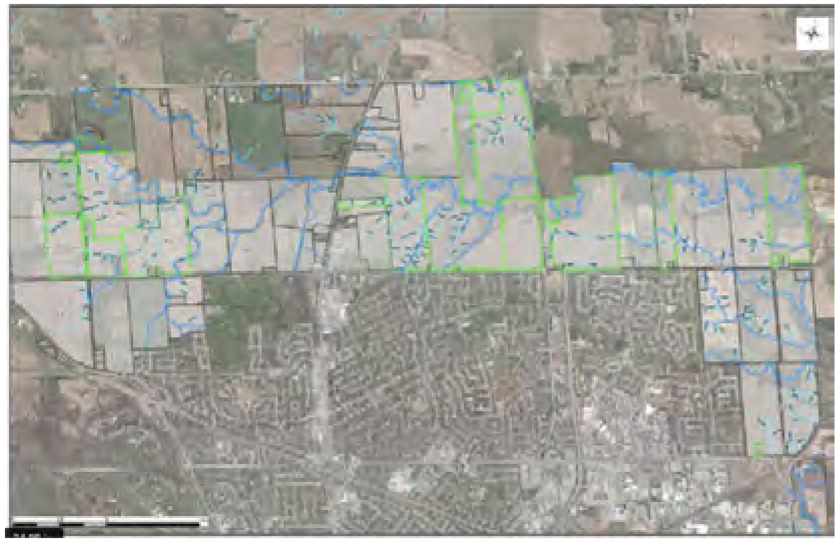
GM BluePlan 14

PHASE 1 INVESTIGATION PROGRESS

Property Access



Drainage Network



Surface Water Drainage Features – Study Components and Status Update

Disciplines
- Geomorphology – channel form, function, process
- Aquatic – general habitat conditions
- Water quality – general conditions

Work Plan
- Desktop Characterization (Completed)
- Field Assessment (Ongoing)
  - Headwater Drainage Features (HDF)
  - Reconnaissance along well defined channels
  - Detailed data collection
- Connect with Landowners (Ongoing)

Progress Update: HDF Assessments
- Up to 3 field assessments/inventory:
  - Channel form
  - Presence/absence of water
  - Adjacent landuse/cover
- Status:
  - 2 rounds completed
  - Last round in July

Other Planned Work
- Reconnaissance level inventory of non-HDF features (August)
- Detailed data collection and processing (August/September/ October)
- Reporting (October, November)

Ecological Assessments - Progress

- Compiled background information and prepared existing conditions and preliminary NHS mapping from:
  - GRCA
  - MNRF
  - County of Brant
  - City of Brantford
- Scoped field surveys of amphibians, winter animal tracks, breeding birds, hedgerows, and wetlands are in progress or have been completed
- Follow-up vegetation and wildlife habitat suitability studies to be completed July – September 2018

Servicing Considerations - Progress

- Water/Wastewater/Stormwater Master Servicing Plan updates underway, including updates to existing infrastructure models
- Prepared catchment analysis using topographical data
- Determined likely stormwater servicing strategies to proposed growth sub-areas based on local constraints
- Other planned work:
  - High level flow estimates under existing and post-development conditions
  - Update analysis of likely stormwater servicing strategies and provide high-level infrastructure needs based on surface drainage features and ecological assessment work
  - Coordinate subwatershed study report including impacts, mitigation, monitoring, and detailed terms of reference for Phase 2 and Phase 3 work

INFORMATION SHARING

Information Sharing – Where are Here to Listen

Any existing/historical reports/surveys?

- Consultant's studies (geotechnical, hydrology, natural heritage, etc.)
- Channel measurements, conditions, processes
- Water quality measurements/observations
- Fish observations

Information regarding tile drainage?

Observations of groundwater discharge?

Any other information?

- Photos
- Species observations
- Other

Thank You!

Subwatershed Study Area

Subwatershed Study Area

Subwatershed Study Area

NW5

Subwatershed Study Area

Subwatershed Background Info Sharing Date 7/9/2018

Attendees: [redacted] (Church Admin + Landowner)
[redacted] Landowner
[redacted] landowner
René VanAcker (Dean @ OAC, Univ. of Guelph, on behalf of J. Fitzgibbon, U of G professor)
Janet Ivey (GRCA)
Nahed Ghbn
Tara Gudgeon
Nicole Wilmot
Alan Waterfield } City
Mariette Pushkar (ERI)
Julien Bell
Carolyn Chan } GM Blueplan

Information:

- Map of F.C. Basin
  - connection – Six Nations water plant nr outlet, + U.N. University (study?) → J.F. has study connection
    ↳ perception that St. George is polluting F.C. "everything is dead"
- Map of County of Brant, from Mr Summerhays.
  ↓ developed from
- O.W.R.C. Report on Water Resources Survey County of Brant, 1964. Includes record of wells at that time.
- Map "Early Brantford and Environs" 1833

Date 7/9/2018

- Map of Jones Creek system w/ hand notes
- Maps from Grand River Regional Groundwater Study
  ↳ suggests Jones Ck. is part of underground river (Bedrock Valley map)
  - water table elev. on Mr. S's property appears to correspond with his understanding of mapped groundwater system.
- Janet: new GW model for St. George wellhead protection study currently underway
- 1835 map of property parcels including [redacted] – mention of [redacted] 999-yr lease
- Folder: Study of fish (DVD shows no fish after stormwater outlet on Baldwin property)
- 1948 then-owner of Baldwin changed stream course
  - Agreement Drain (?)
- Discussion of documents not presented – officials (prov.?) angered that coldwater DS of development became warmwater
- Anecdote – tile systems on Baldwin & Summerhays running more full (WT higher) than before
- (2005/2001) Myrtleville outlet, M hooked into Howard's tiledrainage system illegally (10" tile) → On [redacted] 10" tile blew up near gas main; got NEB involved.

Date 7/9/2018

landowner?
- [redacted] then dug ditches to try to divert water.

- S.

- Carlyle farm property – fields now too wet to work b/c of 403 adjustment etc. (near Paris Rd)

- gave verbal summary of where sand layer drains (several directions)
  - ↳ rail cut-off during Depression suggested to have changed patterns.

- H.S. tried bringing engineers on Food Basics development to PEO but dropped it.

- Myrtleville – "houses sitting on water"

- (Fairchild : protested

- Brantford Commons "Roseland Drain" potential name of ditch

- JB presented overview of OP update & phased subwatershed study process.

- H.S. property ⅔ is camera'd – no access permitted, previous violence/conspiracy (?)

- Suggest copying documents – @ City ? & H.S. must accompany

- Truck Traffic suggestion.

Public Consultation PIC – Landowners' meeting

[redacted] @ Six Nations made the DVD (TV program includes run on Six Nations TV Network?) – does not have permission to share.

Date 7/9/2018

- Built Powerline Rd in 1960 & have had many water issues, tiled various spots

- compiled Tile map (hand drawn) available.

- sinkhole behind [redacted] under hydro line, sank twice & filled.

- Carlyle – low end drainage cut off by Hwy (suggested oil pollution in Creeks in area).

- Sissler/Myrtleville tile crosses powerline Rd.

- WESA report + photographs. of tile blowout – catchbasin.

- mention of high pressure union gas line route

- had to build another ditch near Hyundai. – King George/Powerline corner – drainage issues.

- Wyndham Hills drain changed several times & fill added both sides (increased flooding on Baldwin's, once 80 ac. farmed but now swamp.)

- note: spring near Tranquillity cemetery, filled behind Partoune... (issue if cemetery is wet, not drained properly)

location noted on map

- when 24 was built, the outlet into creek

- tile from car wash into stream – foam observed

Date 7/9/2018

> H.S. 60ft deep well, 40ft to rock. (now operate out of dug well)
- 1955 2 wells put in by Township - one for golf course
  152 ft deep.
  (- City study of well?)

> observation that wells go down when irrigation starts & recharge when stops

↳ Int'l Water Supply test showed aquifers connects all the way to old German School Road

[redacted]

familiar Regional hydrogeology & underground rivers.

(gave precedent cases he expects to be relevant)
- Welland
- Lynch vs. Nfld

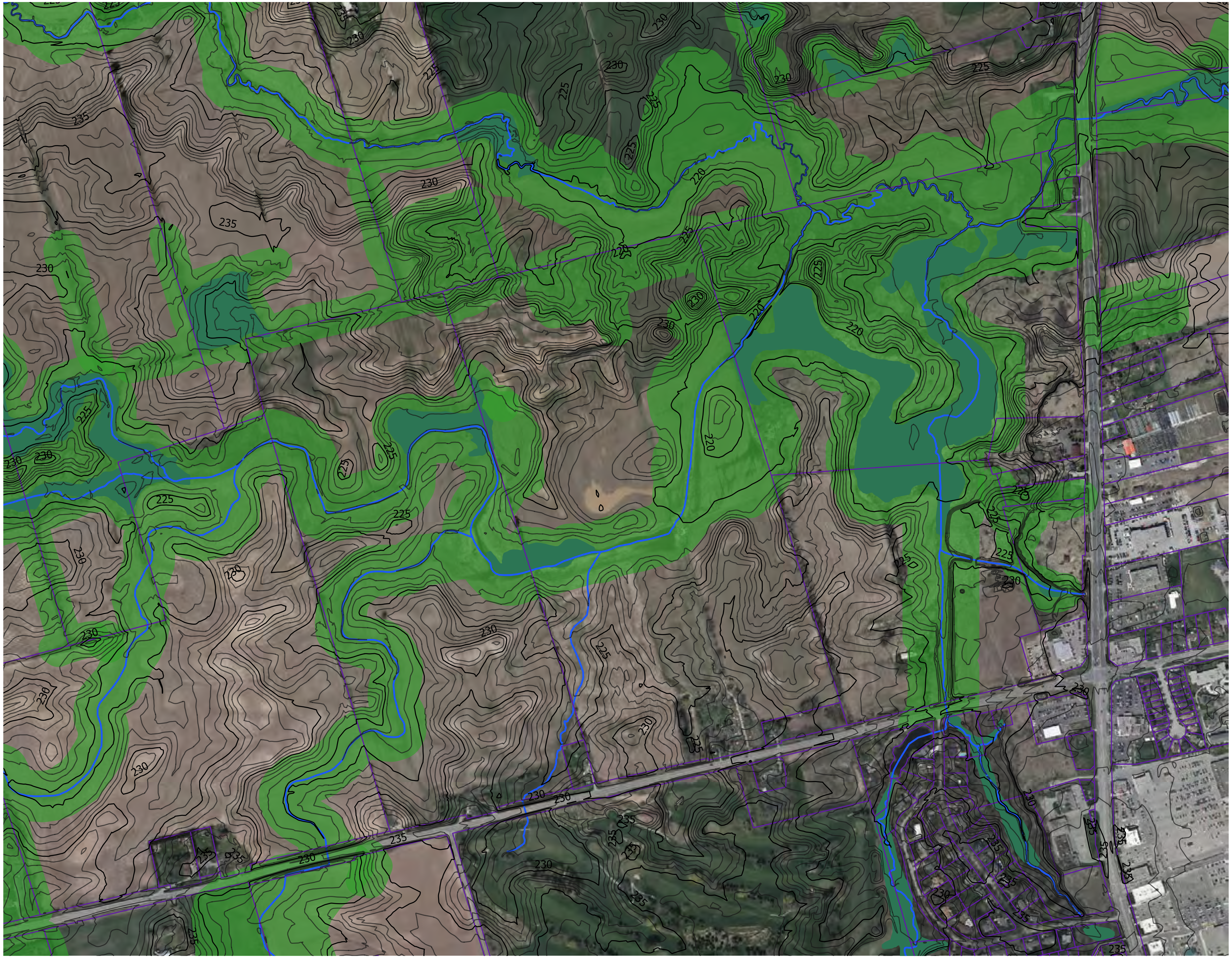
- Discussed sid v. & drainage act review

- Cohoon tried to get Municipal Drain through Summerhays
  ↳ claimed had right to hook into tile

[redacted] concern - phasing + lands remaining ag. land
→ ensure lands remain workable while still Ag.

Janet mentioned temp & level loggers (some moved, stolen etc. over time)
↳ if City wanted GRCA to ~~contribute~~ to long term ecological physical monitoring, should discuss agreement.
↳ spot monitoring summary from MNRF available

505 Powerline Road, Brantford



Legend

CITY_Contours_5m

CITY_Contours

Layers PropertyParcel

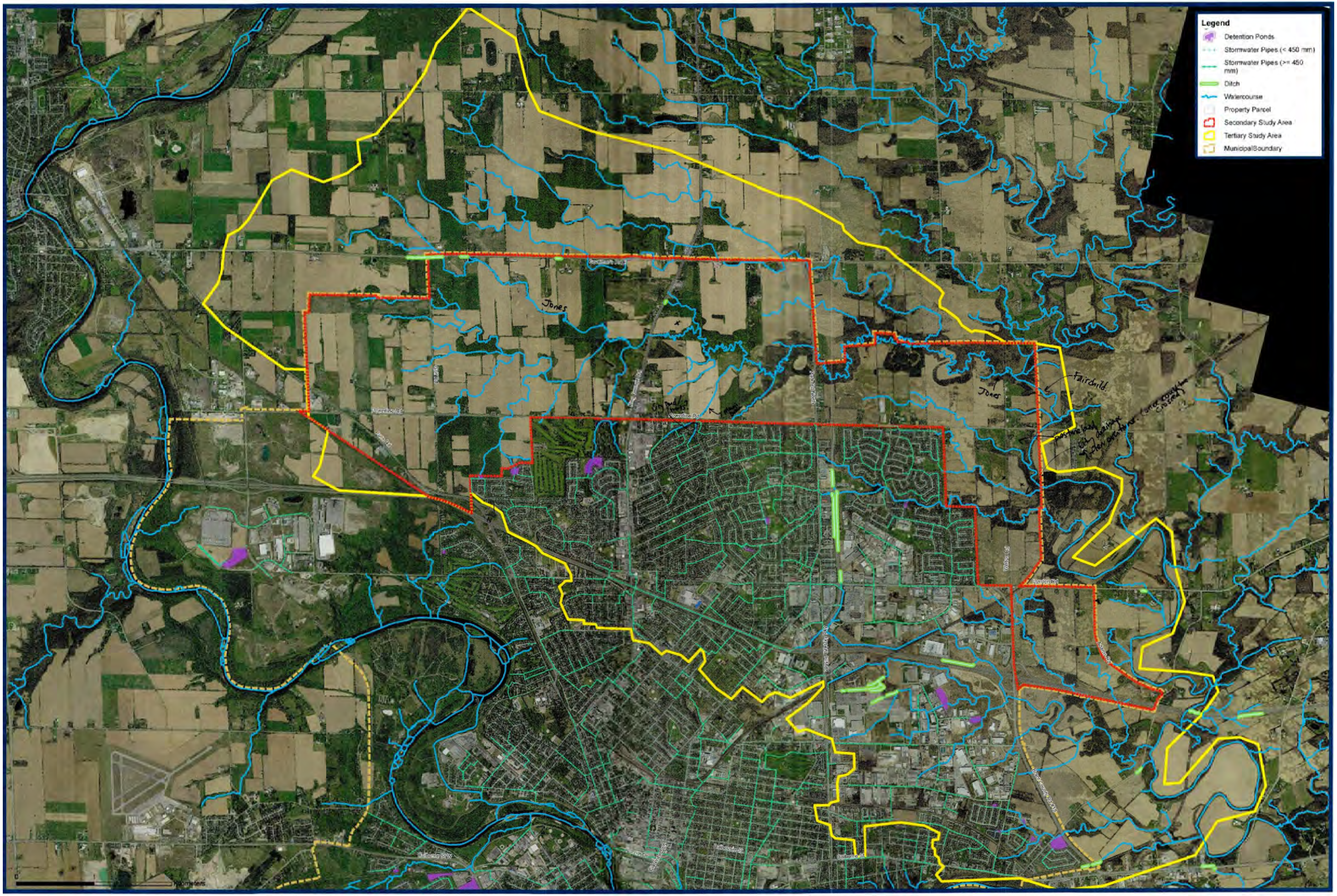
Layers MunicipalBoundary

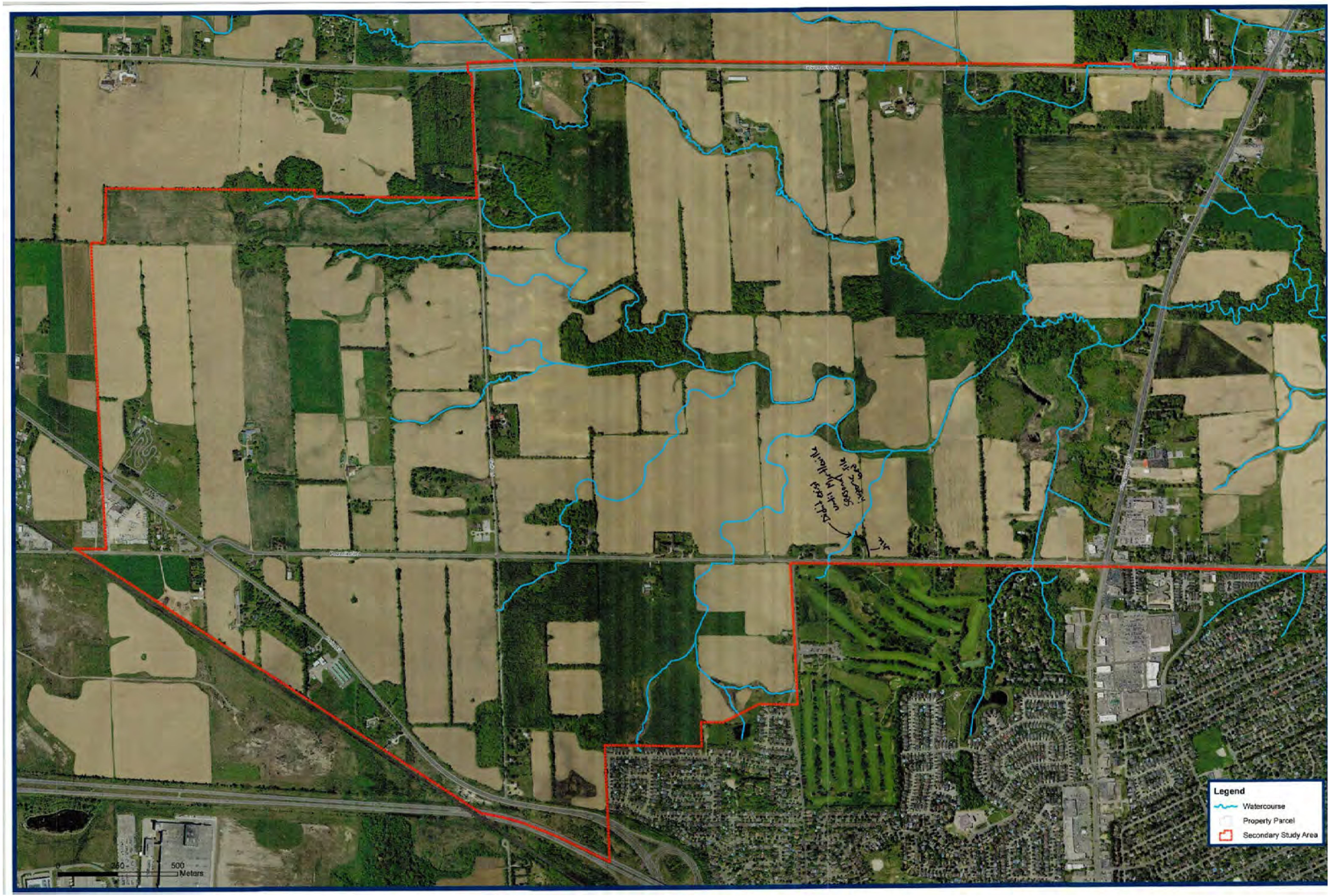
GRCA_Watercourse

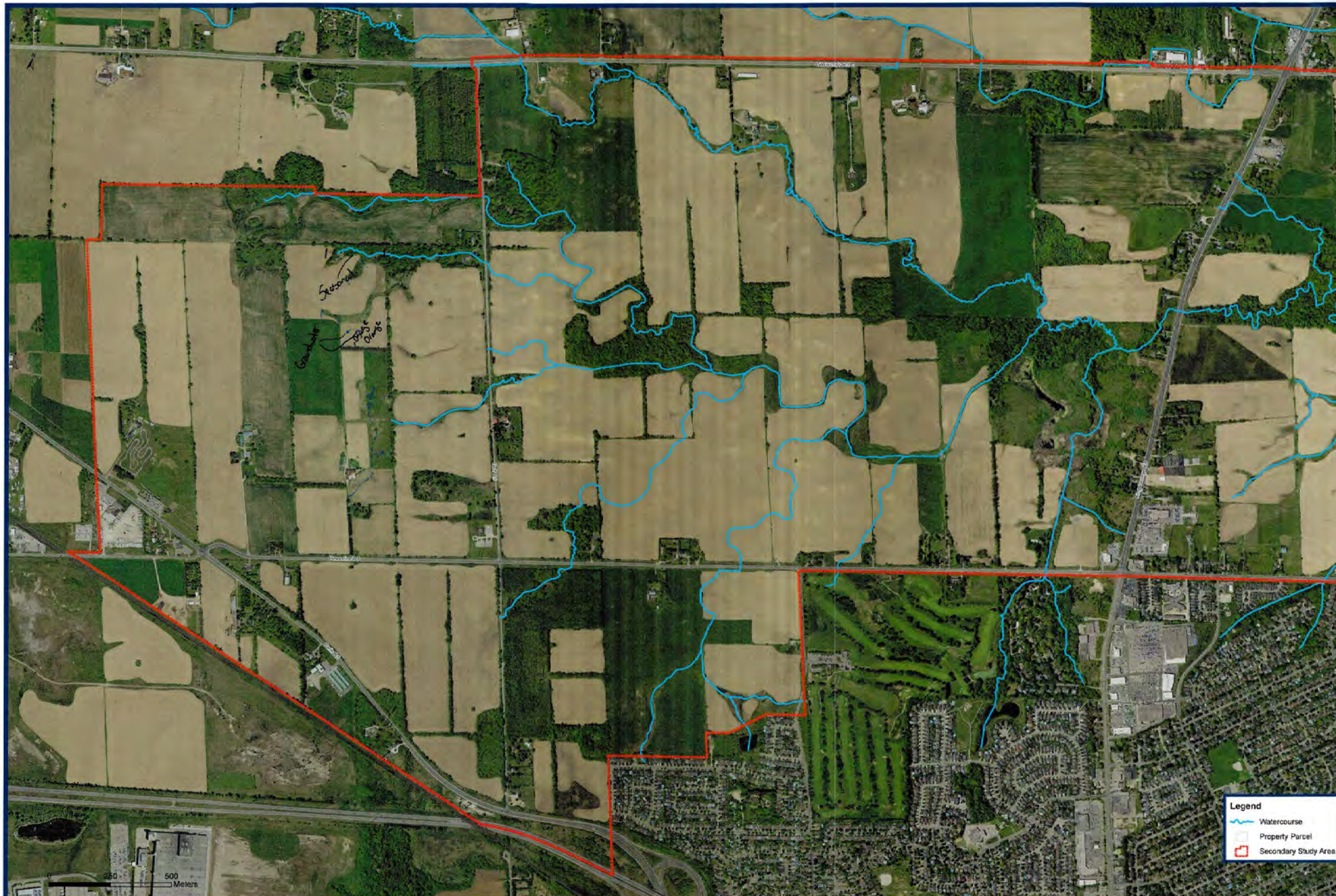
GRCA_Wetland

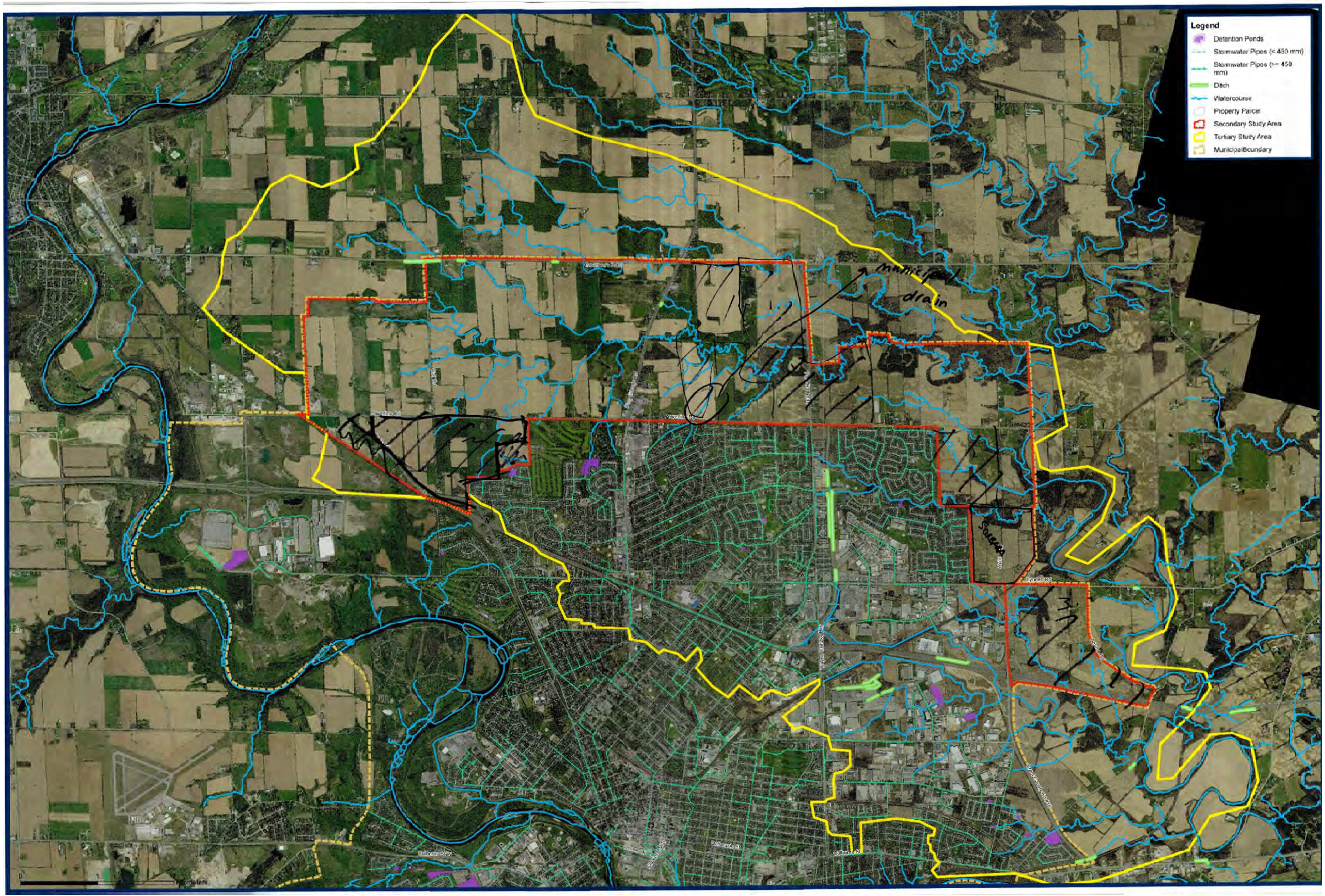
Natural Heritage System

100 0 100 200 300 400 m


Legend
Detention Ponds
Stormwater Pipes (< 450 mm)
Stormwater Pipes (>= 450 mm)
Ditch
Watercourse
Property Parcel
Secondary Study Area
Tertiary Study Area
MunicipalBoundary
Jones
Fairchild
Jones
Kilometers


Legend
Watercourse
Property Parcel
Secondary Study Area
0
250
500
Meters


Legend
Watercourse
Property Parcel
Secondary Study Area
0
250
500
Meters


Legend
Detention Ponds
Stormwater Pipes (< 450 mm)
Stormwater Pipes (>= 450 mm)
Ditch
Watercourse
Property Parcel
Secondary Study Area
Tertiary Study Area
Municipal Boundary
municipal drain

APPENDIX D:
HEADWATER DRAINAGE FEATURE ASSESSMENT

Appendix D – 1

Reach Summaries

Overview of the Rapid Geomorphic Assessment Tool

The RGA is a semi-quantitative assessment of physical evidence of channel stability which also enables identification of the probable mode-of-adjustment (Ontario Ministry of the Environment, 2003). The presence or absence of channel features shown in each of the following four geomorphic processes is assessed during the stream walk:

- Aggradation (AI) – excess deposition of sediment;
- Degradation (DI) – lowering of the channel bed invert;
- Widening (WI) – increase cross-sectional area through widening; and
- Planimetric form adjustment (PI) – change in the meander pattern.

Results from the RGA are then compiled and analyzed to determine which reaches are considered to be stable, moderately stable, or unstable.

The RGA is applied over a channel segment of at least two meander wavelengths or 20 bankfull widths and is ideally applied over the entire reach. During the reconnaissance level field walk, 7 to 10 indices are evaluated as present or absent within the reach for each of the geomorphic processes identified above (aggradation, degradation, widening, and planimetric form adjustment). The results from the field assessment are then compiled to determine the state of the reach.

The indices of the Rapid Geomorphic Assessment are generally applicable to urban systems, with indices referring to the conditions of surface (i.e., bridge footings and outfalls) and subsurface (i.e., sanitary or storm sewer) infrastructure, and erosion mitigation works. The drainage network within the North Brantford Area is impacted by upstream urban development, but is also highly influenced by the rural/agricultural setting that it is situated in; therefore, the existing RGA assessment was not entirely applicable. A review of existing literature was completed to identify indices of channel stability within rural systems, the RGA form was then revised for the North Brantford and Tutela Heights study to better reflect the potential impacted conditions of the watercourses that occur in the study area. The revised indices focus on channel substrate, bed morphology, patterns of erosion and deposition, and floodplain connectivity. The revised RGA field sheet is shown in **Figure D-1**.

Using the data sheets completed during the field walks, a factor value between 0 and 1 is determined for each of the four processes on each reach; this value is calculated as the number of indices present divided by the total number of indices within the process category. The highest factor value gives an indication of the dominant process within the reach.

An overall Stability Index (SI) for the reach is determined by summing the factor values and dividing by 4 to give an average over the four geomorphic processes. The SI value provides an indication of the conditions within the channel (see **Table D-1**). As noted in the table, reaches with an SI value less than 0.2 are generally considered to be stable. Those within an SI value between 0.21 and 0.4 are considered to be moderately stable, and those with an SI value higher than 0.4 are considered to be unstable.

The use of RGAs allows for the identification of the active processes that are operative on a reach basis and is useful for guiding the selection of appropriate restoration methodologies. That is, selection of appropriate restoration approaches should be based on an understanding of the interaction/impact of existing processes on the restoration approaches that are being considered. Further, restoration approaches should, wherever possible, minimize interference with natural channel processes.

Information gleaned from the RGAs pertaining to channel stability within each reach therefore provides relevant background information when determining appropriate restoration solutions.

ecosystem recovery inc. PROFESSIONAL ENGINEERS

Date:

Field Site:
recorder

RAPID GEOMORPHIC ASSESSMENT - RURAL

Watercourse / Reach:

Process	Geomorphic Indicator		Present		Factor Value
	no.	Description	No	Yes	
Evidence of Aggradation (AI)	*1	Soft unconsolidated bed materials			
	**2	Large, uncompacted bars			
	2	Coarse material in riffle embedded			
	3	Siltation in pools			
	*4	Diminished pool depths			
	5	Medial / lateral bars			
	6	Accretion on point bars			
	7	Poor longitudinal sorting of bed materials			
	8	Deposition in overbank zone			
Evidence of Degradation (DI)	1	Exposed bridge footings			
	*2	Bank height increase (downstream direction)			
	***3	Floodplain connectivity (entrenched / incised)			
	***4	Elevated tributary outlets			
	*5	Absence of depositional features (maine)			
	6	Cut face on bar forms			
	7	Head cutting due to knick point migration			
	8	Terrace formation evident in floodplain			
	9	Suspended armor layer visible in bank or bed			
	10	Channel worn into undisturbed overburden/bedrock/till			
Evidence of Widening (WI)	1	Fallen/leaning trees/fence posts/etc			
	2	Occurrence of large organic debris			
	3	Exposed tree roots			
	4	Basal scour on inside meander bends			
	5	Basal scour on both sides of channel through riffle			
	6	Length of basal scour > 50% through subject reach			
	*7	Deposition of mid-channel bars			
	8	Fracture lines along top of bank			
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)			
	2	Evolution of single thread channel to multiple channel			
	3	Evolution of pool-riffle form to low bed relief form			
	4	Cutoff channel(s) / meander scar(s)			
	5	Formation of island(s)			
	6	Thalweg alignment out of phase with meander geometry			
	****7	Significant number of bank erosion areas			
	8	Bar forms poorly formed/reworked/removed			
Stability Index (SI) = (AI+DI+WI+PI)/m				SI =	

What distinguishes this reach from adjoining reaches?

* Maine Department of Environmental Protection. 2009. A Citizen's Guide to Basic Watershed, Habitat, and Geomorphology Surveys in Stream and River Watersheds.
** Sear, D., Newson, M. and Thorne, C. 2010. Guidebook of Applied Fluvial Geomorphology.
*** Vermont Agency of Natural Resources. 2004. Stream Geomorphic Assessment Phase 2 Handbook. Rapid Stream Assessment.
**** Sear, DA. & Newson, MD. 1994. Sediment and gravel transportation in rivers, including the use of gravel traps. National River Authority R&D Note 315, Bristol.

Figure D-1. RGA field sheet example

Table D-1: Interpretation of RGA Form Stability Index Value (Source: Ontario Ministry of the Environment (2003))

Stability Index (SI) Value	Classification	Interpretation
SI ≤ 0.2	In regime	The channel morphology is within a range of variance for streams of similar hydrographic characteristics – evidence of instability is isolated or associated within normal river meander propagation processes
0.21 ≤ SI ≤ 0.4	Transitional or stressed	Channel morphology is within the range of variance for streams of similar hydrographic characteristics but the evidence of instability is frequent
SI > 0.4	In adjustment	Channel morphology is not within the range of variance and evidence of instability is wide spread

Jones Creek

Reach: JC-A

Watercourse:	Jones Creek	**Length:**	290 m
Detailed Site:	None	**Grade:**	0.18 %
Sub-area:	N8	**Sinuosity:**	2.17
Date:	August 30, 2018	**Environment:**	Rural; Partially confined (valley)

Reach Location:

Channel Setting

Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	No
Canopy Cover (%):	51-75%	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Present; some

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	4.5-6.0 m	**Height:**	1.40 m	**Morphology:**	Undulating Bed
Channel Depth:	1.2-1.5 m	**Materials:**	Silty Clay	**Substrate:**	Silty-clay
Wetted Widths:	2.0-2.8 m	**Erosion:**	Bank scour		
Wetted Depths:	0.3-0.9 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Channel Stability:

RGA Score:	0.44	**Stability:**	In adjustment	**Dominant Process(es):**	Degradation/ Widening

Water Quality:

Temperature:	19.7°C	**pH:**	8.02	**TDS:**	406 ppm	**Conductivity:**	812 µS	**DO:**	6.75 mg/L

Photo 1: Typical channel cross-section; overhanging vegetation (herbaceous)

Photo 2: Bank erosion; exposed roots

Field Observations:

- Partially confined reach (right bank)
- Riparian vegetation
    - Mostly herbaceous; some trees (leaning)
    - Banks mostly vegetated – areas lacking vegetation exhibit erosion processes
    - Overhanging vegetation
- Incised – bed less resistant than banks – role of vegetation
    - Clay/silt bank material
    - Steep banks – bank slumping; mass movements (slip?)
    - Clay bank blocks with vegetation in channel
- Low width: depth ratio
- Bed morphology moderately defined
    - Water depth changes slightly through reach
    - Branch accumulation on bed creating riffle-like hydraulic conditions
- Bed material clay/silt – no coarse substrate
    - Firmer areas follow flow trajectory – thalweg influence
- Process – toe erosion
    - Hydration / dissolution
- Reach break – valley setting, greater bed morphology variability, channel widens

Watercourse:	Jones Creek	**Length:**	843 m
Detailed Site:	None	**Grade:**	0.23 %
Sub-area:	N8	**Sinuosity:**	2.06
Date:	August 30, 2018	**Environment:**	Rural; Valley confinement

Reach Location:

Channel Setting			
Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	No
Canopy Cover (%):	51-75%	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Yes; some

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	5.5-8.0 m	**Height:**	1.35 m	**Morphology:**	Undulating Bed
Channel Depth:	1.3-1.5 m	**Materials:**	Silty Clay	**Substrate:**	Silty-clay
Wetted Widths:	0.4-6.0 m	**Erosion:**	Bank scour		
Wetted Depths:	0.2-0.6 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Channel Stability:

RGA Score:	0.42	**Stability:**	In adjustment	**Dominant Process(es):**	Degradation/ Widening

Water Quality:

Temperature:	19.3^{o}C	**pH:**	8.08	**TDS:**	377 ppm	**Conductivity:**	753 µS	**DO:**	7.36 mg/L

Photo 1: Meander bend

Photo 2: Clay bench feature extending from bank toe

Field Observations:

- Meandering planform
- Riparian – herbaceous & trees
    - LWD jams & fallen/leaning trees located on banks
- Floodplain connectivity
    - Lower bank heights when compared to Reach A
        - Steep inside meander bends; bank scouring along outside bends
    - LWD/branches in floodplain
- Substrate consistently clayey silt
- Clay benching at bank toe
- Low width: depth ratio
- Crayfish observed in reach

Watercourse:	Jones Creek	**Length:**	664 m
Detailed Site:	None	**Grade:**	0.04 %
Sub-area:	N8	**Sinuosity:**	1.6
Date:	August 30, 2018	**Environment:**	Rural; Valley confinement

Reach Location:

Channel Setting

Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	No
Canopy Cover (%):	76-100%	**Groundwater:**	Potential (floodplain saturation)
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Present; some

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	5.5-8.0 m	**Height:**	0.80 m	**Morphology:**	Undulating Bed
Channel Depth:	1.3-1.5 m	**Materials:**	Silty Clay	**Substrate:**	Silty-clay
Wetted Widths:	0.4-6.0 m	**Erosion:**	Bank scour		
Wetted Depths:	0.2-0.6 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Channel Stability:

RGA Score:	0.5	**Stability:**	In adjustment	**Dominant Process(es):**	Aggradation/ Widening

Photo 1: Low clay channel banks; floodplain access

Photo 2: Meandering channel pattern

Field Observations:

- Meandering planform
- Meander scars / relic features – more dynamic/active planform
  - Floodplain scour
- Floodplain access - greater – lower banks in comparison to Reach B
- Meandering planform – no emergent riffles
- Bank material uniform – clay/silt; varied firm to soft
- Cross-section more open – bench at the base of the banks is less steep
- Occurrence of LWD
- New floodplain formation
- Floodplain saturation – groundwater
- Clay benching at bank toe
- Low width: depth ratio
- Reach characteristics repeated in reaches upstream

Reach: JC-D

Watercourse:	Jones Creek	**Length:**	919 m
Detailed Site:	None	**Grade:**	0.11 %
Sub-area:	N7	**Sinuosity:**	1.6
Date:	August 30, 2018	**Environment:**	Rural; Partially confined in valley

Reach Location:

Channel Setting

Vegetation Community:	Trees; cropped; herbaceous	**Pollution Sources:**	No
Canopy Cover (%):	26-50%	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Present; few

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	5.0-6.0 m	**Height:**	1.00 m	**Morphology:**	Undulating Bed
Channel Depth:	1.0-1.5 m	**Materials:**	Silty Clay	**Substrate:**	Silty-clay
Wetted Widths:	2.1-3.4 m	**Erosion:**	Bank toe scour		
Wetted Depths:	0.2-0.4 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Channel Stability:

RGA Score:	0.41	**Stability:**	Stressed/ Transitional	**Dominant Process(es):**	Aggradation/ Widening

Photo 1: Reduced floodplain access (high channel banks); herbaceous vegetation

Photo 2: Erosion of clay at bank toe

Field Observations:

- Meandering planform
- Narrow riparian zone left bank – herbaceous / cropped land
- Bank heights increased when compared to Reach C – reduced floodplain access/incision
- LWD in channel; willow roots controlling banks
- Soft clay/silt shelves on bed
- Planform & profile consistent with previous reaches
- Clay benching at bank toe
- Low width: depth ratio
- Reach characteristics repeated in reaches upstream

Reach: JC-E

Watercourse:	Jones Creek	**Length:**	281 m
Detailed Site:	None	**Grade:**	0.08 %
Sub-area:	N7	**Sinuosity:**	1.6
Date:	August 30, 2018	**Environment:**	Rural; Valley confinement

Reach Location:

Channel Setting

Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	No
Canopy Cover (%):	76-100%	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Present; some

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	9.0 m	**Materials:**	Silty Clay	**Morphology:**	Undulating Bed
Channel Depth:	1.5 m	**Erosion:**	Bank scour	**Substrate:**	Silty-clay
Wetted Widths:	3.5 m				
Wetted Depths:	0.3 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Channel Stability:

RGA Score:	0.5	**Stability:**	In adjustment	**Dominant Process(es):**	Aggradation/ Widening

Water Quality:

Temperature:	19.8°C	**pH:**	8.19	**TDS:**	364 ppm	**Conductivity:**	728 µm	**DO:**	9.02 mg/L
	19.9 °C		8.25		410 ppm		818 µm		9.08 mg/L

Photo 1: Meandering planform; valley setting; floodplain access

Photo 2: Bank erosion; exposed tree roots and fallen trees

Field Observations:

- Meander scars / relic features – more dynamic/active planform
    - Floodplain scour
- Floodplain access - greater – lower banks in comparison to Reach B
- Meandering planform – no emergent riffles
- Bank material uniform – clay/silt; varied firm to soft
- Cross-section more open – bench at the base of the banks is less steep
- Occurrence of LWD
- Similar to reach JC-C – dynamic / active channel; floodplain scour
- Shelves on both banks (toe) – slippery clay/silt
- Branch accumulation on bed
- Potential terracing in floodplain
- Fallen trees but not in channel

Reach: JC-F

Watercourse:	Jones Creek	**Length:**	4240 m
Detailed Site:	Jones Creek Site 2	**Grade:**	0.15 %
Sub-area:	N7	**Sinuosity:**	2.1
Date:	August 30, 2018	**Environment:**	Rural; Partially confined in valley

Reach Location:

Channel Setting

Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	No
Canopy Cover (%):	76-100%	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Present; some

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	1.9-9.0 m	**Height:**	1.18 m	**Morphology:**	Undulating Bed
Channel Depth:	0.2-1.6 m	**Materials:**	Silty Clay	**Substrate:**	Silty-clay
Wetted Widths:	2.2-3.5 m	**Erosion:**	Bank scour		
Wetted Depths:	0.2-0.6 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Channel Stability:

RGA Score:	0.31	**Stability:**	Stressed/ Transitional	**Dominant Process(es):**	Aggradation

Reach: JC-F

Water Quality:

Temperature:	19.6°C	**pH:**	8.19	**TDS:**	359 ppm	**Conductivity:**	719 µm	**DO:**	8.64 mg/L
	19.5°C		8.19		354 ppm		706 µm		8.83 mg/L
	19.3°C		8.31		355 ppm		711 µm		9.3 mg/L
	19.5°C		8.34		354 ppm		706 µm		10.22 mg/L
	19.0°C		8.34		359 ppm		720 µm		9.55 mg/L

Photo 1: Bank scour at inside of meander bend

Photo 2: Valley wall contact

Field Observations:

- Narrow riparian zone left bank – herbaceous / cropped land
- Bank heights increased – reduced floodplain access/incision
- LWD in channel; willow roots controlling banks
- Soft clay/silt shelves on bed
- Similar to reach JC-D
- Steep banks
- LWD in channel
- Bed – sculpted into riffle pool
- Exposed tree roots
- Planform change – gradual – incision
- Till is firm where there is little soft silt coverage (holes and cavities in hard till/clay)
- Some areas of valley wall contact

Reach: JC-G

Watercourse:	Jones Creek	**Length:**	208 m
Detailed Site:	None	**Grade:**	0.57 %
Sub-area:	N5	**Sinuosity:**	1
Date:	August 31, 2018	**Environment:**	Rural; Unconfined

Reach Location:

Channel Setting			
Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	No
Canopy Cover (%):	51-75%	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Present; some

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	5.0 m	**Materials:**	Silty Clay	**Morphology:**	Undulating Bed
Channel Depth:	0.2-1.6 m	**Erosion:**	None	**Substrate:**	Silty-clay
Wetted Widths:	0.4 m				
Wetted Depths:	0.2-1.4 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Channel Stability:

RGA Score:	0.34	**Stability:**	Stressed/ Transitional	**Dominant Process(es):**	Aggradation

Water Quality:

Temperature:	15°C	**pH:**	8.38	**TDS:**	376ppm	**Conductivity:**	756µm	**DO:**	8.56mg/L

Photo 1: Road crossing culvert at downstream limit

Photo 2: Straight channel planform

Field Observations:

- Straight channel – modified / straightened for road crossing?
- Park Rd culvert – LWD – potential blockage/obstruction
- Dense vegetation
- More pronounced riffle-pool-like features

Reach: JC-H

Watercourse:	**Jones Creek**	**Length:**	**1515 m**
Detailed Site:	None	**Grade:**	0.05 %
Sub-area:	N5	**Sinuosity:**	2
Date:	August 31, 2018	**Environment:**	Rural; Valley confinement

Reach Location:

Channel Setting			
Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	No
Canopy Cover (%):	76-100%	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Present; abundant

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	4.5-9.0 m	**Height:**	1.22 m	**Morphology:**	Undulating Bed
Channel Depth:	0.8-1.4 m	**Materials:**	Silty Clay	**Substrate:**	Silty-clay
Wetted Widths:	2.6-3.2 m	**Erosion:**	Bank scour		
Wetted Depths:	0.1-0.8 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials.

Channel Stability:

RGA Score:	0.39	**Stability:**	Stressed/ Transitional	**Dominant Process(es):**	Aggradation/ Widening

Water Quality:

Temperature:	15°C	**pH:**	8.29	**TDS:**	371ppm	**Conductivity:**	738µm	**DO:**	9.42mg/L

Photo 1: Large woody debris

Photo 2: Riffle-like feature, clay-based

Field Observations:

- Banks straight; slight grittiness to substrate (minor sand?)
- Meander cut-offs (similar to Reach C) – floodplain scour
- Clay-based riffle-like features
- Floodplain vegetation more mature than Reach G
- Inside bend scour
- Incised
- Sharp meander bends
- Terracing
- LWD and trees across channel
- Consistent clay bed; low grade – low energy
- Consistent low W: D ratio
- Tree roots exposed at top of banks

Reach: JC-I

Watercourse:	Jones Creek	**Length:**	229 m
Detailed Site:	Jones Creek Site 1	**Grade:**	0.60 %
Sub-area:	N5	**Sinuosity:**	1.3
Date:	August 31, 2018	**Environment:**	Rural; Unconfined

Reach Location:

Channel Setting

Vegetation Community:	Trees; herbaceous; grasses	**Pollution Sources:**	No
Canopy Cover (%):	26-50%	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Present; some

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	3.5 m	**Height:**	0.85 m	**Morphology:**	Undulating Bed
Channel Depth:	1.1 m	**Materials:**	Silty Clay	**Substrate:**	Silty-clay
Wetted Widths:	2.5 m	**Erosion:**	None		
Wetted Depths:	0.2-0.8 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials; tributary outlet at upstream limit of reach.

Channel Stability:

RGA Score:	0.31	**Stability:**	Stressed/ Transitional	**Dominant Process(es):**	Degradation/ Widening

Water Quality:

Temperature:	16.8°C	**pH:**	8.32	**TDS:**	369ppm	**Conductivity:**	742µm	**DO:**	11.42mg/L

Photo 1: Floodplain access and riparian vegetation

Photo 2: Fine gravel deposits in bed near confluence with tributary

Field Observations:

- Riparian herbaceous – overhanging / dense
- Low bank heights
- Mostly soft clay/silt – some areas of firm bed
- Some coarser material deposited in bar (pea gravel, sand)
    - Sand bag found in channel – sand source?
- Elevated tributary (Trib K) outlet

Reach: JC-Tributary K

Watercourse:	Jones Creek Tributary	**Length:**	N/A
Detailed Site:	Tributary K Site	**Grade:**	1.09 %
Sub-area:	N5	**Sinuosity:**	N/A
Date:	August 31, 2018	**Environment:**	Rural; Unconfined

Reach Location:

Channel Setting			
Vegetation Community:	Herbaceous; cropped	**Pollution Sources:**	No
Canopy Cover (%):	0-25%	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Absent

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	2.4-6.0 m	**Height:**	0.85 m	**Morphology:**	Riffle-pool
Channel Depth:	1.0-2.0 m	**Materials:**	Clay, till	**Substrate (riffle):**	Till; fine gravel
Wetted Widths:	1.0-1.1 m	**Erosion:**	Bank scour	**Substrate (pool):**	Till; silty-clay
Wetted Depths:	0.1-0.8 m				

Modifications and Controls on Channel Form and Function:

Till boundary materials; potential agricultural tile drainage; areas of root-controlled banks

Channel Stability:

RGA Score:	0.24	**Stability:**	Stressed/ Transition	**Dominant Process(es):**	Degradation/ Widening

Water Quality:

Temperature:	19.3°C	**pH:**	8.2	**TDS:**	1301ppm	**Conductivity:**	2592µm	**DO:**	12.32mg/L
	18.8 °C		7.83		1384ppm		277µm		9.21mg/L

Photo 1: Till/clay banks; bank scour and cantilever failures of bank materials; root exposure

Photo 2: Channel setting from top of bank; agricultural (soy) crops surround the channel

Field Observations:

- Downstream – relative floodplain access; banks dominated by willow roots
- Incised (approx. 2m deep) – steep gradient
  - Near vertical banks
  - Carved into clay (red/brown) and till? (grey/white) layers
    - Sculpted material; fallen blocks/pieces in channel
    - Clay/till ledges exposed under water – sharp edge
- Substrate
  - Coarse: sand (cs, ms) and pea gravel
  - Silt – soft
- Round clay pipe (0.35) into channel – tile drain outlet?
- Scoured / slumped banks
  - Cantilever failures – blocks in channel (some still vegetated)
- Trash line 1.4m above bed
- numerous minnows
- becomes shallower in upstream direction
- upstream limit at 1.5-2m CSP SW culvert – perched approx. 0.7m
  - concrete block wingwall on left bank – scour on right bank
  - concrete splash pad with scour pool
- narrow riparian corridor
  - soy; herbaceous (at top of banks)

Reach: JC-J

Watercourse:	Jones Creek	**Length:**	222 m
Detailed Site:	None	**Grade:**	0.16 %
Sub-area:	N5	**Sinuosity:**	1.7
Date:	September 6, 2018	**Environment:**	Rural; Unconfined

Reach Location:

Channel Setting			
Vegetation Community:	Herbaceous	**Pollution Sources:**	No
Canopy Cover (%):	0-25%	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Present; some

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	3.5 m	**Height:**	0.29 m	**Morphology:**	Undulating Bed
Channel Depth:	1.1 m	**Materials:**	Silty Clay	**Substrate:**	Silty-clay
Wetted Widths:	2.5 m	**Erosion:**	None		
Wetted Depths:	0.2-0.8 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Channel Stability:

RGA Score:	0.29	**Stability:**	Stressed/ Transitional	**Dominant Process(es):**	Aggradation

Water Quality:

Temperature:	17.1°C	**pH:**	8.31	**TDS:**	332ppm	**Conductivity:**	661µm	**DO:**	11.5mg/L

Photo 1: Herbaceous riparian vegetation overhanging straight, narrow channel

Photo 2: Large woody debris; logs across channel

Field Observations:

- Similar to Reach I
- Less incision
- Lower banks
  - o Alternating steeper slope on banks
- Clay/silt bed – no coarser substrate (source from Trib K?)
  - o Bed firmness increases along inside bends
  - o Straight sections – softer material
- LWD – logs across channel

Reach: JC-K

Watercourse:	Jones Creek	**Length:**	619 m
Detailed Site:	None	**Grade:**	0.16 %
Sub-area:	N5	**Sinuosity:**	2.6
Date:	September 6, 2018	**Environment:**	Rural; Confined valley

Reach Location:

Channel Setting

Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	No
Canopy Cover (%):	76-100%	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Present; some

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	8.0 m	**Height:**	0.70 m	**Morphology:**	Undulating Bed
Channel Depth:	0.9 m	**Materials:**	Silty Clay	**Substrate:**	Silty-clay
Wetted Widths:	5.2 m	**Erosion:**	Bank scour, valley wall contact		
Wetted Depths:	0.2-0.5 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Channel Stability:

RGA Score:	0.36	**Stability:**	Stressed/ Transitional	**Dominant Process(es):**	Degradation

Photo 1: Herbaceous riparian vegetation overhanging straight, narrow channel

Photo 2: Bank toe scour at valley wall contact

Field Observations:

- Similar to Reach I
- Less incision
- Lower banks
  - Alternating steeper slope on banks
- Clay/silt bed – no coarser substrate (source from Trib K?)
  - Bed firmness increases along inside bends
  - Straight sections – softer material
- LWD – logs across channel
- Moderate to steep valley walls

Reach: JC-L

Watercourse:	Jones Creek	**Length:**	339 m
Detailed Site:	None	**Grade:**	0.24 %
Sub-area:	N5	**Sinuosity:**	1.9
Date:	September 6, 2018	**Environment:**	Rural; Confined valley

Reach Location:

Channel Setting

Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	No
Canopy Cover (%):	76-100%	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Present; some

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	6.0-8.0 m	**Height:**	0.72 m	**Morphology:**	Riffle-pool
Channel Depth:	0.8-1.1 m	**Materials:**	Silty Clay	**Substrate (riffle):**	Gravel, cobble
Wetted Widths:	2.4-5.2 m	**Erosion:**	Bank scour	**Substrate (pool):**	Silty-clay
Wetted Depths:	0.2-0.5 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials; some willow root control on banks

Channel Stability:

RGA Score:	0.26	**Stability:**	Stressed/ Transitional	**Dominant Process(es):**	Degradation

Water Quality:

Temperature:	19.6°C	**pH:**	8.35	**TDS:**	361ppm	**Conductivity:**	722µm	**DO:**	8.06mg/L

Photo 1: Gravel-cobble riffle feature

Photo 2: Relic channel meander

Field Observations:

- Gravel/cobble substrate introduced – riffle features
    - Developed riffle-pool sequence
    - Some riffles submerged
    - Greater depth variability
- Similar setting to Reach K – just different bed morphology
- Willow root control
- Higher W:D
- Valley wall contact through reach
- Undercut tree roots
- Incised channel setting
- Terraced banks
- Floodplain access – relic channel meanders
- Moderate to steep valley walls

Reach: JC-M

Watercourse:	Jones Creek	**Length:**	450 m
Detailed Site:	None	**Grade:**	0.07 %
Sub-area:	N5	**Sinuosity:**	2.6
Date:	September 6, 2018	**Environment:**	Rural; Unconfined setting

Reach Location:

Channel Setting

Vegetation Community:	Herbaceous; trees (few)	**Pollution Sources:**	No
Canopy Cover (%):	0-25 %	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	Yes
Fish Habitat:	Yes	**Woody Debris:**	Present; abundant

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	6.0-8.0 m	**Materials:**	Silty Clay	**Morphology:**	Riffle-pool
Channel Depth:	0.8-1.1 m	**Erosion:**	Bank scour	**Substrate:**	Silty-clay
Wetted Widths:	2.4-5.2 m				
Wetted Depths:	0.2-0.5 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Channel Stability:

RGA Score:	0.23	**Stability:**	Stressed/ Transitional	**Dominant Process(es):**	Degradation/ Widening

Photo 1: Herbaceous riparian vegetation; relatively high banks and reduced floodplain access

Photo 2: Exposed roots and tree within channel shows evidence of widening / migration

Field Observations:

- Loss of riffle formations / less coarse substrate
- Similar to Reaches J & B
  - Herbaceous riparian
  - Higher banks
  - Uniform / symmetrical cross-section
  - Undercut banks (top of bank)
- Softer bed substrate (particularly in straight sections)
  - Local areas of gravel/cobble substrate – not developed riffles as Reach L
- Aquatic vegetation
- Shelf/bench along bank toe
- Floodplain access increase – valley opens
- Symmetrical channel cross-section

Reach: JC-N

Watercourse:	Jones Creek	**Length:**	443 m
Detailed Site:	None	**Grade:**	0.19 %
Sub-area:	N5	**Sinuosity:**	1.9
Date:	September 6, 2018	**Environment:**	Rural; Confined valley setting

Reach Location:

Channel Setting

Vegetation Community:	Trees	**Pollution Sources:**	No
Canopy Cover (%):	76-100 %	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Present; some

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	6.0 m	**Materials:**	Silty Clay	**Morphology:**	Riffle-pool
Channel Depth:	0.5 m	**Erosion:**	Bank scour, valley wall contact	**Substrate (riffle):**	Gravel, cobble
Wetted Widths:	4.0 m			**Substrate (pool):**	Silty-clay
Wetted Depths:	0.2-0.8 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Channel Stability:

RGA Score:	0.25	**Stability:**	Stressed/ Transitional	**Dominant Process(es):**	Degradation/ Widening

Photo 1: Bank scour, exposed roots, leaning trees

Photo 2: Gravel-cobble riffle feature

Field Observations:

- Similar to JC-L
- Increase channel width
- Coarser substrate
- Valley setting
- Outside meander bend scour
- Willow root control
- Cross-sections generally symmetrical
- Bank height varies
- chute channel at meander bend
- riffle features developed in straight section prior to reach break with Trib N
- two terraces (below valley wall)

Reach: JC-O

Watercourse:	Jones Creek	**Length:**	442 m
Detailed Site:	None	**Grade:**	0.17 %
Sub-area:	N5	**Sinuosity:**	1.38
Date:	September 6, 2018	**Environment:**	Rural; Confined valley setting

Reach Location:

Channel Setting			
Vegetation Community:	Trees	**Pollution Sources:**	No
Canopy Cover (%):	76-100 %	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Present; some

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	5.0-9.0 m	**Height:**	0.43 m	**Morphology:**	Riffle-pool
Channel Depth:	0.6-0.9 m	**Materials:**	Silty Clay	**Substrate (riffle):**	Gravel, cobble
Wetted Widths:	2.6-5.2 m	**Erosion:**	Bank scour	**Substrate (pool):**	Silty-clay
Wetted Depths:	0.1-0.8 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Channel Stability:

RGA Score:	0.32	**Stability:**	Stressed/ Transitional	**Dominant Process(es):**	Degradation/ Planform

Water Quality:

Temperature:	18.8°C	**pH:**	8.3	**TDS:**	380ppm	**Conductivity:**	760µm	**DO:**	9.39mg/L

Photo 1: Valley wall contact and bank scour at outside meander bend

Photo 2: Knickpoint located at meander cutoff; exposed till directly downstream of knickpoint

Field Observations:

- Dynamic planform – floodplain activity
  - Relic channels
  - Chutes
- Riffle pool sequence – well developed
- Exposed tree roots
- Terracing
- Till exposed in riffle features – downcutting into native
- Saturated floodplain – groundwater?
- Tile drain pipe along bed

Watercourse:	Jones Creek	**Length:**	192 m
Detailed Site:	None	**Grade:**	0.36 %
Sub-area:	N5	**Sinuosity:**	1.1
Date:	September 6, 2018	**Environment:**	Rural; Unconfined setting

Reach Location:

Channel Setting

Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	No
Canopy Cover (%):	76-100 %	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Present; some

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	4.3 m	**Height:**	0.48 m	**Morphology:**	Undulating Bed
Channel Depth:	0.6 m	**Materials:**	Silty Clay	**Substrate (riffle):**	Silty-clay; sand
Wetted Widths:	3.2 m	**Erosion:**	Bank scour	**Substrate (pool):**	Silty-clay
Wetted Depths:	0.3 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Channel Stability:

RGA Score:	0.25	**Stability:**	Stable/ In regime	**Dominant Process(es):**	Degradation/ Widening

Photo 1: Bank scour, exposed roots, leaning trees

Photo 2: Road crossing culvert at upstream limit of reach

Field Observations:

- Influence from road crossing
  - Straight planform – modified due to road crossing
  - Sand – road influence?
  - Herbaceous riparian vegetation
- Valley opens – unconfined segment of channel
- Abundance of LWD
- Softer sediment
- US limit at road culvert
- Incised

Reach: JC-Q

Watercourse:	Jones Creek	**Length:**	163 m
Detailed Site:	None	**Grade:**	0.12 %
Sub-area:	N4	**Sinuosity:**	1.1
Date:	September 6, 2018	**Environment:**	Rural; Unconfined setting

Reach Location:

Channel Setting

Vegetation Community:	Manicured lawn	**Pollution Sources:**	No
Canopy Cover (%):	0-25 %	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	No
Fish Habitat:	Yes	**Woody Debris:**	Absent

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	3.4-3.5 m	**Height:**	0.70 m	**Morphology:**	Undulating Bed
Channel Depth:	0.4-1.1 m	**Materials:**	Silty Clay	**Substrate:**	Silty-clay
Wetted Widths:	1.0-2.2 m	**Erosion:**	Bank scour		
Wetted Depths:	0.3-0.7 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials; manicured lawn to water edge – anthropogenic maintenance

Channel Stability:

RGA Score:	N/A	**Stability:**	N/A	**Dominant Process(es):**	N/A

Water Quality:

Temperature:	18.4°C	**pH:**	8.34	**TDS:**	369ppm	**Conductivity:**	741µm	**DO**	9.54mg/L

Photo 1: Road crossing culvert at downstream limit of reach.

Photo 2: Downstream view of channel setting; manicured lawn and pedestrian bridge across channel

Field Observations:

- Originates at road crossing
- Manicured lawn as riparian vegetation– lawn maintained down creek banks
- Homeowner recalls channel narrower in past
- Gravel protection along culvert at crossing new
- Erosion protection present through channel length
- Soft substrate on bed
- Online pond on property – connected through 0.25 CSP
- Conditions assumed to continue through neighbouring yards

Reach: JC-S

Watercourse:	Jones Creek	**Length:**	601 m
Detailed Site:	None	**Grade:**	0.64 %
Sub-area:	N4	**Sinuosity:**	1.9
Date:	September 6, 2018	**Environment:**	Rural; Unconfined setting

Reach Location:

Channel Setting

Vegetation Community:	Herbaceous; grasses	**Pollution Sources:**	Agricultural runoff
Canopy Cover (%):	0-25 %	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	Present
Fish Habitat:	Yes	**Woody Debris:**	Absent

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	3.2-4 m	**Height:**	0.30 m	**Morphology:**	Riffle-pool
Channel Depth:	0.5-0.6 m	**Materials:**	Silty Clay	**Substrate (riffle):**	Silty-clay; till
Wetted Widths:	1.8-2.4 m	**Erosion:**	Bank scour	**Substrate (pool):**	Silty-clay
Wetted Depths:	0.1-0.3 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials; till boundary layer

Channel Stability:

RGA Score:	0.25	**Stability:**	Stressed/ Transitional	**Dominant Process(es):**	Degradation/ Widening

Water Quality:

Temperature:	18.1°C	**pH:**	8.28	**TDS:**	343ppm	**Conductivity:**	685µm	**DO**	9.13mg/L

Photo 1: Unconfined channel setting; herbaceous riparian vegetation which overhangs into channel

Photo 2: Bank scour on outside meander bend; exposed roots and vegetated bank blocks in channel

Field Observations:

- Golden rod left bank; cropped right bank (small riparian buffer of herbaceous in some places)
  - Overhanging veg
- Soft deposits of silty-clay; firm bed along thalweg
- Sculpted till in some locations
- Aquatic vegetation
- Bare banks on bends
- Cross-section asymmetrical
- Relatively high banks – limited floodplain access; unconfined setting
- Root control – willow
- Riffle-pool bed morphology poorly defined

Reach: JC-T

Watercourse: Jones Creek
Detailed Site: None
Sub-area: N4
Date: September 6, 2018

Length: 239 m
Grade: 0.09 %
Sinuosity: N/A
Environment: Rural; Unconfined setting

Reach Location:

Channel Setting			
Vegetation Community:	Herbaceous; cropped	**Pollution Sources:**	Agricultural runoff
Canopy Cover (%):	0-25 %	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	Present
Fish Habitat:	Yes	**Woody Debris:**	Absent

Channel Geometry Overview		Banks		Bed	
Channel Width:	5.2-6.1 m	**Height:**	0.50 m	**Morphology:**	Undulating Bed
Channel Depth:	1.3-1.7 m	**Materials:**	Silty Clay	**Substrate:**	Silty-clay; till
Wetted Widths:	1.3-1.8 m	**Erosion:**	Bank scour		
Wetted Depths:	0.2-0.5 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials; till boundary layer

Channel Stability:

RGA Score:	0.19	**Stability:**	Stable/ In regime	**Dominant Process(es):**	Degradation

Water Quality:

Temperature:	17.6°C	**pH:**	8.36	**TDS:**	326ppm	**Conductivity:**	652µm	**DO**	9.15mg/L

Photo 1: Unconfined channel setting; herbaceous riparian vegetation which overhangs into channel

Photo 2: Bank toe erosion into firm till layer

Field Observations:

- Seems more narrow/less flow than Tributary P
- Willow root control – banks
- Cross-section has hard till on bed
- Better floodplain access one side
- Aquatic vegetation continues
- Overhanging vegetation more dense than Reach S

Reach: JC-U

Watercourse:	Jones Creek	**Length:**	727 m
Detailed Site:	None	**Grade:**	0.26 %
Sub-area:	Outside Sub-areas	**Sinuosity:**	N/A
Date:	September 7, 2018	**Environment:**	Rural; Unconfined setting

Reach Location:

Channel Setting

Vegetation Community:	Herbaceous	**Pollution Sources:**	None
Canopy Cover (%):	0-25 %	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	Present
Fish Habitat:	Yes	**Woody Debris:**	Absent

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	2.6 m	**Materials:**	Silty Clay	**Morphology:**	Undulating Bed
Channel Depth:	0.7 m	**Erosion:**	Bank scour	**Substrate (riffle):**	Silty-clay; gravel
Wetted Widths:	1.6 m			**Substrate (pool):**	Silty-clay
Wetted Depths:	0.2-0.3 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials; bank hardening through private property

Channel Stability:

RGA Score:	N/A	**Stability:**	N/A	**Dominant Process(es):**	N/A

Water Quality:

Temperature:	16.1°C	**pH:**	8.13	**TDS:**	323ppm	**Conductivity:**	643µm	**DO**	9.44mg/L

Photo 1: Unconfined channel setting; herbaceous riparian vegetation

Photo 2: Constructed knickpoint in channel (0.5 m)

Field Observations:

- Herbaceous riparian
- Clay and gravel
    - Orange clay exposed
    - Soft sediment accumulation (RB)
- Hardened through private property
    - Constructed knickpoint – 0.5 m drop

Karek Tributaries

Watercourse:	Fairchild Tributary (Karek Property)	**Length:**	82 m
Reach:	KN-A (NOTE: reclassified as HDF)	**Grade:**	0.91 %
Sub-area:	N9	**Sinuosity:**	N/A
Date:	August 15, 2018	**Environment:**	Rural, Unconfined setting

Reach Location:

Channel Setting			
Vegetation Community:	Trees; grasses	**Pollution Sources:**	Agricultural inputs
Canopy Cover (%):	26-50 %	**Groundwater:**	None observed
Flow Regime:	Intermittent	**Aquatic Vegetation:**	None
Fish Habitat:	No	**Woody Debris:**	Absent

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	2.4	**Materials:**	Silty Clay	**Morphology:**	Poorly-defined
Channel Depth:	0.2	**Erosion:**	Bank scour	**Substrate:**	Silty-clay

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials; root controls; cattle access

Channel Stability:

RGA Score:	N/A	**Stability:**	N/A	**Dominant Process(es):**	N/A

Water Quality:

Temperature:	20.8°C	**pH:**	8.03	**TDS:**	336ppm	**Conductivity:**	N/A	**DO:**	N/A

Photo 1: Channel cross-section; scour on outside bank

Photo 2: Downstream view to confluence with Fairchild Creek

Field Observations:

- Outlet into F.C. was elevated above water level – suggests that there is not enough energy for the watercourse to lower its base level
- Watercourse was dry during observation
- Bed materials was consistently clay along entire reach
- Channel cut through tree roots – erosion along banks
- Local pooling of water

Watercourse:	Fairchild Tributary (Karek Property)	**Length:**	920 m
Reach:	KN-B (NOTE: reclassified as HDF)	**Gradient:**	0.91 %
Sub-area:	N9	**Sinuosity:**	N/A
Date:	August 15, 2018	**Environment:**	Rural, Unconfined setting

Reach Location:

Channel Setting			
Vegetation Community:	Meadow; grasses	**Pollution Sources:**	Agricultural inputs; cattle
Canopy Cover (%):	0-25 %	**Groundwater:**	None observed
Flow Regime:	Intermittent	**Aquatic Vegetation:**	None
Fish Habitat:	No	**Woody Debris:**	Absent

Channel Geometry Overview		Banks		Bed	
Channel Width:	N/A	**Materials:**	Silty Clay	**Morphology:**	Poorly-defined
Channel Depth:	N/A	**Erosion:**	None	**Substrate:**	Silty-clay

Modifications and Controls on Channel Form and Function:

Cattle access – much of the feature has been trampled/grazed

Channel Stability:

RGA Score:	N/A	**Stability:**	N/A	**Dominant Process(es):**	N/A

Photo 1: Wide meadow setting

Photo 2: Culvert under trail (ld Karek Road)

Field Observations:

- Channel was poorly (not) defined until short distance upstream of outlet into Fairchild
- Wide bottom feature; meadow-like setting
- Grazing land for cattle

Watercourse:	Fairchild Tributary (Karek Property)	**Length:**	447 m
Reach:	KS-A (NOTE: reclassified as HDF)	**Grade:**	0.97 %
Sub-area:	N9	**Sinuosity:**	N/A
Date:	August 15, 2018	**Environment:**	Rural, Unconfined setting

Reach Location:

Channel Setting			
Vegetation Community:	Herbaceous; shrubs	**Pollution Sources:**	Agricultural inputs
Canopy Cover (%):	51-75 %	**Groundwater:**	Potential (pooled water)
Flow Regime:	Intermittent	**Aquatic Vegetation:**	Absent
Fish Habitat:	No	**Woody Debris:**	Absent

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	1.0-1.2 m	**Materials:**	Silty Clay	**Morphology:**	Poorly-defined (knickpoints)
Channel Depth:	0.3-0.5 m	**Erosion:**	Bank undercutting	**Substrate:**	Silty-clay
Wetted Widths:	0.1-0.8 m				
Wetted Depths:	0.1-0.6 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials; root control (knickpoints)

Channel Stability:

RGA Score:	N/A	**Stability:**	N/A	**Dominant Process(es):**	N/A

Water Quality:

Temperature:	18.7°C	**pH:**	7.82	**TDS:**	523ppm	**Conductivity:**	1035µm	**DO:**	N/A

Photo 1: Channel setting; local pooling in downstream sections of reach

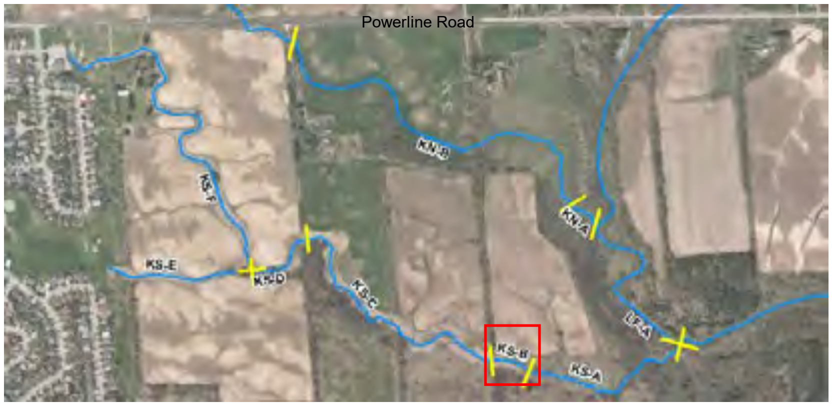
Photo 2: Knickpoint associated with root control

Field Observations:

- Outlet into F.C. was elevated above water level – suggests that there is not enough energy for the watercourse to lower its baselevel
- Watercourse was not flowing during observation, and many sections were dry; local pooling.
- Meandering planform
- Bed materials:
  - consistently clay along entire reach; no differentiation between riffles and pools.
- Bed morphology
  - Generally not well developed; pooling of water occurred in depressions (pools) typically situated along outside bends
  - Pronounced knickpoint (0.84m) at head of incised setting with valley widening
  - Lower knickpoints observed; some coincided with root controls.
- Channel appeared to be incised
- Overall channel gradient appeared to be moderately steep
- Local pooling of water
- Erosion was observed along the outside of meander bends
- Undercutting of banks was observed (0.20 m)
- Riparian vegetation was dense, consisting of shrub and grasses.

Watercourse:	Fairchild Tributary (Karek Property)	**Length:**	97 m
Reach:	KS-B (NOTE: reclassified as HDF)	**Grade:**	0.97 %
Sub-area:	N9	**Sinuosity:**	N/A
Date:	August 15, 2018	**Environment:**	Rural, Unconfined setting

Reach Location:



Channel Setting			
Vegetation Community:	Herbaceous; shrubs	**Pollution Sources:**	Agricultural inputs
Canopy Cover (%):	51-75 %	**Groundwater:**	None observed
Flow Regime:	Intermittent	**Aquatic Vegetation:**	Absent
Fish Habitat:	No	**Woody Debris:**	Absent

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	0.3 m	**Materials:**	Silty Clay	**Morphology:**	Poorly-defined (knickpoints)
Channel Depth:	N/A	**Erosion:**	Bank undercutting	**Substrate:**	Silty-clay
Wetted Widths:	0.3 m				
Wetted Depths:	0.05 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials – clay knickpoints

Channel Stability:

RGA Score:	N/A	**Stability:**	N/A	**Dominant Process(es):**	N/A

Photo 1: Undercut channel bank

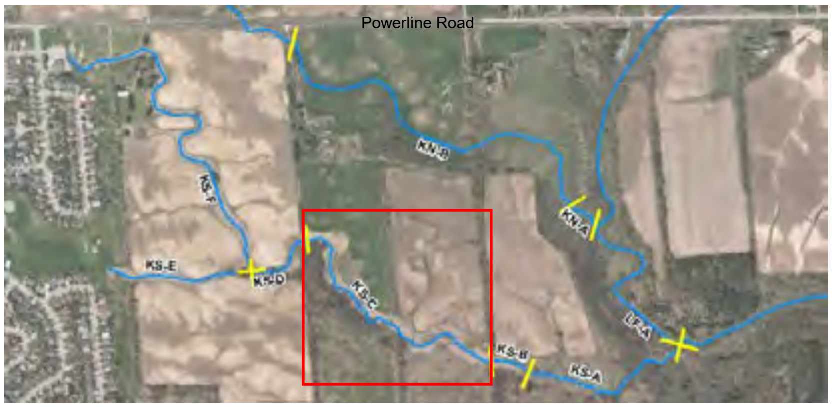
Photo 2: Large knickpoint at downstream limit of reach

Field Observations:

- Short section of meandering planform
- Undercutting 0.15-0.37 m
- Profile
  - o Knickpoints observed (e.g,. 0.25 m high), in clay
- Bed Materials
  - o Consistently clayey
- Floodplain Connectivity
  - o Trash lines in overbank area
  - o Better connected to floodplain than downstream Reach A

Watercourse:	Fairchild Tributary (Karek Property)	**Length:**	633 m
Reach:	KS-C (NOTE: reclassified as HDF)	**Grade:**	0.97 %
Sub-area:	N9	**Sinuosity:**	N/A
Date:	August 15, 2018	**Environment:**	Rural, Unconfined setting

Reach Location:



Channel Setting

Vegetation Community:	Herbaceous; shrubs	**Pollution Sources:**	Agricultural inputs
Canopy Cover (%):	0-25 %	**Groundwater:**	Potential (saturated area)
Flow Regime:	Intermittent	**Aquatic Vegetation:**	Present; wetland
Fish Habitat:	No	**Woody Debris:**	Absent

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	0.6 m	**Height:**	0.18 m	**Morphology:**	Poorly-defined (wetland)
Channel Depth:	0.2 m	**Materials:**	Silty Clay	**Substrate:**	Silty-clay
		Erosion:	None		

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials; vegetation growing throughout feature

Channel Stability:

RGA Score:	N/A	**Stability:**	N/A	**Dominant Process(es):**	N/A

Photo 1: Cattails present in feature

Photo 2: Feature setting – wide wetland-like feature

Field Observations:

- Begins short distance upstream of knickpoint – where channel is poorly (not) defined
- Setting consists of wetland type vegetation including cattail and grasses (growing in feature), with moist soil, no standing water observed.

Watercourse:	Fairchild Tributary (Karek Property)	**Length:**	172 m
Reach:	KS-D (NOTE: reclassified as HDF)	**Grade:**	0.97 %
Sub-area:	N9	**Sinuosity:**	N/A
Date:	August 15, 2018	**Environment:**	Rural, Unconfined setting

Reach Location:

Channel Setting			
Vegetation Community:	Herbaceous; shrubs; trees	**Pollution Sources:**	Agricultural inputs
Canopy Cover (%):	0-25 %	**Groundwater:**	None observed
Flow Regime:	Intermittent	**Aquatic Vegetation:**	None
Fish Habitat:	No	**Woody Debris:**	Present; Few

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	0.7-2.3 m	**Materials:**	Silty Clay	**Morphology:**	Poorly-defined
Channel Depth:	0.2-0.7 m	**Erosion:**	None	**Substrate:**	Silty-clay

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Channel Stability:

RGA Score:	N/A	**Stability:**	N/A	**Dominant Process(es):**	N/A

Photo 1: Channel definition at downstream limit of reach

Photo 2: Woody debris in channel

Field Observations:

- Short section of channel definition up to confluence of north and south branches
- Confluence at upstream limit of reach
- Channel dry at time of assessment

Watercourse:	Fairchild Tributary (Karek Property)	**Length:**	341 m
Reach:	KS-E (NOTE: reclassified as HDF)	**Grade:**	0.97 %
Sub-area:	N9	**Sinuosity:**	N/A
Date:	August 15, 2018	**Environment:**	Rural, Unconfined setting

Reach Location:

Channel Setting			
Vegetation Community:	Herbaceous; wetland	**Pollution Sources:**	Agricultural inputs
Canopy Cover (%):	0-25 %	**Groundwater:**	None observed
Flow Regime:	Intermittent	**Aquatic Vegetation:**	Present
Fish Habitat:	No	**Woody Debris:**	Present; some

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	0.7-0.9 m	**Heights:**	0.17-0.35 m	**Morphology:**	Poorly-defined
Channel Depth:	0.2-0.4 m	**Materials:**	Silty Clay	**Substrate:**	Silty-clay
		Erosion:	None		

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials; root controls; wetland vegetation throughout feature in upstream section (E2)

Channel Stability:

RGA Score:	N/A	**Stability:**	N/A	**Dominant Process(es):**	N/A

Photo 1: Tractor crossing culvert (0.5 m dia.)

Photo 2: Cattails in sub-reach E2

Field Observations:

E1 (downstream sub-reach)

- Well defined dry watercourse; no local pooling of water
- Root controlled bed and banks
- Riparian vegetation consisted of shrubs and herbaceous plants
- Bed morphology generally not well defined
- Tractor crossing with culvert (diameter 0.5 m)
- Desiccation cracking of bed materials

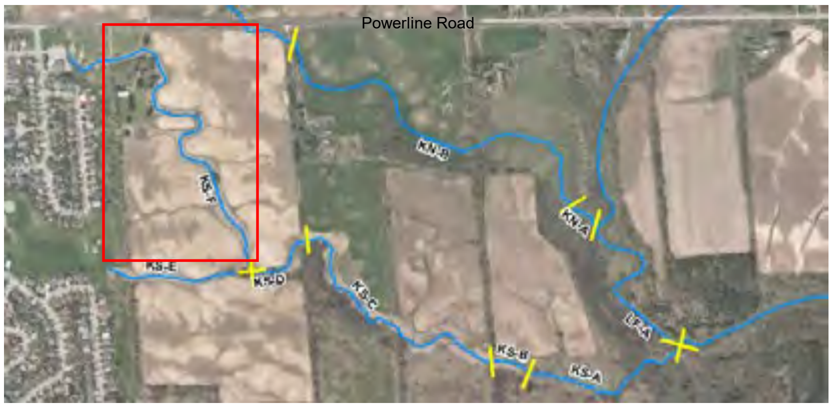
E2 (upstream sub-reach)

- Short distance upstream of tractor crossing, the channel became poorly (not defined)
- Watercourse coincides with wetland vegetation types (cattail, grasses)
- Soil within wetland was moist

Reach: KS-F

Watercourse:	Fairchild Tributary (Karek Property)	**Length:**	927 m
Reach:	KS-F (NOTE: reclassified as HDF)	**Grade:**	0.97 %
Sub-area:	N9	**Sinuosity:**	N/A
Date:	August 15, 2018	**Environment:**	Rural, Unconfined setting

Reach Location:



Channel Setting			
Vegetation Community:	Herbaceous; wetland	**Pollution Sources:**	Agricultural inputs
Canopy Cover (%):	0-25 %	**Groundwater:**	Potential (pooling of water)
Flow Regime:	Intermittent	**Aquatic Vegetation:**	Present (wetland)
Fish Habitat:	No	**Woody Debris:**	Absent

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	2.67 m	**Materials:**	Silty Clay	**Morphology:**	Poorly-defined
Channel Depth:	0.48 m	**Erosion:**	None	**Substrate:**	Silty-clay

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials; root controls; wetland vegetation

Channel Stability:

RGA Score:	N/A	**Stability:**	N/A	**Dominant Process(es):**	N/A

Photo 1: Feature setting

Photo 2: Tractor crossing

Field Observations:

- wetland feature which originates from culvert at property line (Powerline Road)
- dry to saturated soils
- rolling agriculture surrounds feature – drainage to feature
- Phragmites
- Tractor crossing through feature

Silver Creek

Reach: SC-A

Watercourse:	Silver Creek	**Length:**	281 m
Detailed Site:	None	**Grade:**	0.14 %
Sub-area:	N9	**Sinuosity:**	1.1
Date:	September 7, 2018	**Environment:**	Rural, Unconfined setting

Reach Location:

Channel Setting

Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	None
Canopy Cover (%):	76-100 %	**Groundwater:**	Potential (stratigraphic staining)
Flow Regime:	Perennial	**Aquatic Vegetation:**	Absent
Fish Habitat:	Yes	**Woody Debris:**	Absent

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	5.2-6.1 m	**Height:**	1.35 m	**Morphology:**	Riffle-pool
Channel Depth:	1.3-1.7	**Materials:**	Till; clay; silty-clay soil	**Substrate (riffle):**	Till; sand; gravel
Wetted Widths:	2.2-2.3 m	**Erosion:**	Bank scour	**Substrate (pool):**	Clay; till
Wetted Depths:	0.05-0.8 m				

Modifications and Controls on Channel Form and Function:

Clay-till boundary materials

Channel Stability:

RGA Score:	0.41	**Stability:**	In adjustment	**Dominant Process(es):**	Degradation/ Widening

Water Quality:

Temperature:	18°C	**pH:**	7.9	**TDS:**	538ppm	**Conductivity:**	1080µm	**DO**	8.11mg/L

Photo 1: Sculpted till along the channel bed; multiple channels developed; high scoured banks

Photo 2: Bank stratigraphy: till (basal unit), clay (middle unit), silty-clay / soil (top unit)

Field Observations:

- Geologic stratigraphy – 3 units
  - Bottom – sculpted till, white, hard, swirls of varied materials – allows for blocks to erode and fall?
    - Sculpted till layer creates a cascade-like bed profile
  - Middle – clay, brownish, thick, relatively firm
    - Some areas where layer has slipped/slumped down bank?
  - Top – soil, dark, mixed with some silt/clay
  - Stratigraphy similar to Trib K and some reaches of Jones Creek (Reach N?)
  - Groundwater seeps through breaks in stratigraphy
    - Also seeps through the sculpting of till?
- Ravine setting
  - Steep valley walls – incised
  - Bank blocks in channel
  - Ravine bottom – wide with till shelf and meandering watercourse through ravine
- Deposition of sand/gravel
  - Occurring in carved clay ridges
- Roots exposed at top of bank – white roots (recent erosion?)
  - Cantilever top bank failures – bank masses with vegetation in channel on bed
    - Sands deposited along vegetated bank blocks
  - Trash line to top of bank - ~1.5 m high

Reach: SC-B

Watercourse:	Silver Creek	**Length:**	440 m
Detailed Site:	None	**Grade:**	0.58 %
Sub-area:	N9	**Sinuosity:**	1.2
Date:	September 7, 2018	**Environment:**	Rural, Unconfined setting

Reach Location:

Channel Setting

Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	None
Canopy Cover (%):	76-100 %	**Groundwater:**	Potential (stratigraphic staining)
Flow Regime:	Perennial	**Aquatic Vegetation:**	Absent
Fish Habitat:	Yes	**Woody Debris:**	Absent

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	5.2 m	**Height:**	1.55 m	**Morphology:**	Riffle-pool
Channel Depth:	1.4	**Materials:**	Till; clay; silty-clay soil	**Substrate (riffle):**	Till; sand; gravel
Wetted Widths:	2.2 m	**Erosion:**	Bank scour	**Substrate (pool):**	Clay; till
Wetted Depths:	0.3-0.8 m				

Modifications and Controls on Channel Form and Function:

Clay-till boundary materials

Channel Stability:

RGA Score:	0.47	**Stability:**	In adjustment	**Dominant Process(es):**	Widening/ Degradation

Water Quality:

Temperature:	18.6°C	**pH:**	8.15	**TDS:**	637ppm	**Conductivity:**	1280µm	**DO**	8.36mg/L

Photo 1: Scoured banks and cantilever bank failure blocks in channel

Photo 2: Boundary materials - sculpted till stratigraphy

Field Observations:

- Channel widens – occupation of active channel increases
- Slope of channel decreases in comparison to Reach A
- Sinuosity decreases
- Stratigraphy continues as in Reach A
    - Sculpted till broken into platy pieces
- Gravel/sand deposits
- Undercutting at top of bank – fallen trees; exposed roots
- Introduction of cobble substrate
- Urban debris in channel
- Cantilever bank failures – vegetated, in channel
- More erodible clay (second) layer?
    - Undercutting between till and clay
- Deposition of materials occurring throughout reach
    - Bike, grocery carts and other debris buried deep in channel banks
- Tributary B – cobble/boulder lined outfall channel

Reach: SC-C

Watercourse:	Silver Creek	**Length:**	79 m
Detailed Site:	None	**Grade:**	0.08 %
Sub-area:	Outside Sub-areas	**Sinuosity:**	1.0
Date:	September 7, 2018	**Environment:**	Residential, Unconfined setting

Reach Location:

Channel Setting			
Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	None
Canopy Cover (%):	76-100 %	**Groundwater:**	None observed
Flow Regime:	Perennial	**Aquatic Vegetation:**	Absent
Fish Habitat:	Yes	**Woody Debris:**	Absent

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	6.6 m	**Height:**	1.50 m	**Morphology:**	Riffle-pool
Channel Depth:	1.5	**Materials:**	Till; clay; silty-clay soil	**Substrate (riffle):**	Till; sand; gravel
Wetted Widths:	4.1 m	**Erosion:**	Bank scour	**Substrate (pool):**	Clay; till
Wetted Depths:	0.2 m				

Modifications and Controls on Channel Form and Function:

Clay-till boundary materials; potential inputs from residential area (sand and fine gravel substrate)

Channel Stability:

RGA Score:	0.28	**Stability:**	Stressed/ Transition	**Dominant Process(es):**	Degradation/ Widening

Photo 1: Channel setting – bank scour; sand and fine gravel substrate

Photo 2: Cut-face on sand-gravel bar form

Field Observations:

- Begins at bridge crossing
- Dune-like sand deposits along bed
    - Mostly sand and pea gravel – loss of cobble substrate from Reach B
- Further decrease in channel slope
- Less erosion throughout reach – more vegetated banks
- Water taking from private property
- Overhanging vegetation & leaning trees
- Lawn waste dumping
- Less urban debris than downstream
- Crayfish
- Cut bank

Reach: SC-D

Watercourse:	Silver Creek	**Length:**	163 m
Detailed Site:	None	**Grade:**	0.25 %
Sub-area:	N9	**Sinuosity:**	1.01
Date:	September 7, 2018	**Environment:**	Rural, Unconfined setting

Reach Location:

Channel Setting			
Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	None
Canopy Cover (%):	76-100 %	**Groundwater:**	Potential (stratigraphic staining)
Flow Regime:	Perennial	**Aquatic Vegetation:**	Absent
Fish Habitat:	Yes	**Woody Debris:**	Absent

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	5.2 m	**Materials:**	Till; clay; silty-clay soil	**Morphology:**	Riffle-pool
Channel Depth:	1.4			**Substrate (riffle):**	Till; sand; gravel
Wetted Widths:	3.2 m	**Erosion:**	Bank scour	**Substrate (pool):**	Clay; till
Wetted Depths:	0.2 m				

Modifications and Controls on Channel Form and Function:

Clay-till boundary materials

Channel Stability:

RGA Score:	0.47	**Stability:**	In adjustment	**Dominant Process(es):**	Widening/ Degradation

Water Quality:

Temperature:	19.2°C	**pH:**	8.13	**TDS:**	761	**Conductivity:**	1518	**DO:**	8.75

Photo 1: Exposed native till with sand and fine gravel deposits; till eroding at bank toe into blocks / pieces

Photo 2: Influences from residential land use: drainage, water taking, urban debris

Field Observations:

- Like reach SC-B
- Sculpted till
- Bank erosion – bank blocks in channel (vegetated); undercut top of bank – root exposure
- Leaning trees; overhanging vegetation
- Less fine deposition than SC-C
- Riffle formations as a result of till carving
- Urban debris

Fairchild Creek

Reach: LF-A

Watercourse:	Fairchild Creek	**Length:**	1159 m
Detailed Site:	None	**Grade:**	N/A
Sub-area:	N9	**Sinuosity:**	N/A
Date:	August 15, 2018	**Environment:**	Unconfined setting

Reach Location:

Channel Setting

Vegetation Community:	Trees; herbaceous	**Pollution Sources:**	None
Canopy Cover (%):	51-75 %	**Groundwater:**	Absent
Flow Regime:	Perennial	**Aquatic Vegetation:**	Absent
Fish Habitat:	Yes	**Woody Debris:**	Present; some (channel bed)

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	10.0-16.0 m	**Heights:**	Values	**Morphology:**	Plane-bed
Channel Depth:	1.1-5.0 m	**Materials:**	Silty Clay	**Substrate (riffle):**	Silty-clay
Wetted Widths:	6.3-11.0 m	**Erosion:**	Bank toe erosion	**Substrate (pool):**	Silty-clay
Wetted Depths:	0.2-1.4 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials; local bank protection works; cattle access

Water Quality:

Temperature:		**pH:**		**TDS:**		**Conductivity:**		**DO**	
	20.8°C		8.07		336ppm		673µm		
	22.9°C		8.01		658ppm		329µm		
	20.7°C		8.01		362ppm		724µm		6.45mg/L

Photo 1: Channel setting in forested area; low gradient channel with high turbidity; floodplain access

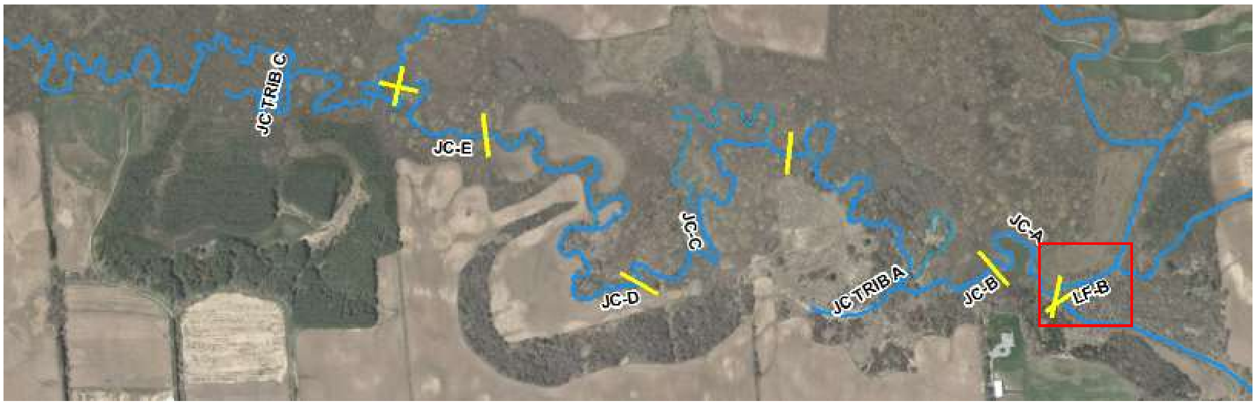
Photo 2: Evidence of cattle access to channel (hoof prints in hydrated substrate at waters edge)

- Erosion
  - Cattle access along steep banks
  - Most banks were steep and erosion was gradual at toe; some of this led to some slope failure (slip)
  - Mechanism of erosion appears to be more wetting/drying (desiccated cracking observed on drying slopes)
  - Lower 30 cm of bank typically exposed/bare
- Floodplain connectivity:
  - The watercourse appeared to be incised
  - Terracing apparent in immediate floodplain – indicative of long term downcutting and some migration.
- Bed materials were consistently clayey along entire reach
  - No bed material differentiation between 'riffle' and 'pool' locations
  - Firm materials tended to coincide with thalweg location
  - A layer of soft, hydrated materials coincided with areas of lower energy
- Local area of bank protection (broken concrete, cinder blocks, gravels) near private property; debris dumping on the slope was also
- Bank materials appeared to be consistently silty clay
  - Benching occurred along the toe of the banks, typically under the water surface, this is typically of clayey boundary materials
- Bed morphology was submerged throughout study area
  - Deeper points tended to coincide with pools (range: 1.04 to > 1.42)
  - Shallower in straighter sections (0.68, 1.28)
- Large woody debris
  - Two LWD jams occurred in channel; where branches became wedged in the cross-section. Given the incised /entrenched condition, there was no overbank area for the branches to become deposited
  - Isolated logs were observed along the banks
  - Local areas of branch accumulation in shallower sections of channel were observed; this also coincided with an accumulation of finer sediment (but no emergent bars were observed)

Reach: LF-B

Watercourse:	Fairchild Creek	**Length:**	128 m
Detailed Site:	None	**Grade:**	N/A
Sub-area:	N8	**Sinuosity:**	N/A
Date:	August 30, 2018	**Environment:**	Unconfined setting

Reach Location:



Channel Setting

Vegetation Community:	Trees; herbaceous; grasses	**Pollution Sources:**	None
Canopy Cover (%):	51-75 %	**Groundwater:**	Absent
Flow Regime:	Perennial	**Aquatic Vegetation:**	Present
Fish Habitat:	Yes	**Woody Debris:**	Present; some (channel bed)

Channel Geometry Overview		**Banks**		**Bed**	
Channel Width:	11.0-14.0 m	**Heights:**	Values	**Morphology:**	Plane-bed
Channel Depth:	2.6-2.8 m	**Materials:**	Silty Clay	**Substrate (riffle):**	Silty-clay
Wetted Widths:	5.0-11.0 m	**Erosion:**	Limited	**Substrate (pool):**	Silty-clay
Wetted Depths:	0.8-1.2 m				

Modifications and Controls on Channel Form and Function:

Silty-clay boundary materials

Water Quality:

Temperature:	21.1°C	**pH:**	8.05	**TDS:**	356ppm	**Conductivity:**	713µm	**DO**	6.3mg/L

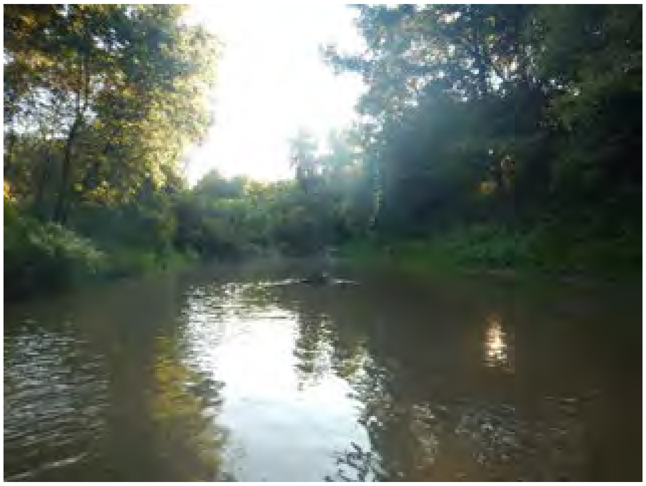


Photo 1: Wider channel cross-section than downstream reach (FC-A); potential influence from woody debris jam

Photo 2: Presence of aquatic vegetation

Field Observations:

- Jones Creek outlet elevated – confluence located on meander bend
- Floodplain connectivity
    - Floodplain access greater on left bank than right bank
        - Greater overall access in comparison to Reach A – defining feature for reach break? Most other characteristics of reach similar to downstream
    - Located in valley – may have slope mass movements occurring
- Bed materials were consistently sticky clay and hydrated soft (silt) layer
    - Shelf of clay/till along the upstream left bank
- Bed morphology was submerged throughout study area
    - Only subtle changes in bed morphology captured with water depth
    - Low gradient system – low energy
- Bank materials consistently silty clay
- Large woody debris
    - Large jam immediately downstream of Jones Creek confluence
    - Branch accumulation on channel bed
- Riparian vegetation of trees and herbaceous
- Water turbid
- Channel wider than downstream (FC-A)

City of Brantford

Urban Boundary Expansion HDF Assessment

November 2018 (Updated December 2019)

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Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	All	December 2019	Update from Rapid to Standard Method of HDF Assessment

Ecosystem Recovery Signatures

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Attachments

Attachment A: Glossary of HDF Feature Types
Attachment B: Summary of feature attributes observed and recorded
Attachment C: Photo log of all HDF
Attachment D: Fish and Terrestrial Habitat Assessment Results

1. Introduction

Headwater Drainage Features (HDF), or "fingertip" tributaries, are the exterior links of the drainage network, meaning that they originate at the source and receive water from no other channels. They include the discontinuous and poorly defined features that become active parts of the drainage network during precipitation events; initiation of a defined channel feature occurs where there is sufficient energy and flow to erode surface materials, resulting in defined channel banks and sorted substrate. Interior links of the drainage network are those channel segments that bring water from various areas of a watershed to a downstream outlet point. HDFs have been referred to as the capillaries of a landscape (Stanfield & Jackson, 2011), and can typically account for 70-80% of the drainage network in terms of both flow and channel length (Meyer et al, 2003; Vought et al., 1995). HDFs represent approximately 63% of the overall drainage density in North Brantford area and 75% in the Tutela Heights area.

An HDF assessment was conducted within the proposed Brantford Urban Boundary expansion area (**Figure 2-1**) to evaluate, classify, and provide management strategies for applicable headwater features as defined in the TRCA and CVC (2014) Guideline Document. The HDF assessment was completed in 2018, following the Rapid Method of assessment. At the request of the City, the assessment was updated in 2019 to include all components of the Standard Method, except for the ELC mapping. This report provides an overview of HDF origin, form, and function and presents results of the updated HDF assessment completed within the Urban Boundary Area, and outside of the Natural Heritage System. Supporting documentation is provided in Attachments to this report.

2. Headwater Drainage Features

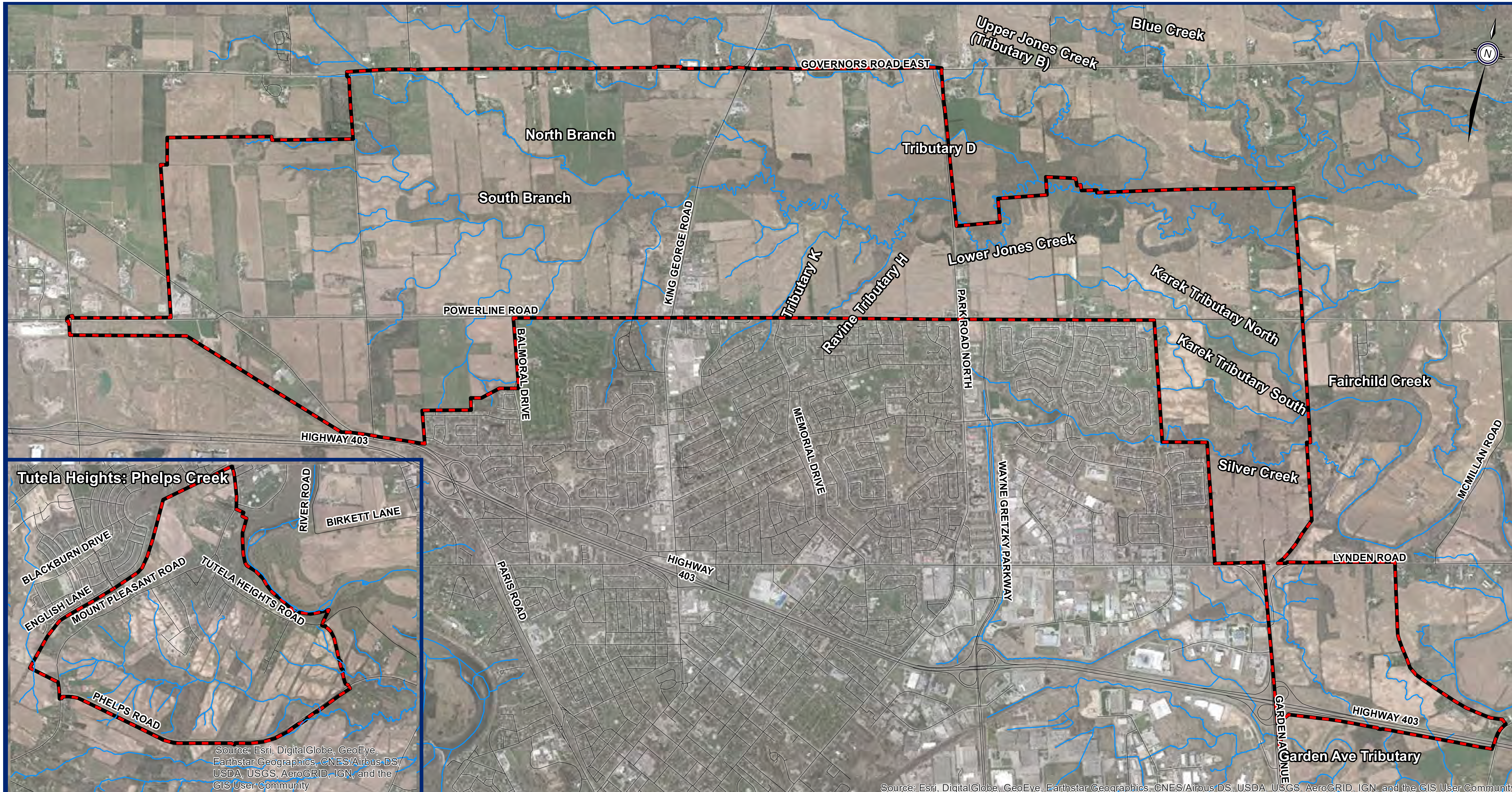
2.1 Feature Form

Where the soil conditions and the intensity of rainfall events enable infiltration of precipitation, then minimal surface flow is generated. Where infiltration potential is limited, or decreases, (i.e., antecedent moisture condition, high intensity of precipitation), then surface runoff is generated, and surface depressions may temporarily store water. Additional runoff links surface depressions and dry swales to enable continual downstream flow conveyance. It follows then, that the active drainage network (i.e., that which conveys flows) will expand and contract through time, in response to fluctuations and magnitude in precipitation patterns and antecedent soil moisture conditions (Gregory and Walling, 1968; EPA, 2011). Thus, during precipitation events the shallow topographic depressions in the landscape may become part of the active drainage network.

CVC and TRCA (2014) define HDFs as "non-permanently flowing drainage features that may not have defined bed or banks; they are first-order and zero-order intermittent and ephemeral channels, swales and connected headwater wetlands." Stream order refers to the Horton-Strahler classification system of surface drainage networks where the fingertip tributaries or HDF are referred to as zero or first-order channels; as tributaries of the same order converge, stream order increases. TRCA (2007) provides the following descriptions of the low order channels:

> **Zero-order**: depression or hollow that lacks distinct stream banks but channels water, sediment, nutrients and other materials during rain and snowmelt.
>
> **First-order**: smallest watercourse exhibiting distinct channel conditions (i.e., defined channel features – bed, banks, substrate, etc.).

Thus, during precipitation events, zero-order channels become an active part of the drainage network.



THE CORPORATION OF THE CITY OF BRANTFORD

Boundary Expansion Lands Master Plan

Study Area

0 2 Kilometers

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Figure 2-1
Headwater Drainage Features
Overview of Study Area

ecosystem recovery inc. PROFESSIONAL ENGINEERS

March, 2019
NAD 1983 UTM Zone 17N

The density of HDFs in a watershed is a function of the surficial geology (Stanfield and Jackson, 2011). Permeability of the surficial materials is a defining factor of headwater drainage density, with greater densities common to less permeable materials which do not allow for infiltration, and therefore, induce headwater headcutting or feature development. Furthermore, the hydrologic response of headwater features is largely a product of the geological setting and land use attributes, rather than precipitation event intensity or duration (Stanfield and Jackson, 2011).

Surficial geology within the assessment area is primarily that of clay deposits (OGS, 2017); this was confirmed during field assessment. The headwater area (west) of the Jones Creek subwatershed drains the Paris-Galt Moraine which has been identified as supplying cold water to the drainage network (MacVeigh, 2016). Corridors of sand deposits are present surrounding major tributaries, including Jones Creek and the Garden Avenue Tributary.

2.2 Role of Headwater Drainage Features in Landscape

Headwater drainage features differ from downstream reaches by their close coupling to hillslope processes and greater temporal and spatial variation (Gomi et al., 2002). Although HDFs may be small, they are crucial components of a drainage network both from the perspective of hydrologic function and biotic habitat (direct and/or indirect).

Variability among the features is demonstrated through feature definition, dimensions, and physical characteristics, as well as processes and responses occurring within headwater features.

Specific roles attributed to headwater features include (Dunne and Leopold, 1978; Schollen et al., 2006; TRCA, 2007; Stanfield and Jackson, 2011; OHI, 2016):

- Hydrograph moderation through flow attenuation and storage;
- Production zone of sediment and flow (Schumm, 1977);
- Excess sediment storage;
- Groundwater recharge potential;
- Contribution of organic energy inputs that sustain aquatic biota and contribute to the productivity of the downstream watercourse (Wallace et al. 1997);
- Nutrient retention and uptake (Alexander et al. 2000, Peterson et al. 2001);
- Strongest association between terrestrial and aquatic environments (Schlosser, 1991);
- Temperature moderation;
- Habitat for terrestrial and aquatic species and biota (Morse et al, 1993); and
- Seasonal contribution to biota habitat (CVC and TRCA, 2014).

As an active component of the drainage network, alterations that impact HDFs accumulate in the downstream direction. The impacts of alterations are typically underestimated, or ignored, due to the small size of headwater features. The function of headwater features within the river continuum, is increasingly recognized and regulators are moving towards replicating headwater channel functions in any proposed landuse changes, to minimize downstream negative effects due to the removal or alteration of upstream headwater features. This is reflected in the CVC and TRCA (2014) Headwater Feature Guidance Document.

2.3 Modifiers of Headwater Drainage Features

Alteration of the surface drainage network commonly occurs when land is used for anthropogenic purposes. This can include direct alteration to drainage features (e.g., crop, cattle) and removal of the feature from the surface drainage network. Removal of HDF from the surface drainage network occurs through urbanization and/or through establishment of a tile drain network in otherwise poorly drained agricultural fields. Since HDFs have not traditionally been a component of most monitoring efforts, there is a knowledge gap within the existing literature regarding the specific functions and vulnerabilities of the headwater features that occur in rural or agricultural settings. Much of the existing literature on HDFs is focussed on permanent flow in high-gradient forested settings (TRCA, 2007).

CVC and TRCA (2014) state that documentation of modifiers is necessary, and “suspected impacts of the modifier and changes expected to occur when the modifier is removed” should be considered when planning any changes to the HDF network. A brief discussion of the effects of agricultural tile drains and urbanization on HDF systems in general, with examples from within the study area, is provided in the following sub-sections of this report.

2.3.1 Agricultural Landuse and Tile Drains

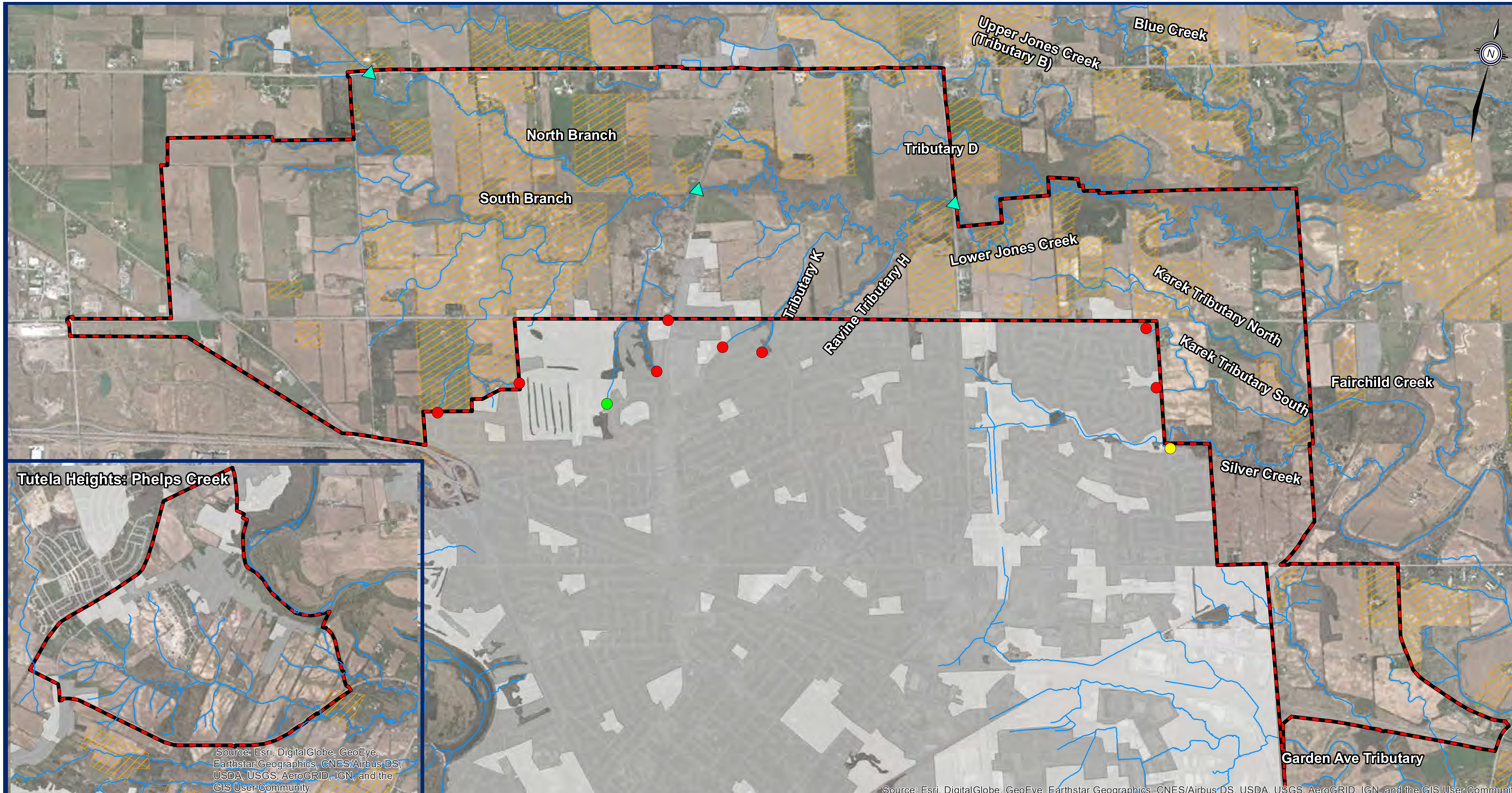
The headwater drainage features within the Brantford Urban Boundary Expansion study area are primarily located within agricultural lands. Potential effects of agriculture on headwaters include inputs of eroded soil, nutrients and pesticides; reduction of the natural riparian canopy; disruption of the hydrologic regime (i.e., agricultural drainage measures such as tile drains); and physical disturbance through ploughing activity, livestock grazing and trampling, and dredging (Fraser and Fleming, 2001; TRCA, 2007).

When cultivation practices plough the entire land surface, interference with channel forming processes occurs; this reduces the potential for a permanent feature to establish and can make proper field classification difficult. Nevertheless, surface drainage channels, albeit poorly defined, do tend to re-form in response to the concentration of surface runoff in topographic low points within the landscape on a seasonal basis. When left undisturbed by landuse activities, then headwater channels have the potential to become permanent features in the landscape. Given the potential for alteration of HDF in agricultural fields, CVC and TRCA (2014) recommend that field assessments of such features be based on at least two site visits.

Much of the agricultural lands in southern Ontario have tile drain systems installed beneath the ground surface. Tile drains reduce the amount of surface runoff by allowing for greater temporary subsurface storage through greater infiltration into the soil profile (Fraser and Fleming, 2001). With the reduction in surface runoff through tile drainage, the amount of sediment produced through hillslope and headwater feature erosion is lessened. The water that is captured and conveyed through the subsurface tile drain system is typically discharged into a ditch or defined watercourse feature; this alters the shape of the flow hydrograph of the receiving watercourse (i.e., more rapid time to peak flow, and increase in flow magnitude) and can exacerbate erosion within that watercourse.

Since the presence of tile drains influence both the hydrologic and sediment regimes of the landscape, they alter the form and function of the HDF and can impact the connecting fluvial system; hence, the impacts of tile drainage are not only local, but extends downstream. The actual impacts of tile drains are dependent on a number of site specific factors, including drain size and depth, soil type and permeability, topography, and water budget conditions (Fraser and Fleming, 2001).

The majority of tile drainage systems present within the study area occur in the clay-based plains (i.e., where infiltration rates are lessened due to the fine, cohesive substrate materials). Tile drainage mapping for the study area was obtained from the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), where fields that contain known tile drainage networks are mapped (i.e., the actual drainage network of tiles is not shown) (**Figure 2-2**). It is evident that the occurrence of tile drainage varies within the study area; while tile drains appear to be absent between 505 and 317 Powerline Road (i.e., immediately west of King George Road to Park Road), tile drains appear to generally occur to the east and west limits of the study area. The tile drains outlet to tributaries, or the main branch of Jones Creek, and/or Fairchild Creek within the study area.



Boundary Expansion Lands
Master Plan

Study Area

Tile Drainage (OMAFRA, 2018)

Community Series (LIO. 2018)

Built-up Area Impervious

Built-up Area Pervious

Stormwater Discharge Point

Controlled

Partially Controlled

Uncontrolled

0 2 Kilometers

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Figure 2-2
Headwater Drainage Features
Tile Drainage, SWM Outlets, Built-up Area

March, 2019
NAD 1983 UTM Zone 17N

2.3.2 Urban Landuse and Drainage Network Alteration

The establishment of urban land use within the landscape is associated with various impacts to watercourses and other drainage features. Historically, changes to the drainage network occur as small HDFs are removed from the landscape and replaced with an extensive system of stormwater and drainage infrastructure. The increase in impervious surfaces in urban environments alters the flow regime within a catchment, increasing both the frequency of flow events and volume and peak flow rates of those flows into the receiving watercourses.

In addition to the change in hydrologic characteristics that occur due to the stormwater drainage network, an increase in sediment loading may also occur, both through overland runoff (e.g., winter road maintenance sand) and in-stream erosion.

2.3.3 Stormwater Management

The change in hydrologic characteristics within a watercourse that are associated with urbanization are commonly referred to as urban hydromodification. Review of the scientific literature clearly documents that an increase in drainage basin imperviousness alters the frequency and magnitude of flows, in addition to flow volume and the shape of the storm hydrograph. Bledsoe (2002) found that the greatest increase in erosion potential from urbanization was associated with minor flow events or sub-bankfull flows. Booth (1991) suggested that the threshold for channel stability occurs when the impervious cover within a watershed is 10%. Further research has demonstrated that a notable decrease in quality of aquatic habitat occurs when watersheds are 10 – 15 % impervious (Booth and Reinhelt, 1993; and Shaver et al., 1995). Beyond this threshold, aquatic habitat quality in streams was typically found to be poor.

GIS analysis of the Jones Creek watershed suggests that ~ 5.7% of the watershed has impervious cover. This percentage for individual tributary watersheds is higher. Perhaps more important than impervious cover is the ‘effective impervious’ cover or ‘directly connected’ area; this refers to the % impervious cover that is connected to the stormwater drainage system that discharges into the Jones Creek drainage network. Further work is needed to determine the effective impervious cover for each of the watercourses in the North Brantford and Tutela Heights areas.

Within the study area, stormwater runoff is discharged into tributaries of Jones Creek and Fairchild Creek; several of these are low order (headwater) watercourses. **Figure 2-2** shows the location of the ten (10) stormwater pipe outlets and indicates whether the discharge from these pipes is controlled (1), partially controlled (1) or uncontrolled (8).

2.3.4 Headwater Drainage Features in the North Brantford and Tutela Heights Subwatersheds

A total of 30 km of HDFs were identified and assessed through the field program. This length of headwater features represents approximately 70% of the channel length within the Jones Creek and Fairchild Creek Tributary watersheds within the Brantford BEA; however, as some properties were not accessible through the study area, this percentage is considered to be below the actual value. Based on mapping analyses, when all potential HDFs within the area are considered (i.e., including those in properties for which permission to enter was not gained), the percentage of channel represented by HDFs fall into the anticipated range of 70-80% (Meyer et al, 2003; Vought et al., 1995) for both the North Brantford and Tutela Heights areas

An assessment of drainage density, stream order and bifurcation ratio for the study area, including the HDFs, is provided in the Settlement Area Boundary Expansion - Geomorphic Assessment report prepared by ERI (2019) for the City of Brantford. Results presented in that report indicate that, within the Settlement Area boundary expansion lands, there are approximately 48 km of HDFs; approximately 36 km in the North Brantford area, and 12 km in the Tutela Heights area. HDF represent approximately 63% of the overall drainage density in North Brantford area and 75% in the Tutela Heights area. These percentages fit within the range identified by Meyer et al. (2003).

3. Assessment Methodology

The headwater drainage feature (HDF) assessment used in this study followed the process outlined in the CVC and TRCA (2014) *Evaluation, Classification, and Management of HDFs Guidelines* document. That document recognizes that “all HDFs contribute, to some degree, to the overall health of a watershed, and that their individual contribution to watershed health varies”. The guidance document is intended to enable a consistent method of evaluating the contribution of each HDF with respect to their sediment, food and flow transport to downstream reaches, and the use of the HDF features by biota. The evaluation is used to inform the feature classifications that form the basis for management recommendations. An overview of the evaluation and classification processes is provided in this report section.

3.1 Part 1: Evaluation

3.1.1 Study Design and Data Gathering

The HDFs within the study area were identified through desktop analyses of existing watercourse mapping (obtained from GRCA), and aerial photography. The mapping was updated, following field verification, to more accurately reflect the surface drainage network that including zero- and first-order features. The study area focused on features outside of the Natural Heritage System.

The identified HDFs were discretized into segments during field investigations if a change in hydrologic and/or riparian conditions was observed. Identification of feature form is required to support the hydrology classification of the HDF (see **Section 3.2.1)**

3.1.2 Scoping and Sampling Effort

CVC and TRCA (2014) advocate a tiered approach to evaluating HDFs that balances information needs with the likelihood that alterations to HDF conditions could result in cumulative impacts to local and watershed health. The sampling effort to assess the HDF features in a study area are intended to be commensurate with reach sensitivity and consider the potential impacts of HDF alteration. The CVC and TRCA (2014) document outlines several sampling methods for HDF assessment. The ‘Rapid Method’ was considered appropriate to support the Subwatershed level characterization of the Urban Boundary Expansion Area in 2018. Subsequently, at the request of the City, the HDF features were assessed using the ‘Standard Method’ of the evaluation process; this was considered relevant to confirm management strategy to better inform urban planning. As part of the ‘Standard Method’ the mandatory data requirements including flow and riparian condition assessments, were supplemented by fish and fish habitat, and terrestrial assessments. The additional data requirements were collected for HDFs located outside of the Natural Heritage System (NHS), as HDFs located within the NHS will not be exposed to direct alteration. Assessment of the HDF features in the context of the Ecological Land Classification (ELC) was not completed through the Standard Method; updates to the results in this report will need to be undertaken once ELC assessments have been completed.

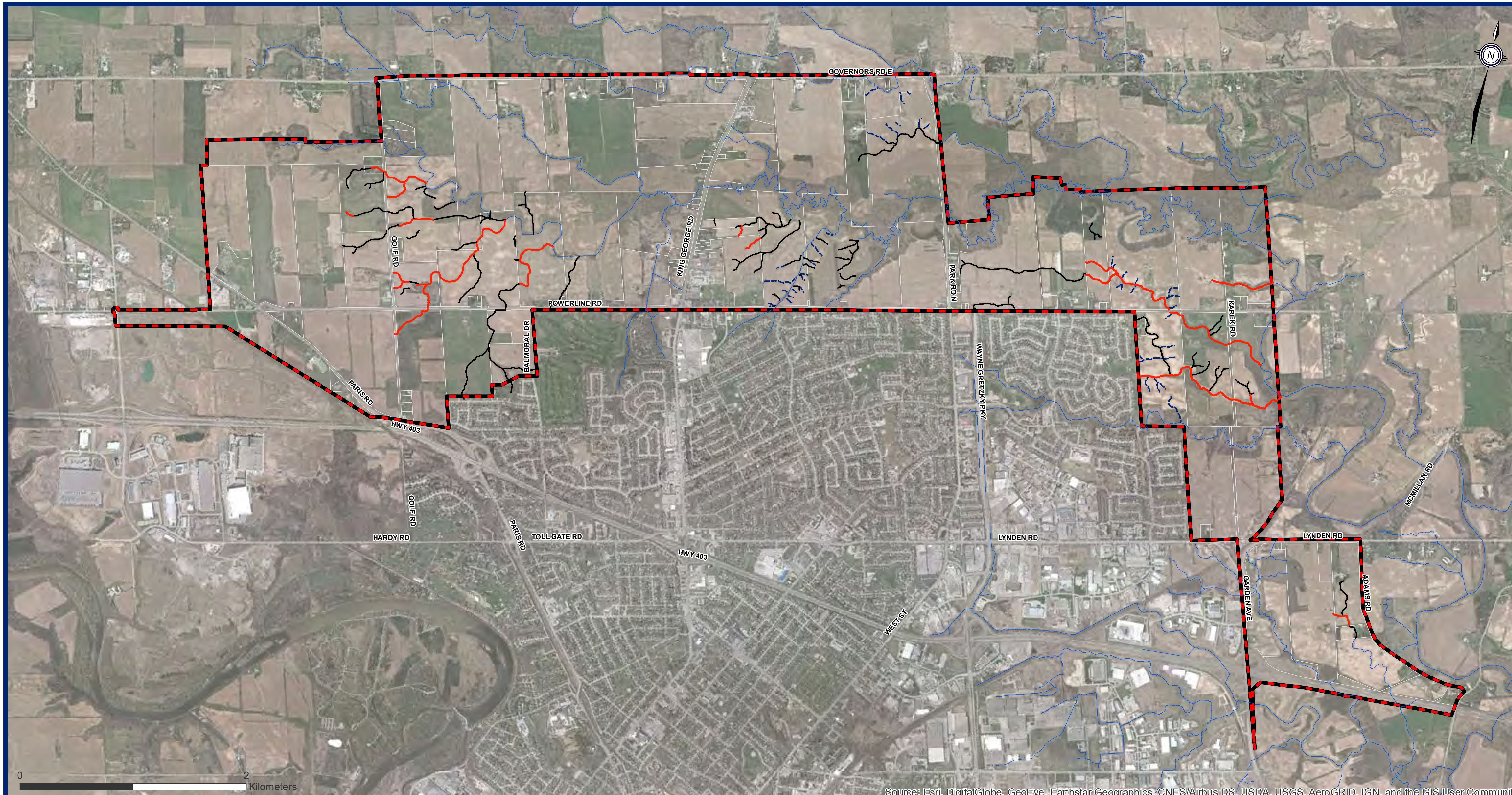
3.1.3 Timing of Assessments

The timing of the field assessments followed the Ontario Stream Assessment Protocol (OSAP S4. M10; 2017). The timed sampling events were undertaken for the study area, and the requirements or objectives of the field sample are summarized in **Table 3-1**. Three field sample events were completed over two (2) field seasons in 2018 and 2019 to examine the hydrologic condition of each identified HDF as per OSAP S4. M10 (2017) requirements (**Table 3-1**). Photos and documentation of feature conditions were collected, and georeferenced in the field, using digital data collection software (Epicollect 5).

Results included within this report reflect feature conditions from the 2019 season HDF assessment. For results from the 2018 season, refer to the March 2019 report. **Figure 2-1** highlights the features that were updated based on the 2019 conditions.

Table 3-1. HDF Sampling Events

Sample Event	2018 Dates	2019 Dates	Requirements (OSAP S4. M10, 2017)
1	April 23, 24, 27	April 23, 24, 30	Assessment following an extended warm period that enables frost to leave the ground; surface flows from recent rain or melt conditions are sufficient to generate bankfull flows; vegetation has yet to establish in riparian areas. Typically, this occurs in late winter and spring; weather patterns in 2018 extended these conditions into late April; this was confirmed by GRCA.
2	June 4 and 11	May 21 and 22	Preferably prior to leaf out, with at least three days of no precipitation. Note: weather conditions in early spring delayed leaf out condition into late May – early June.
3	August 13	September 5 and 6	Following at least three days without a significant (i.e., flow generating) precipitation event.



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Evaluation and/or Classification Updates

- 2018
- 2019 Updates
- Study Area
- Property Parcel
- Rill Erosion
- Watercourse

Figure 3-1
Headwater Drainage Features
2019 Updates

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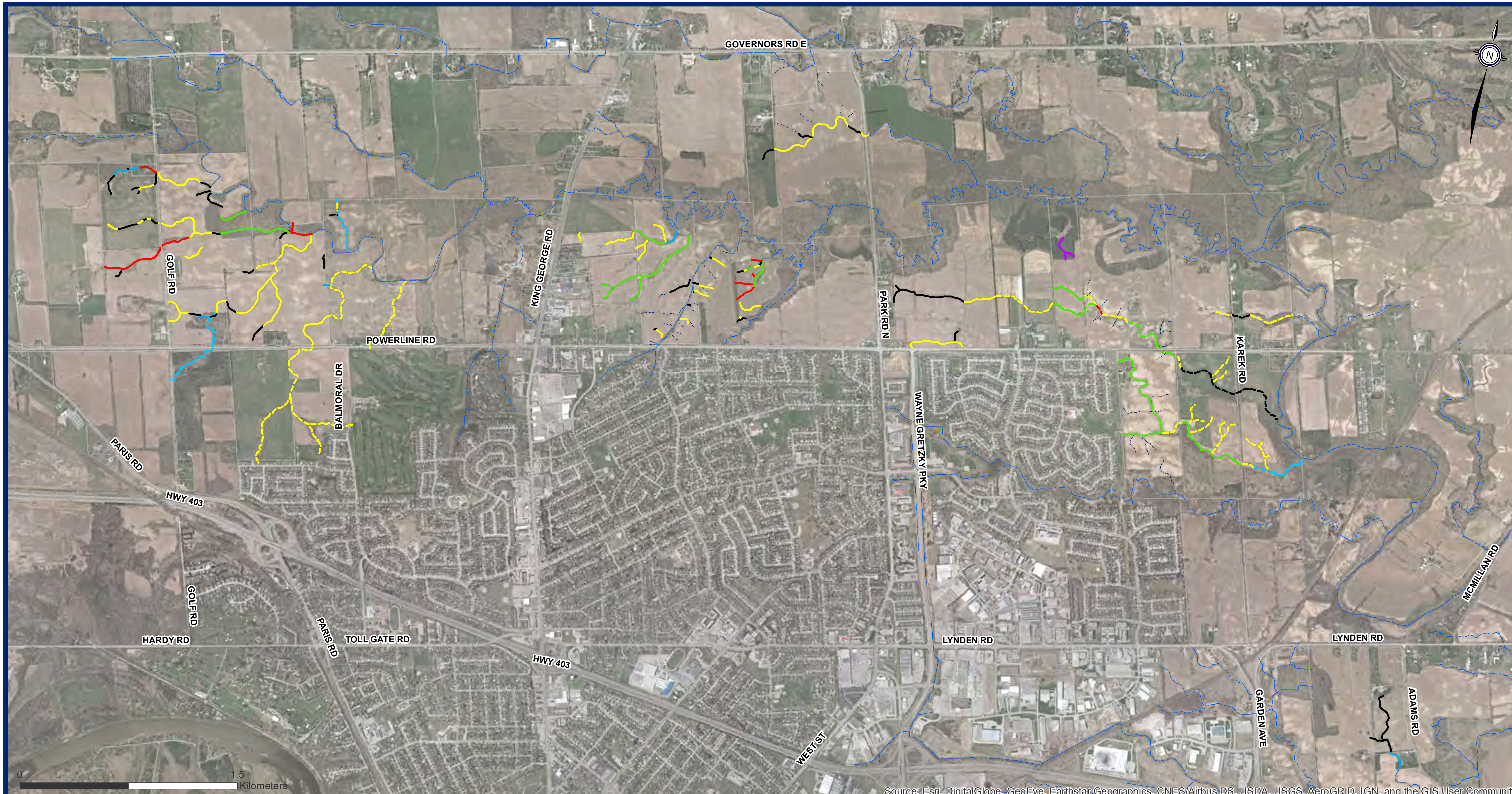
3.1.4 Feature Identification

The HDFs within the study area were identified through desktop analyses of existing watercourse mapping (obtained from GRCA), and aerial photography. A total of 26 km of HDFs were assessed during the investigation; however, 4.4 km of the features were identified as rills, which under the CVC and TRCA (2014) Guideline, do not require management recommendations. Therefore, the mapping was updated following field verification, to more accurately reflect the surface drainage network that includes zero- and first-order features (**Figure 3-2** and **Figure 3-3**). The assessment was intended to focus primarily on those features situated outside of the Natural Heritage System (NHS). Photos and documentation of feature conditions were collected, and georeferenced in the field, using digital data collection software (Epicollect 5).

Each of the field identified/verified HDFs was classified according to feature type, which supports the hydrologic classification (see **Section 3.2.1**). Feature types identified in the study area included the following categories:

- Defined natural channel;
- Modified or constrained;
- Multi-thread;
- No defined feature;
- Tiled;
- Wetland;
- Gullies;
- Rills;
- Swale; and
- Roadside ditch.

Definition and description of each feature type is provided in **Attachment A**; the definition is illustrated with a photograph and includes examples of occurrence within the study area. **Figure 3-2** and **Figure 3-3** demonstrate the occurrence of each feature type within the study areas. The assessment included observation of flow conditions, riparian vegetation, channel connectivity and measurement of feature width and depth (where feasible) based on the OSAP S.4 M.10 (2017). All feature attributes observed and recorded are provided in **Attachment B**. A photo log of the features is provided in **Attachment C**.



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Feature Type

- Defined Natural Channel
- Gully
- Modified or Constrained
- No Defined Feature
- Swale
- Wetland

Feature Type*

- Defined Natural Channel
- Modified or Constrained
- No Defined Feature
- Swale
- Wetland
- Rill Erosion

- Watercourse
- Property Parcel

* Site access for these watercourses occurred after April 2018 and thus the full three season Headwater Drainage Feature Assessment was incomplete. Further assessment is required to confirm appropriate management strategy for these features.

Figure 3-1
Headwater Drainage Features
Feature Type - Northern BEA

November, 2018
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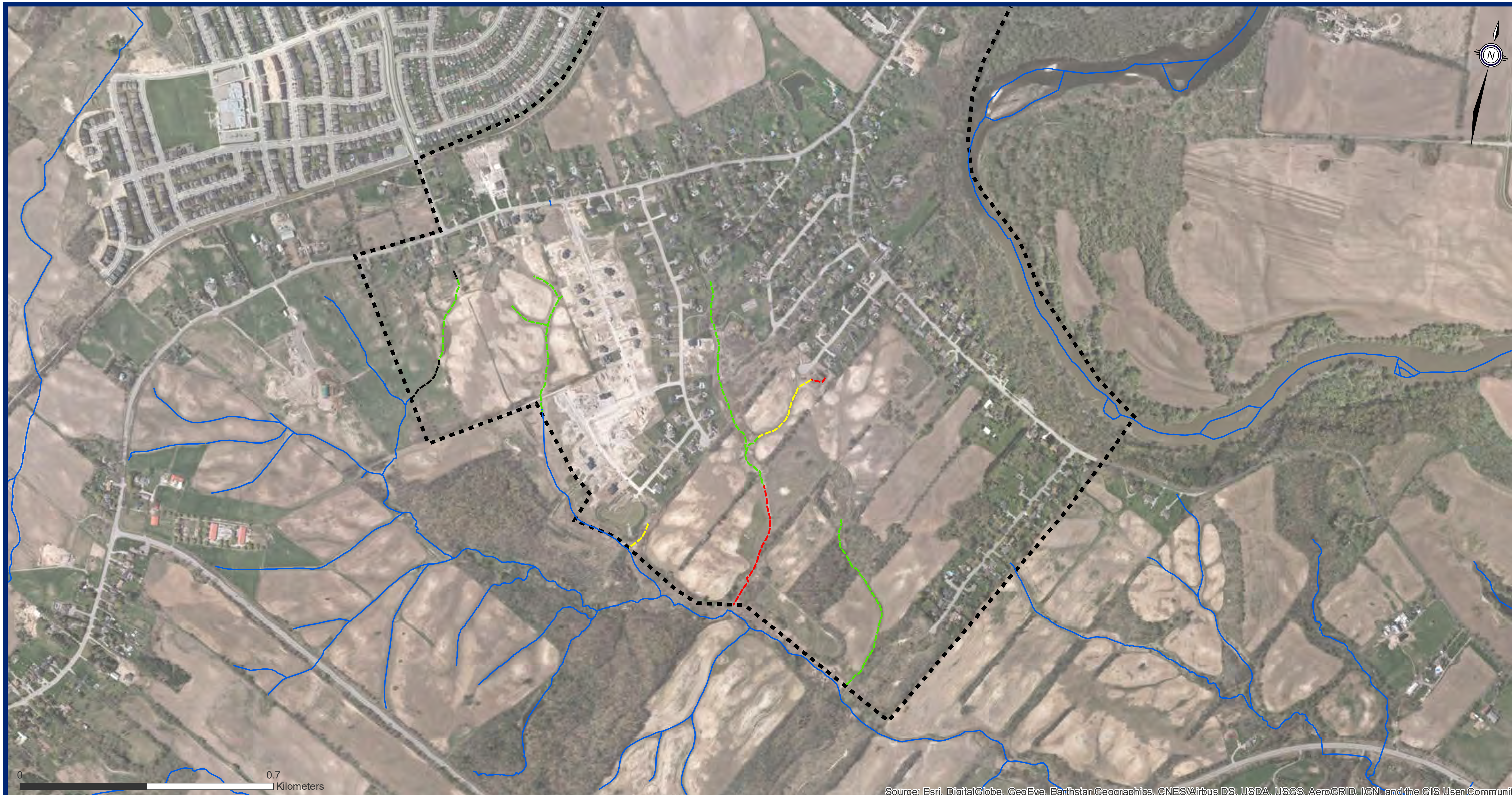

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Boundary Expansion Lands Master Plan

Feature Type*

- Defined Natural Channel
- Modified or Constrained
- No Defined Feature
- Swale
- Wetland
- Rill Erosion
- Watercourse
- Property Parcel

* Site access for these watercourses occurred after November 2018 and thus the full three season Headwater Drainage Feature Assessment was incomplete. Further assessment is required to confirm appropriate management strategy for these features.

Figure 3-2
Headwater Drainage Features
Feature Type - Tutela Heights

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The assessment was conducted over the spring and summer seasons of 2018 and 2019, and focused specifically on the HDF features situated within the short listed sub-areas of the BEA lands. HDF assessments were limited by landowner property access permissions, as access was not granted to all properties within the study area.

Assessed features generally followed topographic low points or depressions within the landscape. Where hillslope processes dominated the landscape, the development of rill features was characteristic. Features ranged in flow and riparian conditions. Many features had pooling or moist depressions which serve to attenuate flow potentially providing local benefits to habitat. Riparian conditions were dominated by cropped land throughout the primarily agricultural setting, with natural vegetation buffers ranging in dimensions or size.

3.1.5 Hydrologic Condition Evaluation

Assessment of the features hydrologic condition requires more than one field visit, to determine permanence of flow condition; the highest hydrologic function that is observed is used to determine the hydrologic condition. In accordance with OSAP (2017) and CVC / TRCA (2014) guidelines, hydrologic conditions were evaluated as follows:

- **No surface water:** feature is dry;
- **Standing water:** feature has standing water, but there is no visible flow. Features often alternate between standing water and dry conditions;
- **Interstitial flow:** feature exhibits flow in the pavement layer of the substrate;
- **Surface flow – minimal:** feature exhibits flow that is estimated to be less than 0.5 litres per second; and
- **Surface flow – substantial:** feature exhibits flow that is estimated to be greater than 0.5 litres per second.

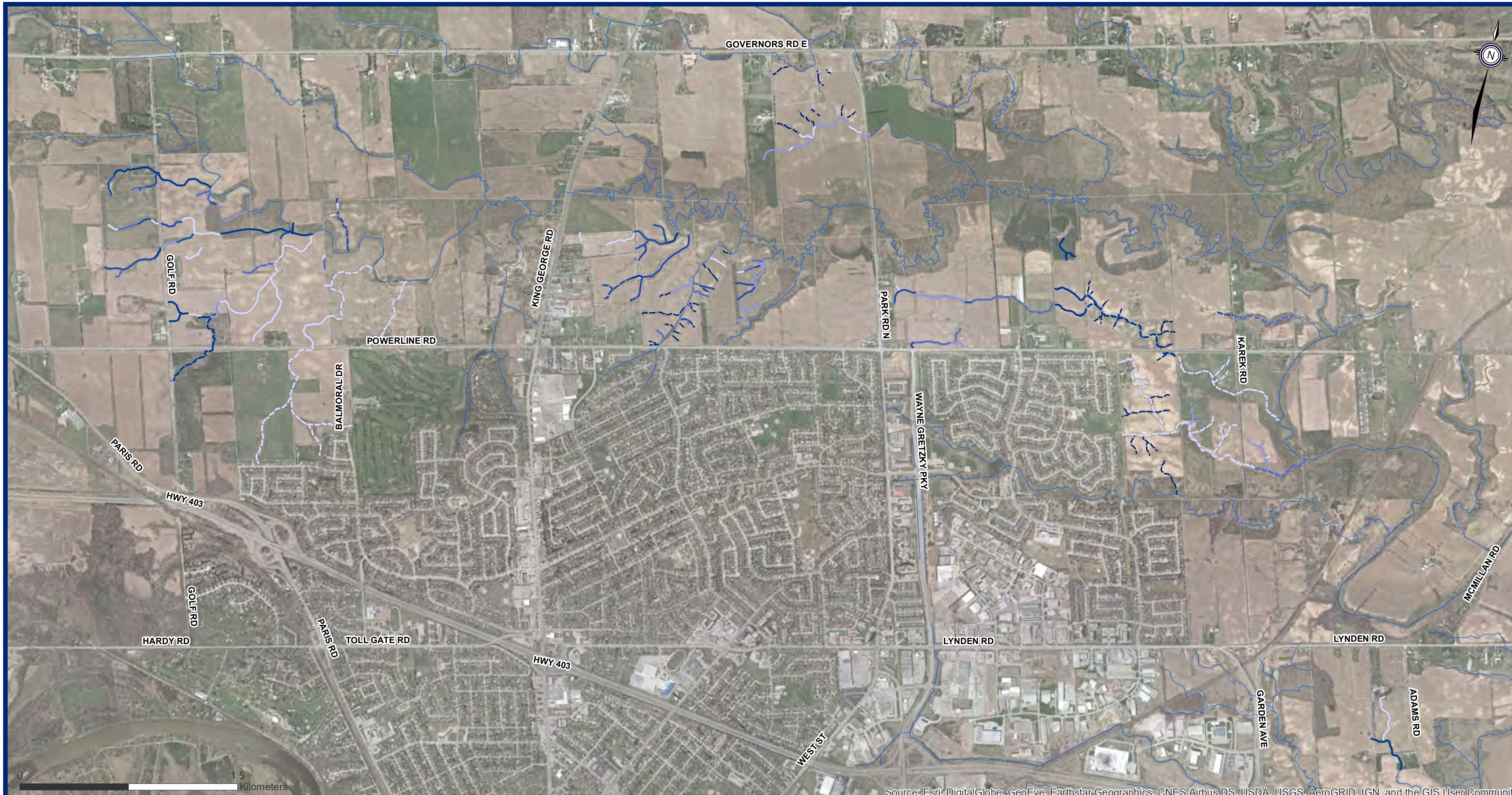
Hydrologic conditions of the HDFs are provided in **Figure 3-4** and **Figure 3-5**.

3.1.6 Riparian Condition Evaluation

In accordance with OSAP (2017) and CVC / TRCA (2014) guidelines, riparian vegetation conditions were evaluated as follows:

- **Lawn:** grasses are not allowed to reach a mature state due to mowing;
- **Cropped land:** planted or tilled in preparation for planting of agricultural crops; plants typically arranged in rows; may be subject to periodic tillage;
- **Meadow:** less than 25% tree/shrub cover; characterized by grasses, forbs and sedges
- **Scrubland:** between 25-60% trees and shrubs interspersed with grasses and forbs (transitional between forest and meadow);
- **Wetland:** dominated by water tolerant wetland plants including rushes, and water tolerate trees or shrubs; and
- **Forest**: more than 60% of the canopy is covered by the crowns of trees.

Riparian conditions of the HDFs are provided in **Figure 3-6** and **Figure 3-7.**



Boundary Expansion Lands
Master Plan

Flow Condition

- No Surface Water
- Standing Water
- Interstitial Flow
- Surface Flow - Minimal
- Surface Flow - Substantial

Flow Condition*

- No Surface Water
- Standing Water
- Interstitial Flow
- Surface Flow - Minimal
- Surface Flow - Substantial

- Rill Erosion
- Watercourse
- Property Parcel

* Site access for these watercourses occurred after April 2018 and thus the full three season Headwater Drainage Feature Assessment was incomplete. Further assessment is required to confirm appropriate management strategy for these features.

Figure 3-3
Headwater Drainage Features
Hydrologic Evaluation - Northern BEA

November, 2018
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Boundary Expansion Lands Master Plan

Flow Condition*

Symbol	Description
- - - -	No Surface Water
- - - -	Standing Water
- - - -	Interstitial Flow
- - - -	Surface Flow - Minimal
- - - -	Surface Flow - Substantial
- - - -	Rill Erosion
▭	Property Parcel
——	Drainage Network

* Site access for these watercourses occurred after November 2018 and thus the full three season Headwater Drainage Feature Assessment was incomplete. Further assessment is required to confirm appropriate management strategy for these features.

Figure 3-4
Headwater Drainage Features
Hydrologic Evaluation - Tutela Heights

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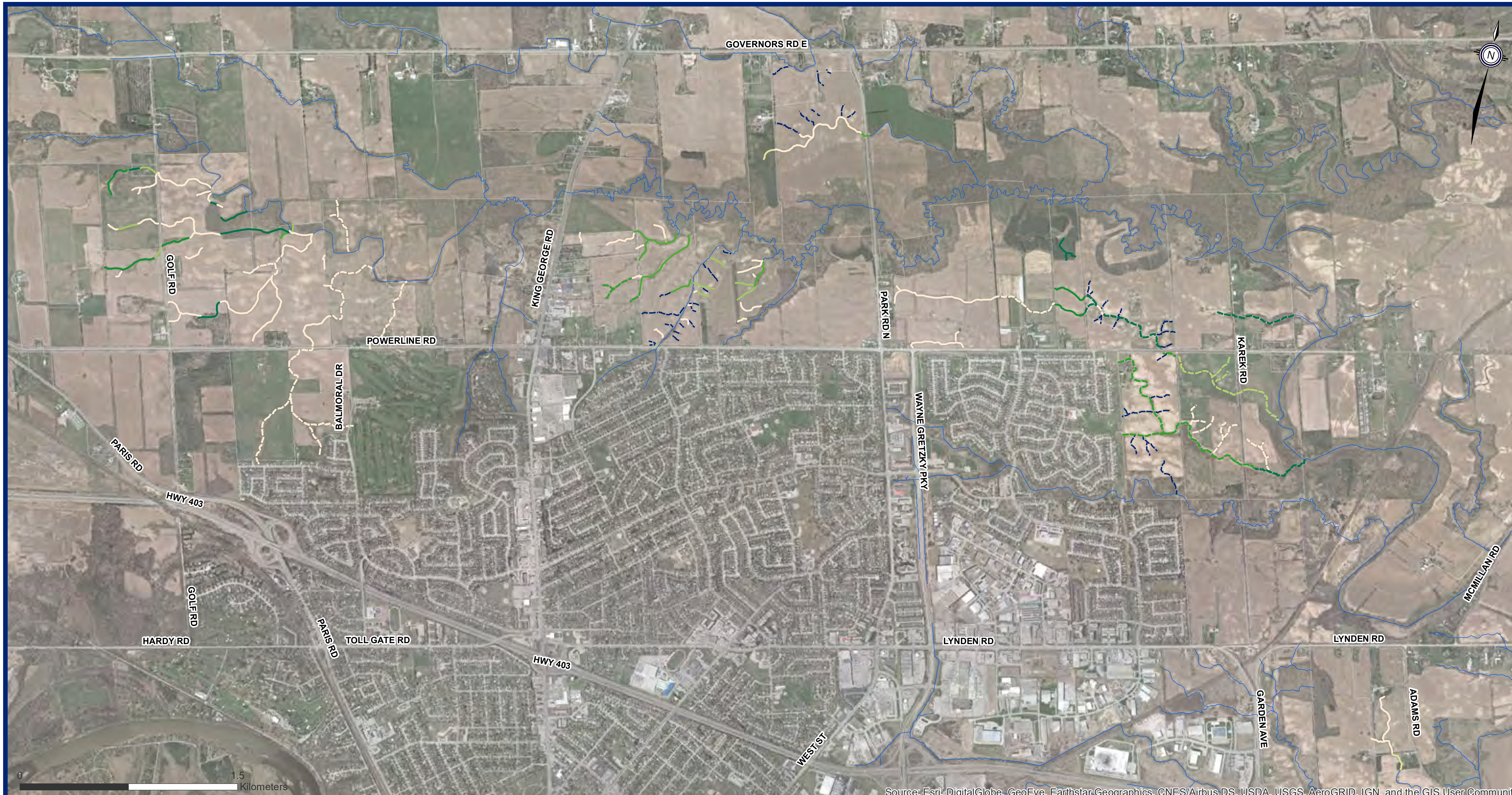

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Riparian Condition	Riparian Condition*	
Cropped Land	Cropped Land	Property Parcel
Lawn	Meadow	
Meadow	Wetland	
Wetland	Scrubland	
Scrubland	Rill Erosion	
Forest	Watercourse	

* Site access for these watercourses occurred after April 2018 and thus the full three season Headwater Drainage Feature Assessment was incomplete. Further assessment is required to confirm appropriate management strategy for these features.

Figure 3-5
Headwater Drainage Features
Riparian Evaluation - Northern BEA

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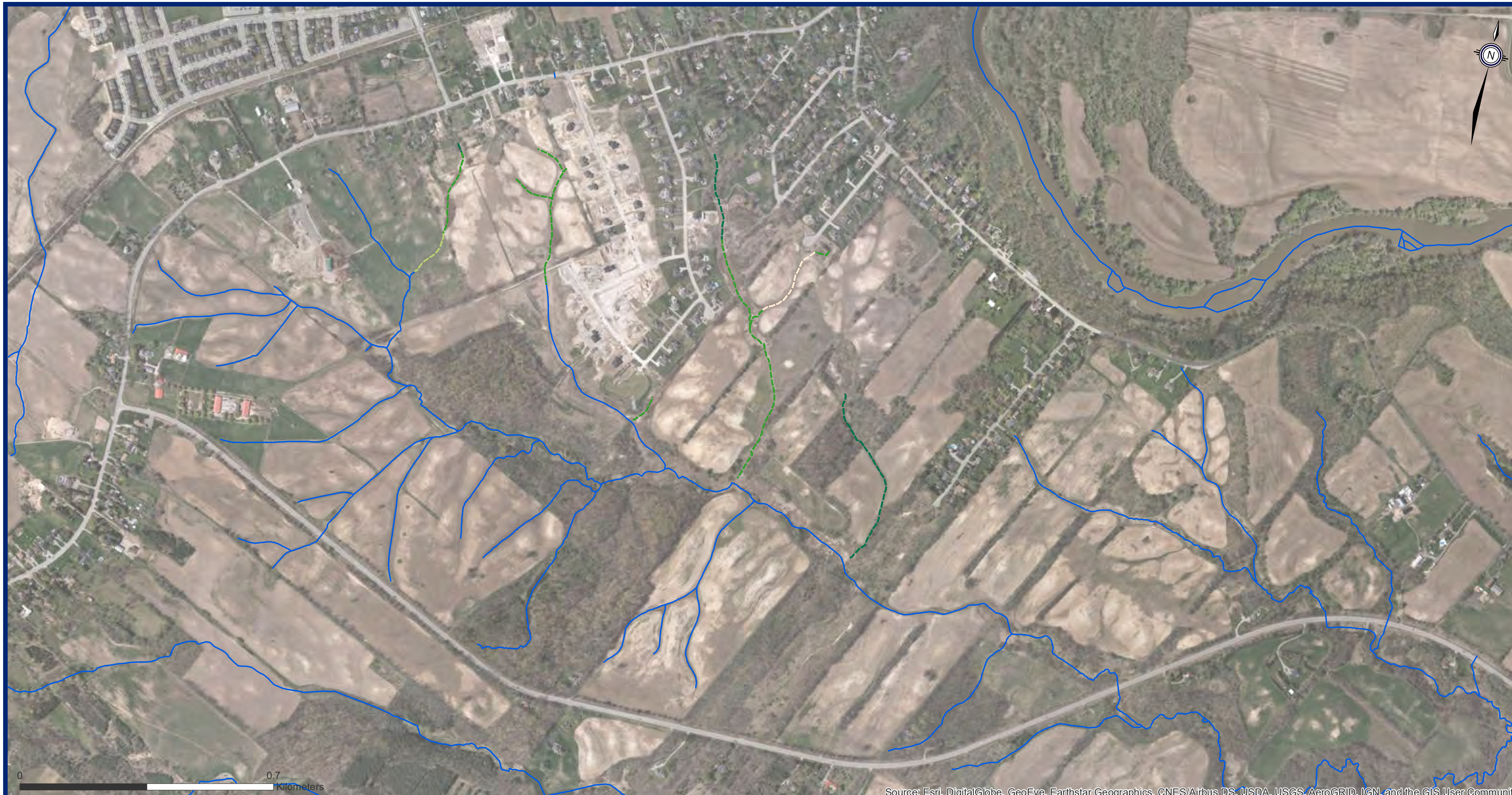

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Boundary Expansion Lands Master Plan

Riparian Condition*

- Cropped Land
- Meadow
- Wetland
- Scrubland
- Rill Erosion
- Property Parcel
- Drainage Network

* Site access for these watercourses occurred after November 2018 and thus the full three season Headwater Drainage Feature Assessment was incomplete. Further assessment is required to confirm appropriate management strategy for these features.

Figure 3-6
Headwater Drainage Features
Riparian Evaluation - Tutela Heights

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3.2 Part 2: Classification

Classification of each HDF identified through the field sample events occurs through consideration of the hydrologic and riparian conditions of the feature, in addition to the feature type (**Section 3.1.4**). The classification of HDFs is the process in which the function of the feature is identified. Through the Rapid Method, function is defined by hydrology, riparian conditions, and aquatic and terrestrial habitat. The function of the feature forms the basis for management recommendations. The following sections outline the classification process.

3.2.1 Hydrologic Classification

Step 1 of the HDF classification is the hydrologic classification that is determined by the relative importance of biotic feature function which considers the flow condition and feature type. The classification of a feature using such parameters is outlined in **Table 3-2**; a hierarchical method from OSAP S4.M10 (2017).

The classification includes four classes:

A. Important Functions - Permanent Stream: watercourse with a year round flow, composed of groundwater discharge and runoff.

B. Valued Functions – Intermittent Stream: watercourse with a flow, composed of groundwater discharge and runoff, that may vary seasonally with groundwater table fluctuations, such that it flows permanently for a portion of the year, then flows only in response to runoff events at other times of the year.

C. Contributing Functions – Ephemeral Stream: watercourse that flows only in response to runoff events.

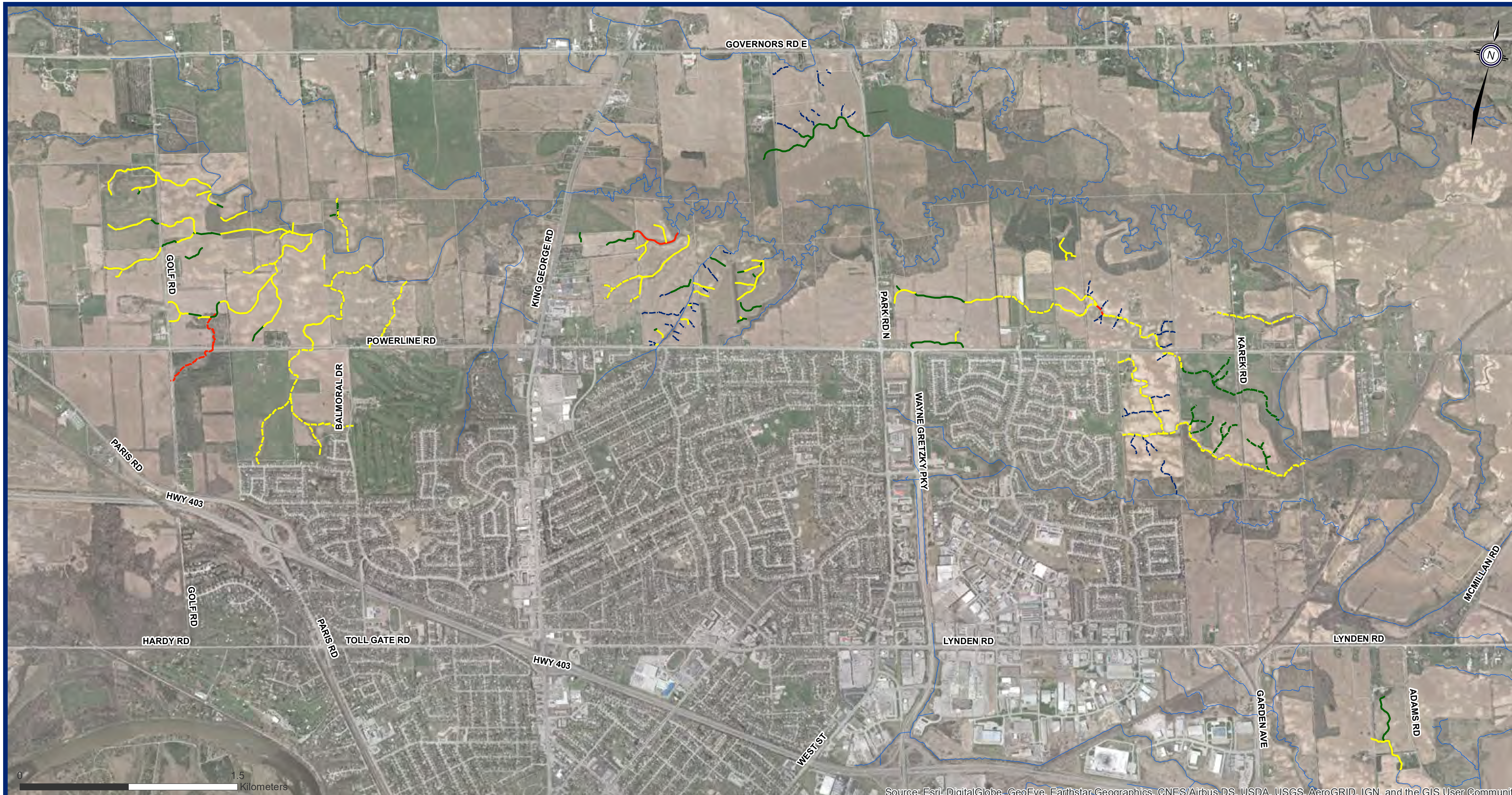
D. Recharge Functions – Dry or Standing Water: no surface flow occurs; key function is groundwater recharge and maintenance of downstream aquatic functions via groundwater connections to streams.

The hydrologic classification of the HDF within the study area is illustrated on **Figure 3-8** and **Figure 3-9**. Hydrologic condition functions (limited or recharge; valued or contributing; important) are hierarchical; thus, the highest level or most significant function satisfied during any of the three sampling events was used to classify HDFs.

Table 3-2. Hydrologic classification using flow condition and feature type (from OSAP S4.M10, 2017).

Assessment Period	Limited or Recharge		Valued or Contributing		Important	
	Flow	Feature Type	Flow	Feature Type	Flow	Feature Type
Spring freshet (late March – mid-April)	No Surface Water *or* Standing Water	No Defined Feature *or* Swale	Interstitial Flow *or* Surface Flow Minimal *or* Surface Flow Substantial	All Feature Types		
Late April – May	No Surface Water *or* Standing Water	No Defined Feature *or* Swale	No Surface Water *or* Standing Water	Defined Channel or Channelized or Multi-thread or Wetland*		
			Interstitial Flow *or* Surface Flow Minimal *or* Surface Flow Substantial	Multi-thread or No Defined Feature or Tiled Drainage or Wetland*		
July – August					Standing Water *or* Interstitial Flow *or* Surface Flow Minimal *or* Surface Flow Substantial	Defined Channel or Channelized or Multi-thread or Roadside Ditch
					Standing Water	Wetland

* If wetland occurs at upstream portion of HDF segment



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Flow Classification

- Limited or Recharge
- Valued or Contributing
- Important

Flow Classification*

- Limited or Recharge
- Valued or Contributing
- Important

- Rill Erosion
- Watercourse
- Property Parcel

* Site access for these watercourses occurred after April 2018 and thus the full three season Headwater Drainage Feature Assessment was incomplete. Further assessment is required to confirm appropriate management strategy for these features.

Figure 3-7
Headwater Drainage Features
Hydrologic Classification - Northern BEA

November, 2018
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Master Plan

Flow Classification*

- Limited or Recharge
- Valued or Contributing
- Important
- Rill Erosion
- Property Parcel
- Drainage Network

* Site access for these watercourses occurred after November 2018 and thus the full three season Headwater Drainage Feature Assessment was incomplete. Further assessment is required to confirm appropriate management strategy for these features.

Figure 3-8
Headwater Drainage Features
Hydrologic Classification - Tutela Heights

November, 2018
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3.2.2 Riparian Classification

Step 2 of the HDF classification is based on the riparian conditions (i.e., highest functioning vegetation type) observed adjacent to the features

The riparian condition classification includes the following categories:

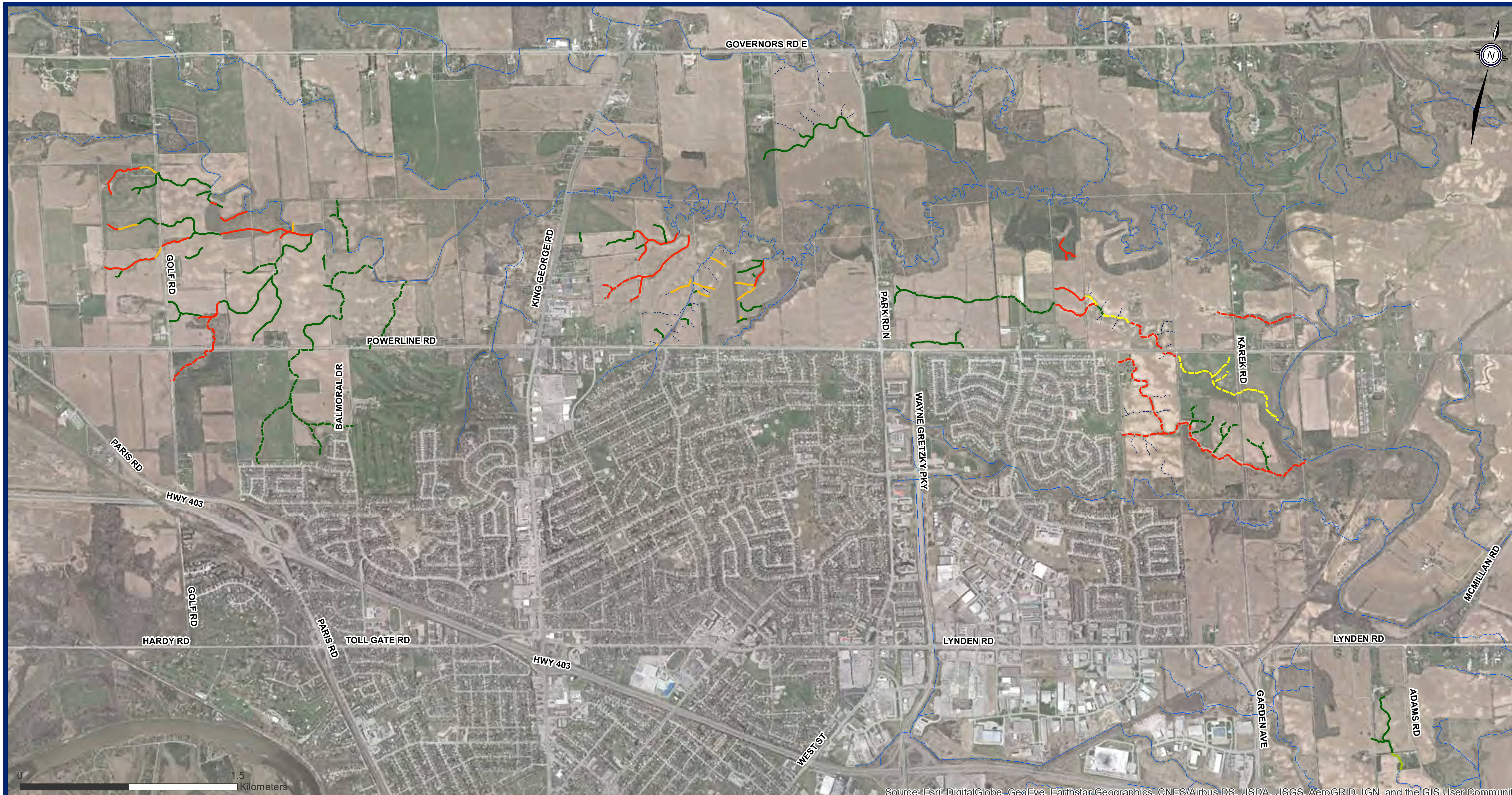
A. Important Functions: dominated by forest or thicket/scrubland communities or wetland

B. Valued Functions: dominated by meadow and there are no important riparian functions

C. Contributing Functions: dominated by lawn and there are no important or valued riparian functions

D. Limited Functions: dominated by cropped land or no vegetation, and there are no important, valued, or contributing riparian functions.

The riparian classification of the HDF within the study area is illustrated on **Figure 3-10** and **Figure 3-11**.



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Riparian Classification	Riparian Classification*	
Limited	Limited	Watercourse
Contributing	Valued	Property Parcel
Valued	Important	
Important	Rill Erosion	

* Site access for these watercourses occurred after April 2018 and thus the full three season Headwater Drainage Feature Assessment was incomplete. Further assessment is required to confirm appropriate management strategy for these features.

Figure 3-9
Headwater Drainage Features
Riparian Classification - Northern BEA

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Boundary Expansion Lands Master Plan

Riparian Classification*

- Limited
- Valued
- Important

- Rill Erosion
- Property Parcel
- Drainage Network

* Site access for these watercourses occurred after November 2018 and thus the full three season Headwater Drainage Feature Assessment was incomplete. Further assessment is required to confirm appropriate management strategy for these features.

Figure 3-10
Headwater Drainage Features
Riparian Classification - Tutela Heights

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3.2.3 Fish and Fish Habitat Classification

Fish Community Assessment

Prior to completing a fisheries assessment, background review of all available resources was completed including information from the Grand River Conservation Authority (GRCA). This information was used to confirm existing species and aided in the determination of data gaps prior to field-based assessments. The following documents and data sources were reviewed prior to field surveys:

- Natural Heritage Information Centre (NHIC);
- DFO Species at Risk Mapping; and
- GRCA Fish Records

Fish Community Methods

No previous fish community studies have been completed for the sites assessed as part of the fish community assessment. ERI's aquatic biologist assisted in the HDF assessment and identified all potential fish habitats within the study area. Two locations were identified of having the potential for fish habitat, Site A on Powerline Road and Site B on Golf Road (**Figure 3-12**).

Site A was a small pond located on private property in an agricultural area. It is surrounded by agricultural fields and has a small area of meadow habitat surrounding its borders. It was a shallow pond, with soft substrate with a total area of 940 m^2.

Site B is another small pond habitat, with soft substrate and low water levels. The banks area heavily vegetated and surrounded by meadow and thicket habitat. The larger surrounding is all agricultural fields, which likely contribute sediment into the water course and pond. The total area of the pond is 563 m^2.

A License to Collect Fish for Scientific Purposes was obtained from the MNRF Guelph District prior to completing the fish community survey. The fish community assessment was completed on August 19th and 20th in 2019 using minnow traps and cod/fyke nets for 12-24 hour duration. These were baited with dog treats and bread. All fish and minnows sampled were returned to the same water body. Fish measurements were recorded including were weight and fork length.

Fish Community Results and Discussion

Fish and minnow species found within the fish community assessment are typical of warm and cool water tributaries found within the local area and include brook stickleback (*Culea inconstans*), common shiner (*Luxilus cornutus*), and fathead minnow (*Pimephales promelas*). Results of the fish community assessment for both Site A and B are presented in **Attachment D.**

HDF Classification

Step 3 of the HDF classification is based on the fish habitat conditions present within the headwater features.

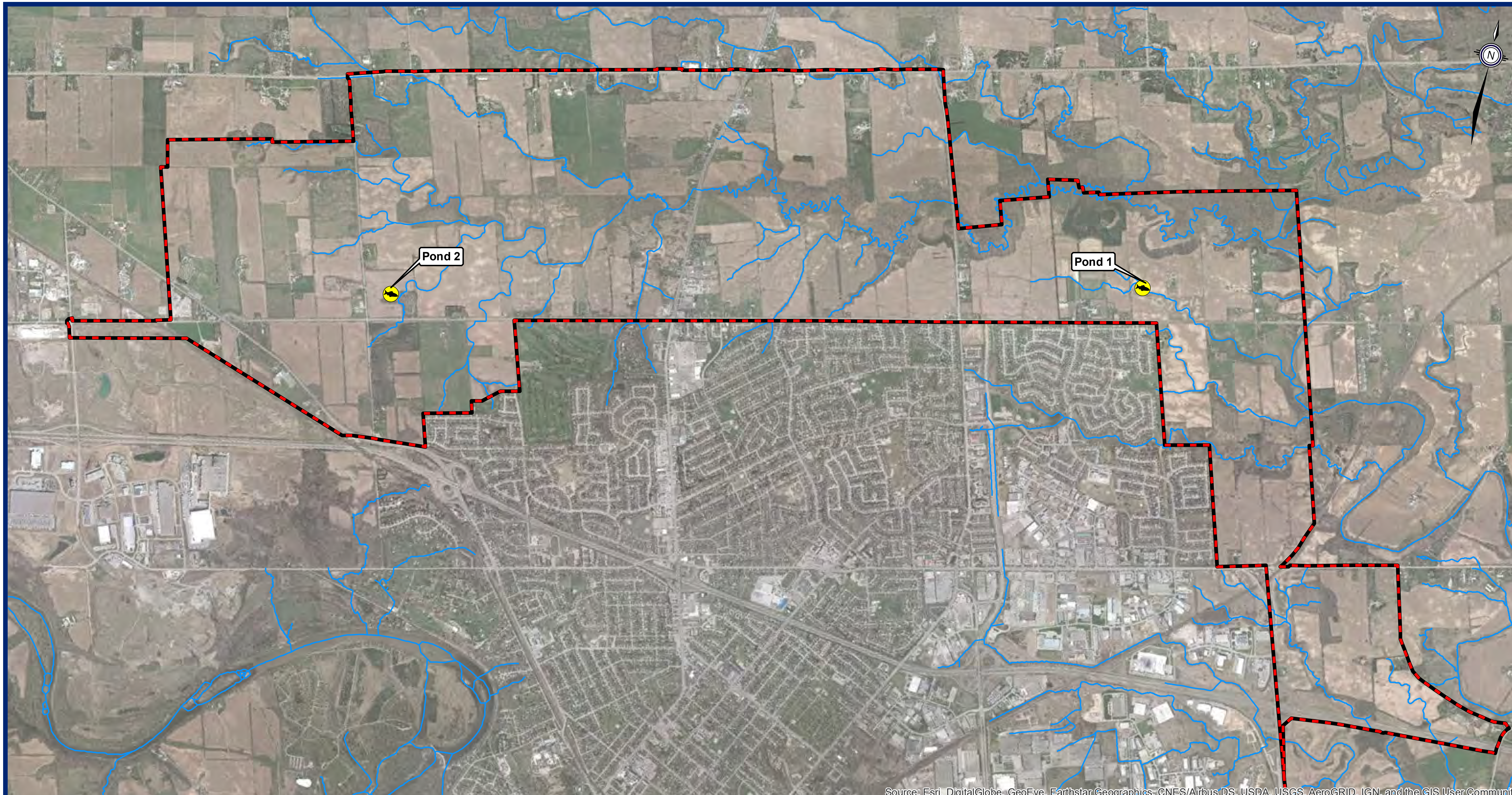
The fish and fish habitat classification includes the following categories:

A. <u>Important Functions</u>: any fish species present in spring and mid-summer; suitable spawning habitat for any fish species; species-at-risk present at any time; or feature provides critical habitat to downstream species-at-risk

B. <u>Valued Functions</u>: fish present in spring only or suitable habitat identified for feeding, cover, refuge, migration; or contributing habitat for species-at-risk

C. <u>Contributing Functions</u>: allochthonous transport through feature to downstream habitat

The fish and fish habitat classification of the HDF within the study area is illustrated on **Figure 3-13** and **Figure 3-14**.



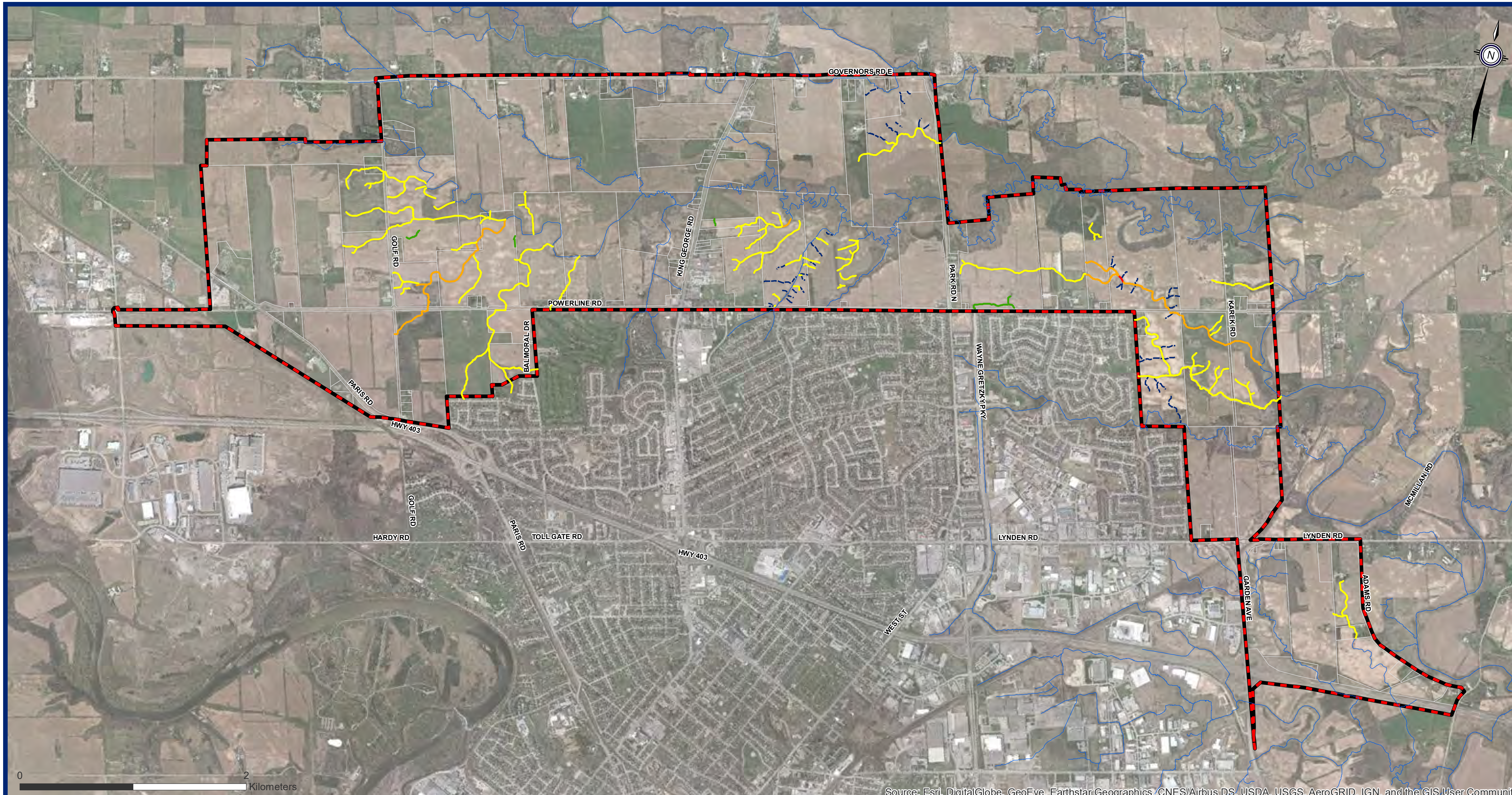
Study Area
Drainage Network
Fish Habitat Sampling Site

0 2 Kilometers

Boundary Expansion Lands Master Plan

Figure 3-12
Headwater Drainage Features
Fish Community Site Locations

November, 2019
NAD 1983 UTM Zone 17N



Boundary Expansion Lands Master Plan

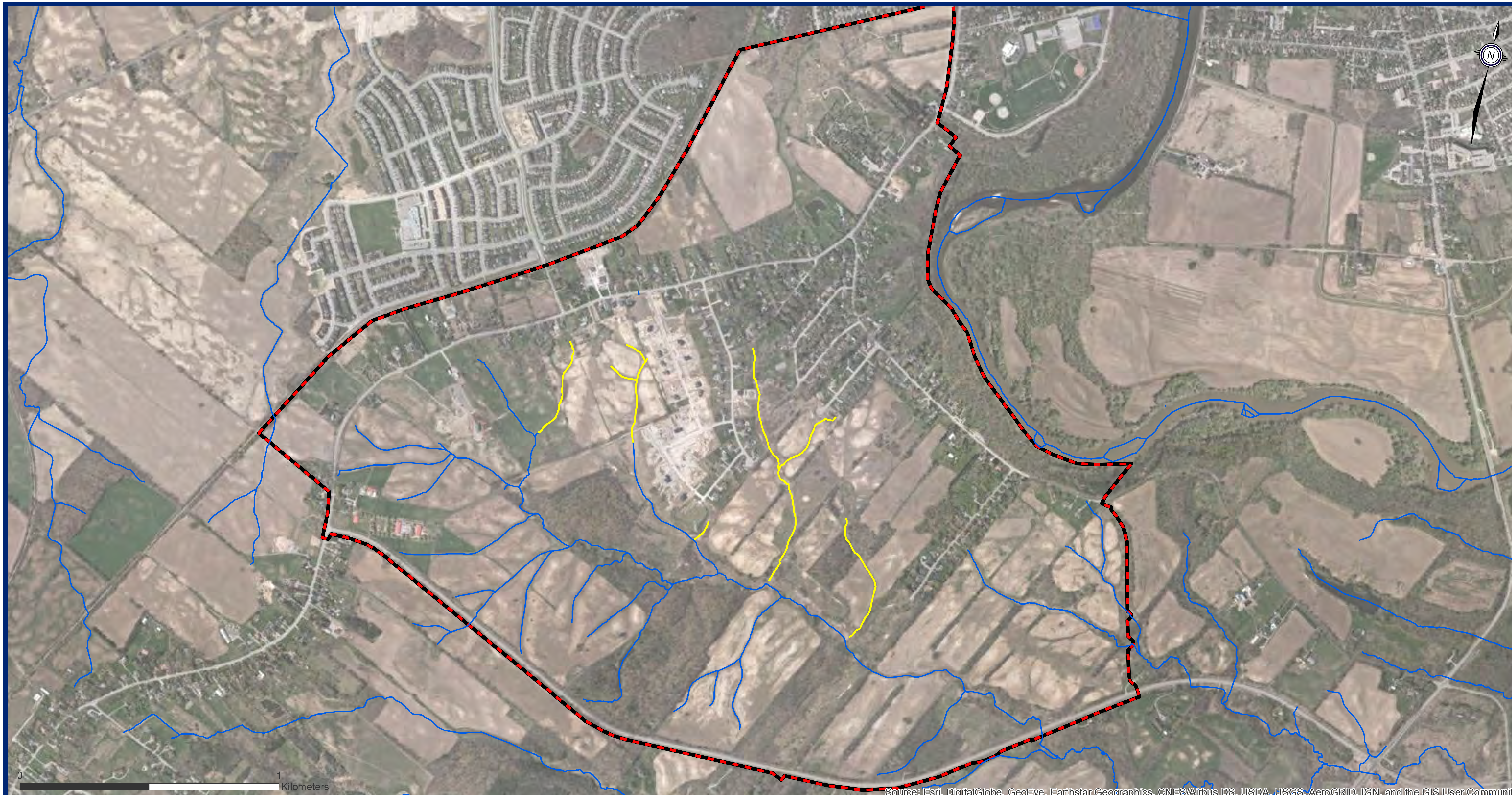
Fish Habitat

- No Significance
- Contributing
- Valued
- Important

- Study Area
- Property Parcel
- Rill Erosion
- Watercourse

Figure 3-13
Headwater Drainage Features
Fish and Fish Habitat Classification - Northern BEA

November, 2019
NAD 1983 UTM Zone 17N



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Boundary Expansion Lands Master Plan

Fish Habitat

- No Significance
- Contributing
- Valued
- Important

- Study Area
- Rill Erosion
- Drainage Network

Figure 3-14
Headwater Drainage Features
Fish and Fish Habitat Classification - Tutela Heights

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3.2.4 Terrestrial Habitat Classification

Terrestrial Habitat Assessment

Amphibian call surveys are an important component of environmental studies as they are an indicator of wetland and ecosystem health. These studies are typically included in baseline environmental studies to develop an understanding of species composition, abundance and breeding activity of anuran species, which are typically sensitive to environmental effects.

Prior to completing the amphibian call surveys, a background review of the Ontario Reptile and Amphibian Atlas (Ontario Nature) was collected to identify species of amphibians that have been recorded in close proximity to the study area. No significant amphibian species were identified as occurring within the study area as part of the background review.

Terrestrial Habitat Methods

Following the Marsh Monitoring Program Participant's Handbook from Bird Studies Canada for surveying Amphibians, three surveys must be completed between April 1st and June 30th in the appropriate timing, season and weather conditions. Surveys are three minutes in duration and commence not earlier that one half hour after sunset and ends before midnight.

Surveys must take place during evenings with little wind and a minimum night temperature of 5°C, 10°C and 17°C for each of the three respective survey periods. It should be noted call surveys can be conducted at lower temperatures if there is strong calling activity observed. Surveys were conducted using a semi-circular sampling area at each site.

The surveys typically face a waterbody or wetland. Subsequent surveys must be conducted at the same survey locations. For each call heard, the approximate distance to each call is recorded as being greater than or less than 100 m from the survey location and call level codes were assigned as follows:

- Code 0: None heard;
- Code 1: individual calls do not overlap and calling individuals can be discretely counted;
- Code 2: calls of individuals sometimes overlap, but numbers of individuals can still be estimated; and
- Code 3: overlap among calls seems continuous, and count estimate is impossible.

Three amphibian surveys were conducted by ERI on May 3rd, May 25th and June 12th. As it was a late spring, after an extended winter, these surveys were delayed until optimal temperatures for conducting the surveys and calling activities. The surveys were completed during suitable weather conditions and commenced no earlier than 30 minutes after sunset, in compliance with the protocol.

The start and end time of the survey was recorded along with air temperature, wind speed and level of precipitation during the survey. Amphibian species, general location of calling and call codes are recorded per the monitoring protocols.

Terrestrial Habitat Results and Discussion

Six stations were identified across the study area for terrestrial assessment, as shown on **Figure 3-15**. A total of five species of amphibians were recorded by ERI at all stations throughout the study area. No provincially listed Species at Risk were observed at any of the stations during the ERI field surveys. A list of the herpetofauna species observed for each station can be found in **Attachment D**.

Station A was located facing a large irrigation pond on the northwest corner of the study area and included a small wetland near the west portion of tributary A. This station had little call activity. It was noted that this pond has been stocked with small-mouth bass, which may limit the amphibian populations.

Station B is located near Ruijs Boulevard and is a cattail and phragmities marsh wetland type. It has surface water present in shallow depths in portion of the wetland. The wetland is surrounded by agricultural fields and is fed by a small tributary and overland flow. Amphibian call activity was recorded during each site visit and species found include American toad, spring peeper, northern leopard frog, gray treefrog, and green frog. Overall, this was a very active amphibian call site in comparison to the average call activity found at other sites as part of this study.

Station C is a phragmites meadow marsh located in the middle of an agricultural field near a fence line. It did not have water present above the surface, but the soil was moist during the time of assessments. No amphibian activity was reported within the feature, but many species of amphibians were hear in close proximity within private property, which was not able to be accessed.

Station D is located along Adams Road and a private residential property. It is located in an agricultural field and the wetland tributary is seasonal in nature, with mineral substrate and sporadic emergent vegetation. American toad was the only amphibian recorded at this site within 100m, and only during the first survey, otherwise spring peepers and gray treefrog were heard further away from the site.

Station E is a man build pond located on private residential property along Adams Road. The areas surrounding this pond are manicured grass and the pond is an open water feature with no aquatic vegetation. A small seasonal tributary connects with this pond. No amphibians were found within the pond, but in very near proximity American toad were found.

Station F is located near Golf Road and is a small seasonal wetland that is wet during the spring and part of summer and dry the rest of the wear. There is a hickenbottom installed within the water feature. No vegetation is present in the wet area, but it is surrounded by trees and meadow habitat. The greater surrounding area is agricultural fields. No amphibians were found within the survey area, but American toad were heard outside of the 100 m distance on multiple occasions.

HDF Classification

Step 4 of the HDF classification is based on the terrestrial habitat conditions present along the headwater features.

The terrestrial habitat classification includes the following categories:

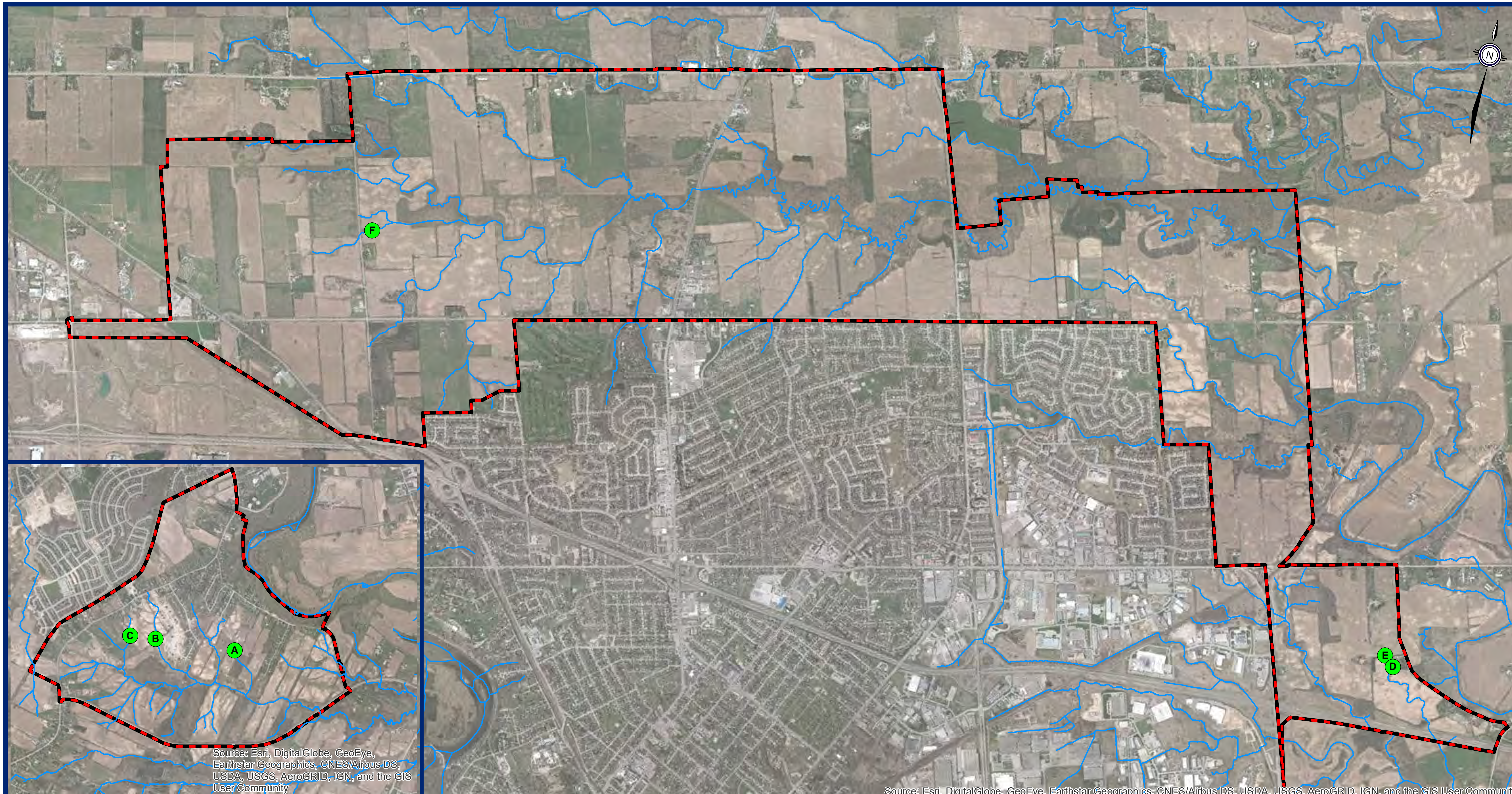
A. Important Functions: wetlands with breeding amphibians

B. Valued Functions: general amphibian habitat: stepping stone habitat (stop over to higher quality habitat) or suitable for feeding or hydration for low mobility wildlife (i.e., amphibians). Wetland habitat occurs within the corridor, but no breeding amphibians are present.

C. Contributing Functions – Movement corridors: the feature has riparian conditions that connects two other features upstream and downstream (e.g. forest or wetland features that will be protected through the planning process), thereby providing movement opportunities for non-amphibian (i.e. higher mobility species). No wetland habitat occurs within the corridor, but other vegetation may be present to facilitate wildlife movement.

E. Limited Functions: no terrestrial habitat present.

The terrestrial habitat classification of the HDF within the study area is illustrated on **Figure 3-16** and **Figure 3-17**.



THE CORPORATION OF THE CITY OF BRANTFORD

Boundary Expansion Lands Master Plan

Study Area
Drainage Network
Terrestrial Habitat Assessment Station

0 2 Kilometers

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Figure 3-15
Headwater Drainage Features
Terrestrial Habitat Site Locations

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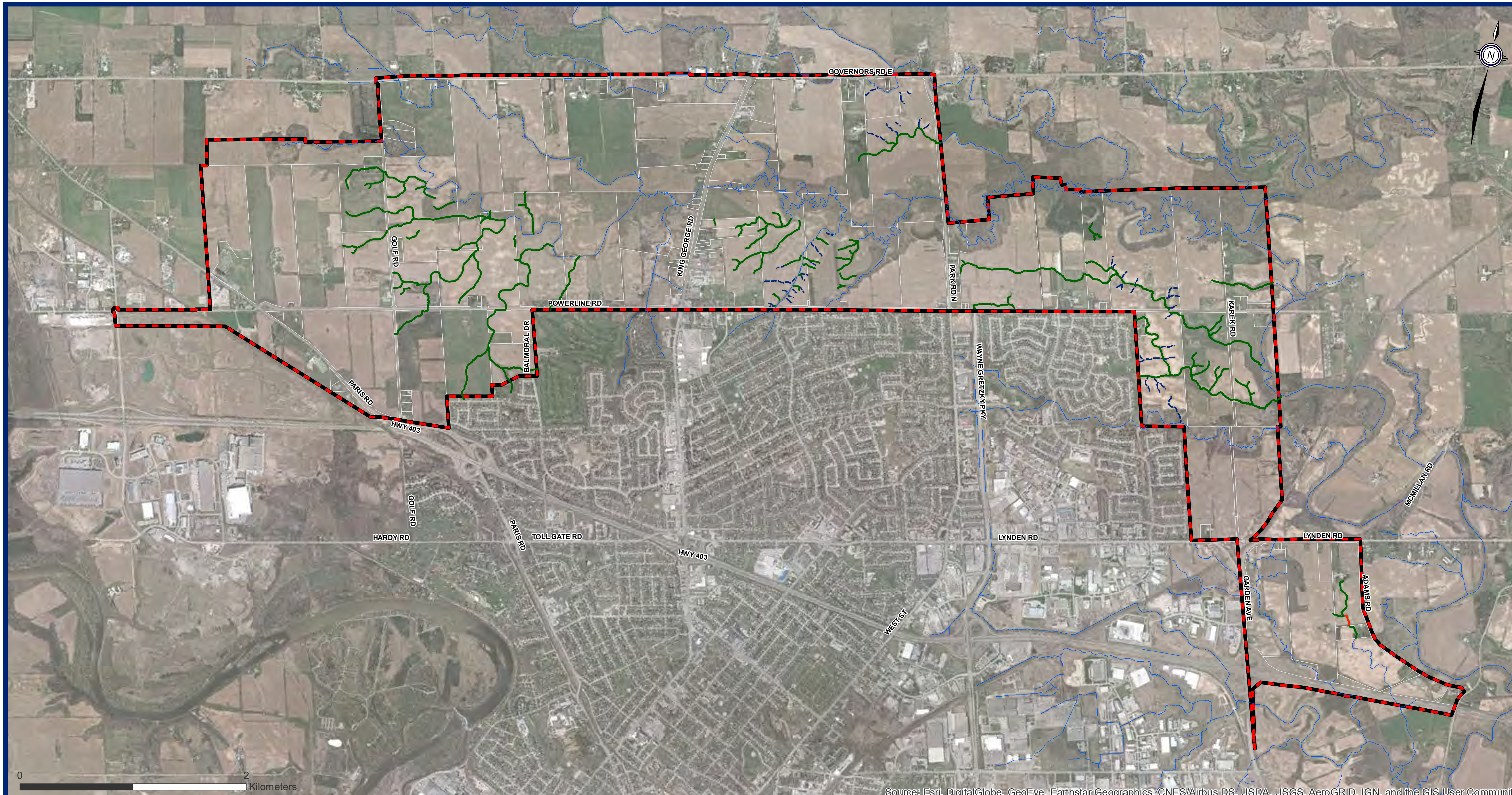
November, 2019
NAD 1983 UTM Zone 17N



Boundary Expansion Lands Master Plan

Terrestrial Habitat Function

- Limited
- Contributing
- Important

- Study Area
- Property Parcel
- Rill Erosion
- Watercourse

Figure 3-16

Headwater Drainage Features

Terrestrial Habitat Classification - Northern BEA

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Boundary Expansion Lands Master Plan

Terrestrial Habitat Function

- Limited
- Contributing
- Important

- Study Area
- Rill Erosion
- Drainage Network

Figure 3-17

Headwater Drainage Features

Terrestrial Habitat Classification - Tutela Heights

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November, 2019
NAD 1983 UTM Zone 17N

4. Management Recommendations

The management recommendations provided in CVC and TRCA (2014) are structured as a science-based decision-making framework that applies a precautionary principle. Based on the evaluation and classification of the HDF within a study area, management recommendations for the protection, conservation and mitigation of HDF functions are intended to be implemented through design of a project. A flow chart is provided in the CVC and TRCA (2014) document that guides the process of selecting appropriate management recommendations based on the HDF classifications completed. A copy of the flow chart is provided in **Figure 4-1**. The process leading to identification of preliminary management recommendations is progressive and intended to be transparent. The subsequent sections outline the process followed to identify the appropriate management recommendations for the HDF observed within the study area.

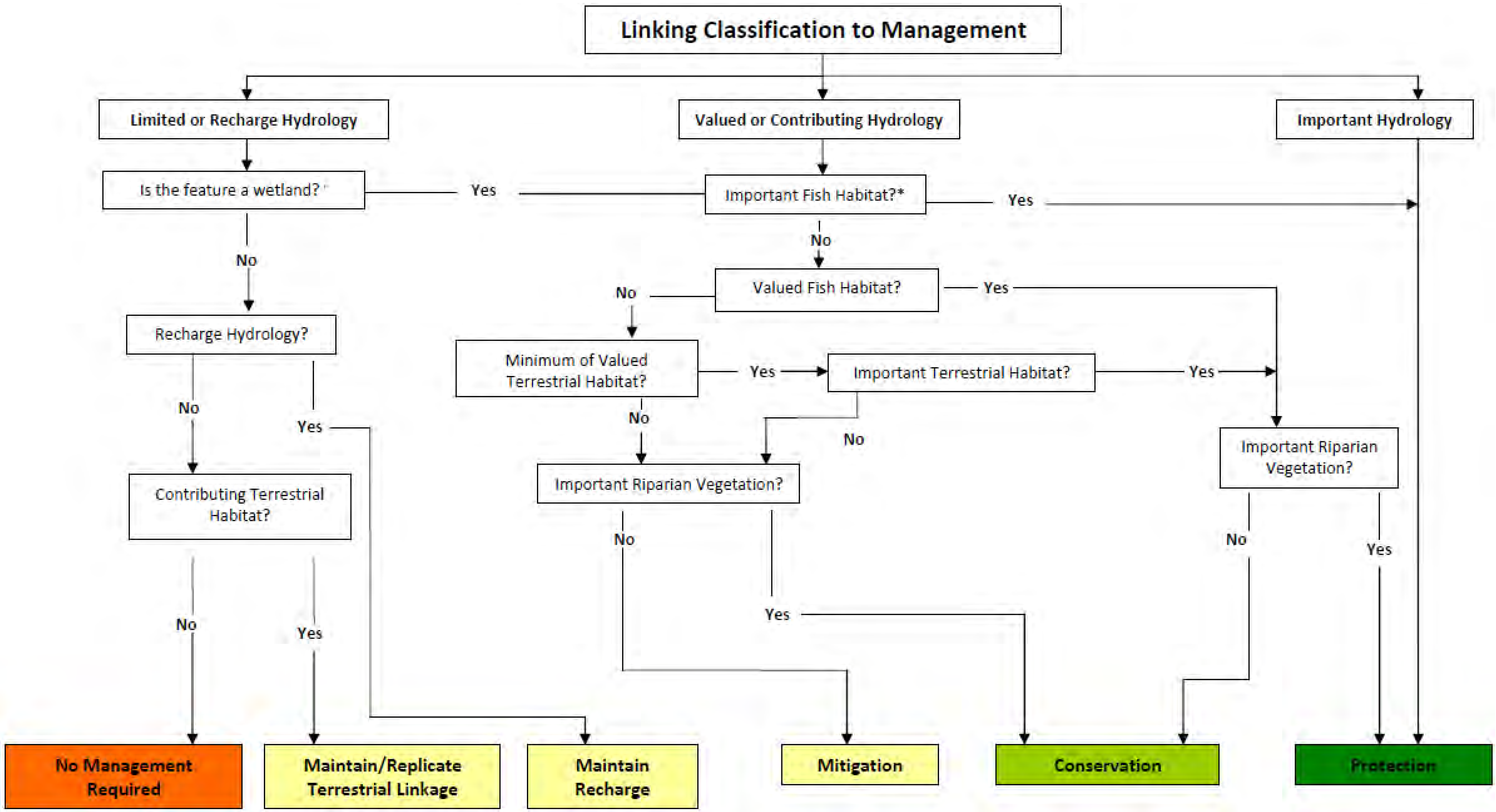


Figure 4-1. Functional classification management table (CVC and TRCA, 2014)

4.1 Management Recommendations

As stated in the guidance document, "management recommendations should consider the cumulative effects on the drainage network," (CVC and TRCA, 2014), suggesting a broader-scale assessment for recommendations, which will allow for cumulative impacts downstream and within the system to be considered and captured. Headwater features differ from downstream reaches by their close coupling to hillslope processes, more temporal and spatial variation, and their need for different means of protection from landuse (Gomi et al, 2002). Any management recommendations should therefore consider the role of headwater features from the hydrologic and biotic perspectives and from a consideration of overall channel functions. Moreover, modifiers of the headwater feature (**Section 2.3**) must be considered during the management recommendation process.

For the 27 km of confirmed HDF features that were identified and assessed in the study area, the feature type, hydrologic and riparian classifications were reviewed, and relevant management recommendations determined based on application of the CVC and TRCA (2014) Management Recommendations Flow Chart (**Figure 4-1**). This process resulted in a management strategy for HDFs based solely on the CVC and TRCA (2014) protocol, which is mapped in **Attachment B**. A description of each management class is provided in **Table 4-1** and the corresponding implications for land development is provided in **Table 4-2**.

Once determined, the management strategy resulting from application of the flow chart was reviewed to determine appropriateness, given other site specific considerations (e.g., existing tile drains, connectivity to existing SWM network, and downstream conditions) and study area understanding. Review of the management recommendations were also compared to the draft Natural Heritage System Mapping prepared by Plan B (2019). For those instances in which a change in the management recommendation was considered to be appropriate, then justification for this change was documented in the Functional Classification and Management Table situated in **Attachment B;** maps showing the progression of management recommendations are shown in **Figure 4-2** and **Figure 4-3**, and are also provided in **Attachment B**.

Once the preliminary management classification was determined, a field site orientation was held with GRCA to discuss the classification. The intent of the field site orientation was to provide GRCA staff with an overview of conditions and rationale for the preliminary classification. In 2019, the management recommendations, as presented in this report were updated according to the Standard Method of assessment, with the exception of the ELC mapping component of the assessment. The level of detail associated with ELC mapping typically corresponds to work tasks undertaken to develop more detailed site planning. The management recommendations from this report should be updated in consideration of the ELC mapping to fully complete the Standard Method of HDF Assessment.

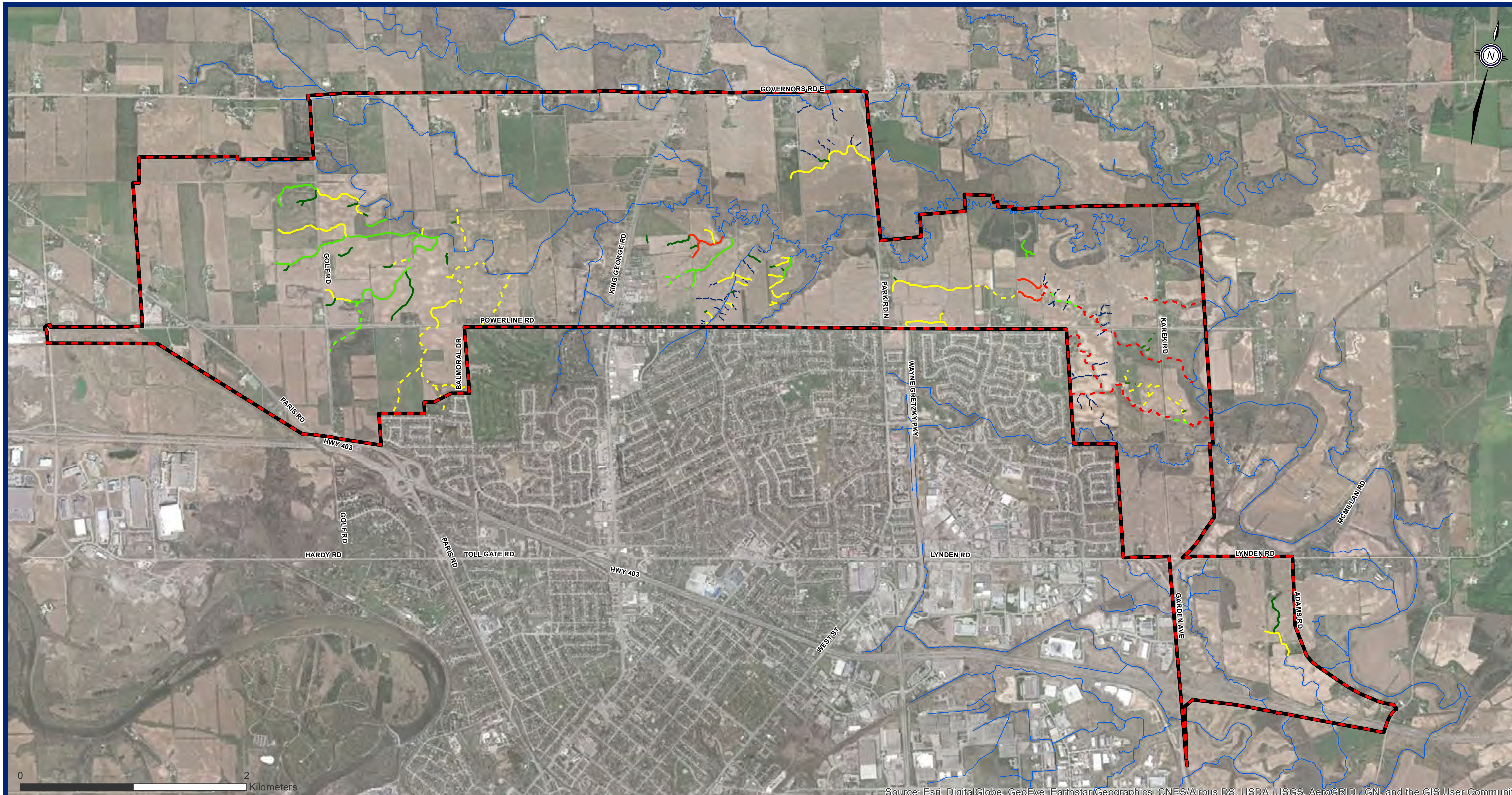
Permission from the GRCA is required to develop in river or stream valleys, wetlands, shorelines or hazardous lands; alter a river, creek, stream or watercourse; or interfere with a wetland. Within these regulated areas, GRCA Policies for the Administration of the Development, Interference with Wetlands and Alterations to Shorelines and Watercourses Regulation apply (Ontario Regulation 150/06). Recommendations derived from the HDF assessment are in addition to, but do not supersede, regulatory requirements.

Table 4-1. HDF Management Strategies (from CVC and TRCA, 2014).

Management Category	Intent of Management Actions
Protection – Important Functions:	• Protect and / or enhance the existing feature and its riparian zone corridor, and groundwater discharge or wetland; • Maintain hydroperiod; • Incorporate shallow groundwater and base flow protection techniques such as infiltration treatment; • Use natural channel design techniques or wetland design to restore and enhance existing habitat features, if necessary; realignment not generally permitted • Design and locate the stormwater management system to avoid impacts to the feature.
Conservation – Valued Functions:	• Maintain, relocate, and/or enhance drainage feature and its riparian zone corridor; • Maintain or replace on-site flows using mitigation measures and/or wetland creation, if necessary; • Maintain or replace external flows; • Use natural channel design techniques to maintain or enhance overall productivity of the reach; • Drainage feature must connect to downstream.
Mitigation – Contributing Functions:	• Replicate or enhance functions through enhanced lot level conveyance measures, such as well-vegetated swales (herbaceous, shrub and tree material) to mimic online wet vegetation pockets, or replication through constructed wetland features connected to downstream; • Replicate on-site flow and outlet flows at the top end of the system to maintain feature functions with vegetated swales, bioswales, etc. • Replicate functions by lot level conveyance measures (e.g., vegetated swales) connected to the natural heritage system, as feasible, and/or Low Impact Development (LID) stormwater options.
Recharge Protection – Recharge Functions	• Maintain overall water balance by providing mitigation measures to infiltrate clean stormwater; • Terrestrial features may need to be assessed separately through an Environmental Impact Study to determine whether there are other terrestrial functions associated with them.
Maintain or Replicate Terrestrial Linkage – Terrestrial Functions:	• Maintain the corridor between the other features through in-situ protection or if the other features require protection, replicate and enhance the corridor elsewhere; • If the feature is wider than 20 m, it may need to be assessed separately through an Environmental Impact Study to determine whether there are other terrestrial functions associated with it.
No Management Required – Limited Functions:	• The feature that was identified during desktop pre-screening has been field verified to confirm that no feature and/or functions associated with HDFs are present on the ground and/or there is no connection downstream. These features are generally characterized by lack of flow, evidence of cultivation, furrowing, presence of seasonal crop, and lack of natural vegetation. No management recommendations required.

Table 4-2. Management recommendations and implications for development proposals (CVC and TRCA, 2014)

Management Implications	Protection	Conservation	Mitigation	Recharge Protection	Maintain Terrestrial Linkage	No Management Required
Must remain open	Yes	Yes	Yes	N/A	Yes	N/A
Relocate using natural channel design	Not permitted, enhancement only	May be considered, not preferred	Natural Channel Design not required	N/A	N/A	N/A
Maintain or replicate groundwater or wetlands	Maintain or enhance	Maintain or replicate, restore if possible	N/A	Maintain overall infiltration rates at site	N/A	N/A
Maintain hydroperiod	Yes	Yes	Yes	N/A	N/A	N/A
Direct connection to downstream	Yes	Yes	Yes	N/A	N/A	N/A
Replicate function through enhanced lot level conveyance	N/A	N/A	Replicate using bioswales, LID, vegetated swales or constructed wetlands	N/A	N/A	N/A



THE CORPORATION OF THE CITY OF BRANTFORD

Boundary Expansion Lands Master Plan

Preliminary Management Recommendations*

- No Management Required
- Mitigation
- Conservation
- Protection

Preliminary Management Recommendations*

- No Management Required
- Mitigation
- Conservation
- Protection

- Rill Erosion
- Drainage Network
- Property Parcel
- Study Area

* Site access for these watercourses was not granted by landowner or occurred after April 2018. Therefore, the full three season Headwater Drainage Feature Assessment was incomplete. Further assessment is required to confirm appropriate management strategy for these features.

Figure 4-2

Headwater Drainage Features

Revised Management Recommendation - Northern BEA

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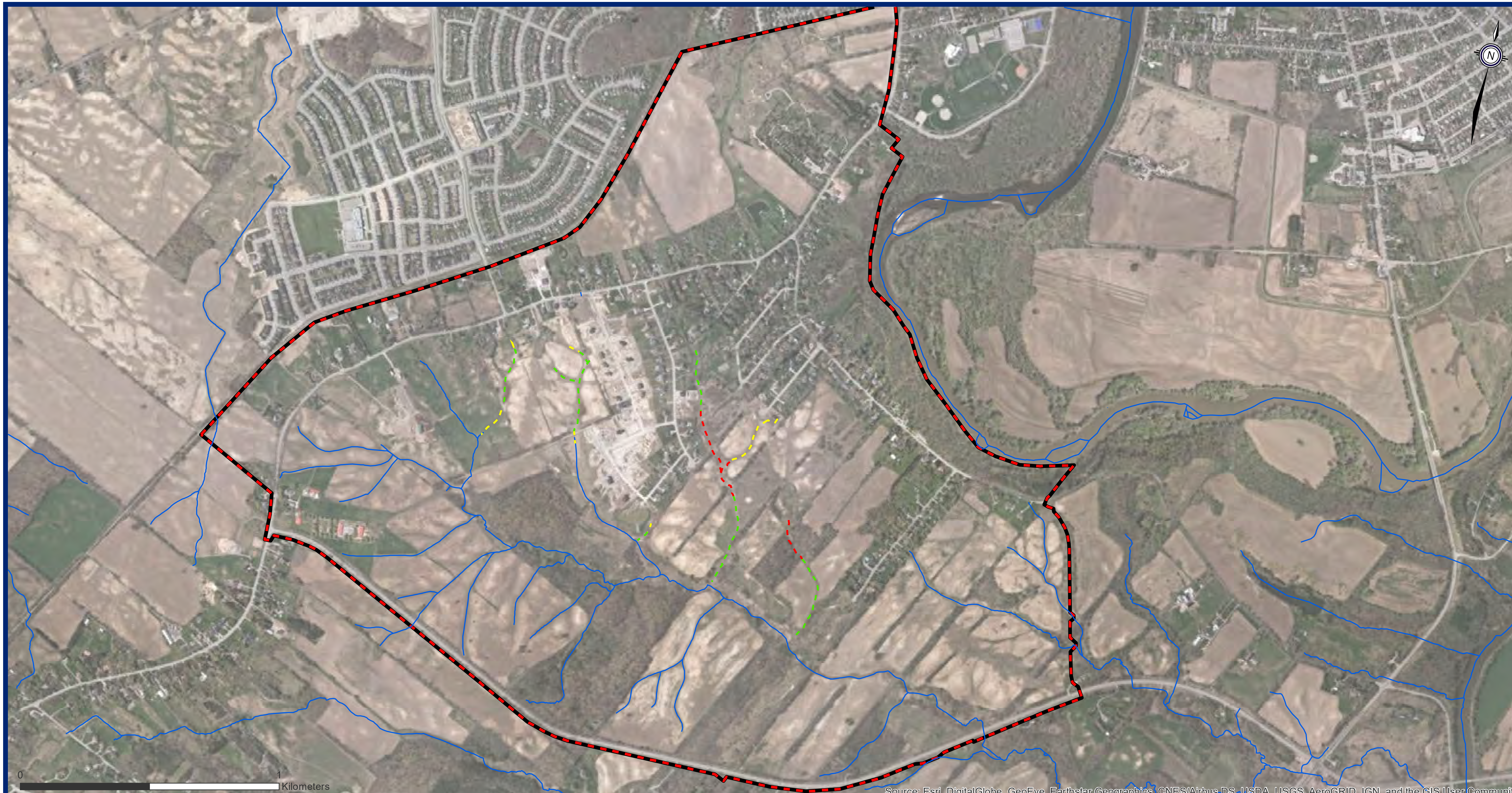
March, 2019
NAD 1983 UTM Zone 17N



Boundary Expansion Lands Master Plan

Preliminary Management Recommendations*

- No Management Required
- Mitigation
- Conservation
- Protection
- Rill Erosion
- Property Parcel
- Drainage Network
- Study Area

* Site access for these features was not granted by landowner or occurred after November 2018. Therefore, the full three season Headwater Drainage Feature Assessment was incomplete. Further assessment is required to confirm appropriate management strategy for these features.

Figure 4-3
Headwater Drainage Features
Revised Management Recommendation - Tutela Heights

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March, 2019
NAD 1983 UTM Zone 17N

References

Credit Valley Conservation (CVC) & Toronto and Region Conservation Authority (TRCA). 2014. Evaluation, Classification and Management of HDFs Guidelines.

Dunne, T. and Leopold, L.B. 1978. Water in Environmental Planning. Freeman, New York.

Environmental Protection Agency (EPA). 2011. Headwater streams – what are they and what do they do? Office of Research and Development, National Exposure Research Laboratory, Ecological Exposures Research Division.

Fraser, H. and Fleming, R. 2001. Environmental benefits of tile drainage – literature review. University of Guelph. Prepared for Land Improvement Contractors of Ontario (LICO).

Gomi, T., Sidle, R.C., and Richardson, J.S. 2002. Understanding processes and downstream linkages of headwater systems. BioScience, Vol. 52.

Goudie, A., Atkinson, B.W., Gregory, K.J., Simmons, I.G., Stoddart, D.R., and Sugden, D. 1985. The Encyclopedic Dictionary of Physical Geography. Second Edition. Basil Blackwell Ltd.

Holeton, C. 2013. Sources of Nutrients and Sediments in the Grand River Watershed. Grand River Watershed Water Management Plan. Prepared for the Water Quality Working Group.

Horton, R.E. 1945. Erosional development of streams and their drainage basins. Bulletin – Geological Society of America, Vol. 56.

Knighton, D. 1998. Fluvial Forms and Processes. John Wiley & Sons Inc. New York.

Meyer, J.L., Kaplan, L.A., Newbold, D., Strayer, D.L., Woltemade, C.J., Zedler, J.B., Beilfuss, R., Carpenter, Q., Semlitsch, R., Watzin, M.C., and Zedler, P.H. 2003. Where rivers are born: the scientific imperative for defending small streams and wetlands. America Rivers and Sierra Club, USA.

The Ontario Headwaters Institute (OHI). 2016. Protecting Ontario’s Headwaters; Extending the Co-ordinate Land Use Planning Review to preserve Ontario’s natural heritage, watersheds, and ecological integrity.

Peterson, B.J., Wollheim, W.M., Mulholland, P.J., Webster, J.R., Meyer, J.L., Tank, J.L., Marti, E., Bowden, W.B., Valett, H.M., Hershey, A.E., McDowell, W.H., Dodds, W.K., Hamilton, S.K., Gregory, S., and Morrall, D.D. 2001. Control of nitrogen export from watersheds by headwater streams. Science, Vol. 292.

PLAN B Natural Heritage. 2019. Comprehensive Environmental Impact Statement – North Brantford and Tutela Heights Secondary Plan, City of Brantford.

Schlosser, I.J. 1991. Stream fish ecology: a landscape perspective. BioScience, Vol. 41

Schollen & Company Inc. 2006. Markham Small Streams Study – Principles and Strategies for the Protection and Management of Small Drainage Courses. Produced in association with Aquafor Beech Ltd., The Planning Partnership and Lura Consulting for the City of Markham.

Schumm, S.A. 1977. The Fluvial System. John Wiley and Sons, New York.

Stanfield, L.W. 2017. Ontario Stream Assessment Protocol (OSAP). Version 10.

Stanfield, L.W. and Jackson, D.A. 2011. Understanding the factors that influence headwater stream flows in response to storm events. Journal of the American Water Resources Associated, Vol. 47 (2).

Strahler, A.N. 1957. Quantitative analysis of watershed geomorphology. Transactions, American Geophysical Union, Vol. 38.

Toronto and Region Conservation Authority (TRCA). 2007. The Natural Functions of HDFs: A Literature Review.

ATTACHMENT A

Glossary of HDF Feature Types:

- Swale
- Rill
- Gully
- Modified or Constrained;
- Wetland
- No Defined Feature
- Defined Natural Channel
- Multi-thread
- Roadside Ditch

HDFs

The HDFs within the study area were identified through desktop analyses of existing watercourse mapping (obtained from GRCA), and aerial photography. Each of the field identified/verified HDFs was classified according to feature type, which supports the hydrologic classification. Feature types identified included nine (9) categories which are described and illustrated in the table below.

Type	Description	Photo
Swale	A depression in regions of undulating glacial moraine, a trough between beach ridges produced by erosion, or an area of low ground between dune ridges (Goudie et al, 1985). A shallow gentle depression in the earths surface that collects some water, considered a drainage course, not a stream (Schollen & Company Inc., 2006). Trough-like depression that carries water flow during rainstorms or snowmelt, has ill-defined banks. Water conveyance primary function. Flow not sufficiently sustained to cause substrate sorting or to prevent instream vegetation (CVC and TRCA, 2014).	

		
Rill	A small (maximum of a few centimetres) channel that changes location with every run-off and that can be obliterated by ploughing. Rills, formed by the merging of sheet wash into channel flow, may join to form larger permeant gullies. Rills are conduits for water and sediment transport (Goudie et al, 1985). Microchannels with typical dimensions of 50-300 mm wide and up to 300 mm deep. Usually discontinuous, ephemeral features often obliterated between one storm and the next. Persistent rilling requires slopes steeper than 2-3^{o} (Knighton, 1998). Rills observed within the study area typically originated at a headcut on a slope and terminated at the downstream limit with a depositional fan-like feature where the slope angles decreased. Under the CVC and TRCA (2014) guideline, rills are not included in headwater features that require management recommendations.	

		
Gully	Relatively permanent water courses, steep sides, low width depth ratios and stepped profiles with characteristically headcut at the upslope end (Knighton, 1998). Gullies are typically considered to have a depth greater than 0.6 m.	

Modified or Constrained	Channel banks and sorted substrate are visible and there is evidence that the stream has been historically dredged or straightened (Stanfield, 2017). Anthropogenic influence of the feature is readily identifiable.	 

Wetland (Linear)	Feature with sustained water storage function. Abundant water has caused the formation of hydric soils and has favoured the dominance of either hydrophytic plants or water tolerant plants (CVC and TRCA, 2014). Depression that supports wetland vegetation and or is underlain by hydric soils that collects and conveys runoff along a linear flow path – Markham Small Streams Study	
No Defined Feature	No identifiable depression to convey water – water transport through overland or sheet flow (Stanfield, 2017).	

Defined Natural Channel	Channel banks and sorted substrates visible; no evidence that feature was historically dredged or straightened (Stanfield, 2017). An identifiable depression in the ground in which a flow of water occurs regularly or continuously (CVC and TRCA, 2014).	
Multi-thread	Multiple channels for one flow source; multi-thread channels are subdivided at low-water stages by multiple midstream bars of sand or gravel. At high water, many or all bars are submerged (Stanfield, 2017).	

Roadside Ditch	A watercourse that conveys roadside and other impervious cover drainage that has been directed to run parallel with a roadway (Stanfield, 2017).	

ATTACHMENT B

Summary of feature attributes observed and recorded

HDF FUNCTIONAL CLASSIFICATION AND MANAGEMENT TABLE

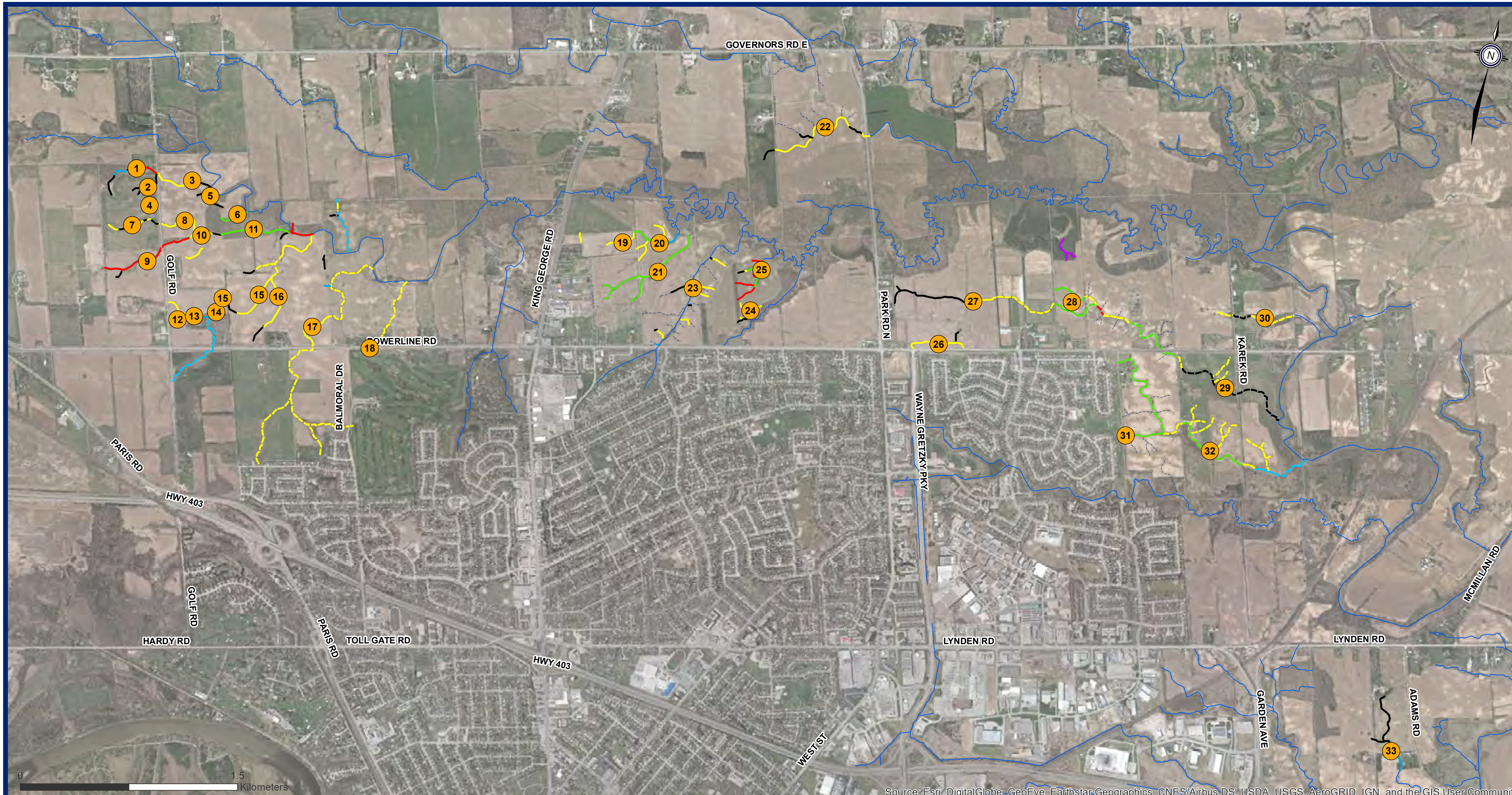
#	Name	Date (Survey 1)	Feature Type	Hydrological Evaluation	Riparian Evaluation	Connectivity	Hydrologic Classification	Riparian Classification	Protocol Management	Preliminary Management	Reasoning for Management Alteration (if applicable)
0	UJT2-61H1g	24/04/2018	No Defined Feature	Interstitial Flow	Meadow	Connected	Valued or Contributing	Valued	Mitigation	Mitigation	
1	LJT6-2-H1	27/04/2018	Swale	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
2	LJT4-H3A	23/04/2018	Modified or Constrained	Surface Flow - Minimal	Meadow	Connected	Valued or Contributing	Valued	Mitigation	Mitigation	
3	Ljt5-h4	23/04/2018	Modified or Constrained	Surface Flow - Minimal	Meadow	Connected	Valued or Contributing	Valued	Mitigation	Mitigation	
4	LJT4-H1C	23/04/2018	Wetland	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
5	LJT5-H1a	23/04/2018	No Defined Feature	Standing Water	Wetland	Connected	Limited or Recharge	Valued	No Management Required	Mitigation	Feature present through three season assessment - potential wetland plants
6	FCT3-2-H1	27/04/2018	No Defined Feature	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Mitigation required upstream - connectivity.
7	Ujt2-8-h2e	24/04/2018	Swale	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	No Management Required	Local swale - no defined feature to connect to drainage network.
8	Ujt2-8-h2g	24/04/2018	No Defined Feature	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
9	Ujt2-4-h3a	24/04/2018	Swale	Surface Flow - Substantial	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
10	Gdt1-2-h6	27/04/2018	No Defined Feature	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
11	Ujt2-8-h2c	24/04/2018	No Defined Feature	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	No Management Required	Roadside ditch
12	Ujt2-8-h2D	24/04/2018	Swale	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	No Management Required	Local swale - no defined feature to connect to drainage network.
13	Ujt2-8-h2f	24/04/2018	Swale	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	No Management Required	Function of headwater feature can be mitigated in main tributary.
14	UJT2-8	24/04/2018	Swale	Surface Flow - Substantial	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
15	Ujt2-8a	24/04/2018	Modified or Constrained	Surface Flow - Substantial	Meadow	Connected	Valued or Contributing	Valued	Mitigation	Conservation	Conservation required upstream; defined feature from anthropogenic modification.
16	Ujt2-8b	24/04/2018	Defined Natural Channel	Surface Flow - Substantial	Forest	Connected	Valued or Contributing	Important	Conservation	Conservation	
17	Ujt2-8c	24/04/2018	No Defined Feature	Surface Flow - Substantial	Wetland	Connected	Valued or Contributing	Important	Conservation	Conservation	
18	Ujt8d	24/04/2018	Defined Natural Channel	Surface Flow - Substantial	Scrubland	Connected	Valued or Contributing	Important	Conservation	Conservation	
19	Ujt2-8-h4a	24/04/2018	Defined Natural Channel	Surface Flow - Substantial	Forest	Connected	Valued or Contributing	Important	Conservation	Conservation	
20	Ujt2-8-h3	24/04/2018	No Defined Feature	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	No Management Required	No defined feature.
21	Ujt3-8-h4b	24/04/2018	No Defined Feature	Surface Flow - Minimal	Scrubland	Connected	Valued or Contributing	Important	Conservation	Conservation	
22	UJT2-4-H1	24/04/2018	No Defined Feature	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	No Management Required	No defined feature.
23	UJT2-2-H10	24/04/2018	Defined Natural Channel	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
24	UJT2-2-H11	24/04/2018	No Defined Feature	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	No Management Required	No defined feature; not connected to drainage system.
25	UJT2-2-H12	24/04/2018	No Defined Feature	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	No Management Required	No defined feature; not connected to drainage system.
26		24/04/2018	Modified or Constrained	Surface Flow - Substantial	Meadow	Connected	Valued or Contributing	Valued	Mitigation	Mitigation	
27	UJT2-6B	24/04/2018	No Defined Feature	Surface Flow - Minimal	Wetland	Connected	Valued or Contributing	Important	Conservation	Conservation	
28		24/04/2018	No Defined Feature	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
29		24/04/2018	No Defined Feature	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	No Management Required	No defined feature.
30		24/04/2018	No Defined Feature	Surface Flow - Minimal	Forest	Connected	Valued or Contributing	Important	Conservation	Mitigation	No defined feature.
31		24/04/2018	Wetland	Standing Water	Forest	Connected	Valued or Contributing	Important	Conservation	Conservation	
32		24/04/2018	No Defined Feature	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
33	Ljt6-22-h0	27/04/2018	Swale	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
34	LJT6-22H1A	27/04/2018	Swale	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
35	Ljt6-21-h1	27/04/2018	Swale	Surface Flow - Minimal	Wetland	Connected	Valued or Contributing	Important	Conservation	Protection	
36	Ljt6-21h1a	27/04/2018	Swale	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	No Management Required	Functions of headwater feature maintained in connected features.
37		27/04/2018	Wetland	Surface Flow - Substantial	Cropped Land	Connected	Valued or Contributing	Important	Conservation	Conservation	
38	LJT6-1	27/04/2018	Wetland	Surface Flow - Minimal	Wetland	Connected	Valued or Contributing	Important	Conservation	Conservation	
39	Ljt6-22-1b	27/04/2018	Defined Natural Channel	Surface Flow - Substantial	Wetland	Connected	Important	Important	Protection	Protection	
40	UJT2-61H1a	24/04/2018	Swale	Interstitial Flow	Wetland	Connected	Valued or Contributing	Important	Conservation	Mitigation	Mitigation strategy required upstream and downstream of segment.
41	UJT2-61H1b	24/04/2018	Swale	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Mitigation strategy required upstream and downstream of segment.
42	UJT2-61H1c	24/04/2018	No Defined Feature	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Mitigation strategy required upstream and downstream of segment.
43	UJT2-61H1d	24/04/2018	Swale	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
44	UJT2-61H1e	24/04/2018	No Defined Feature	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
45	UJT2-61H1f	24/04/2018	Swale	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
46	UJT2-61H1h	24/04/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Important	Mitigation	Mitigation	
47	UJT2-6-H0K	24/04/2018	Modified or Constrained	Surface Flow - Substantial	Meadow	Connected	Valued or Contributing	Valued	Mitigation	Conservation	Conservation required upstream - connectivity.
48	UJT2-6-H0L	24/04/2018	Modified or Constrained	Surface Flow - Minimal	Scrubland	Connected	Valued or Contributing	Important	Conservation	Conservation	
49	UJT2-6-H0M	24/04/2018	No Defined Feature	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	No Management Required	Funciton of headwater feature can be mitigated in main tributary.
50	UJT2-6-H2A	24/04/2018	Swale	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
51	UJT2-6-H2B	24/04/2018	Swale	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
52	UJT2-6-A	24/04/2018	No Defined Feature	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Conservation	Conservation required upstream - connectivity.
53	UJT2-6-B	24/04/2018	Swale	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Conservation	Conservation required upstream - connectivity.
54	UJT2-6-C	24/04/2018	Swale	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Conservation	Conservation required upstream - connectivity.
55	UJT2-6-D	24/04/2018	Modified or Constrained	Surface Flow - Minimal	Scrubland	Connected	Valued or Contributing	Important	Conservation	Conservation	
56	UJT2-6-E	24/04/2018	Modified or Constrained	Standing Water	Scrubland	Connected	Limited or Recharge	Important	No Management Required	Conservation	Conservation required upstream - connectivity.
57	UJT2-61H0A	24/04/2018	Swale	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
58	UJT2-61H0B	24/04/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
59	Ujt2–0-h	24/04/2018	No Defined Feature	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
60	Ujt2–0-h	24/04/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	No Management Required	Poorly defined swale.
61	UJ2A	24/04/2018	Swale	No Surface Water	Cropped Land	Not Connected	Valued or Contributing	Limited	Mitigation	Conservation	GRCA-recommended update 20181114

#	Name	Date (Survey 1)	Feature Type	Hydrological Evaluation	Riparian Evaluation	Connectivity	Hydrologic Classification	Riparian Classification	Protocol Management	Preliminary Management	Reasoning for Management Alteration (if applicable)
62	UJ2A	24/04/2018	Swale	Standing Water	Forest	Connected	Limited or Recharge	Important	No Management Required	Conservation	GRCA-recommended update to Conservation 20181114
63	UJ2C	24/04/2018	Defined Natural Channel	Surface Flow - Substantial	Forest	Connected	Valued or Contributing	Important	Conservation	Conservation	Tiled drained. Removal - increases in flow. Future attenuation required.
64	UJ2A	24/04/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Conservation	GRCA-recommended updates 20181114
65	UJ2A-B	24/04/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Conservation	GRCA-recommended updates 20181114
66	LJT5-H5a	23/04/2018	Defined Natural Channel	Surface Flow - Substantial	Meadow	Connected	Valued or Contributing	Valued	Mitigation	Mitigation	
67	LJT5h6A	23/04/2018	Swale	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
68	LJT5h6b	23/04/2018	No Defined Feature	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
69	Ljt5-h7A	23/04/2018	Swale	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
70	Ljt5-h7C	23/04/2018	Swale	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
71	Ljt5-h10b	23/04/2018	Swale	No Surface Water	Meadow	Connected	Limited or Recharge	Valued	No Management Required	No Management Required	
72	Ljt5-h10A	23/04/2018	No Defined Feature	No Surface Water	Meadow	Connected	Limited or Recharge	Valued	No Management Required	No Management Required	
73	LJT4-H1A	23/04/2018	No Defined Feature	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Mitigation required upstream - connectivity.
74	LJT4-H1B	23/04/2018	Swale	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
75	LJT4-H1D	23/04/2018	Swale	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
76	LJT4-H1E	23/04/2018	No Defined Feature	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
77	LJT4-h6	23/04/2018	Modified or Constrained	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
78	LJT4-h5	23/04/2018	Swale	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Gully formation at downstream limit of feature - indication of feature activity.
79	LJT4	23/04/2018	Wetland	Standing Water	Wetland	Connected	Valued or Contributing	Important	Conservation	Conservation	
80	Ljt5-h6	23/04/2018	Swale	Interstitial Flow	Meadow	Connected	Valued or Contributing	Valued	Mitigation	Mitigation	
81	Ljt5-h?	23/04/2018	No Defined Feature	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Gully formation at downstream limit of feature - indication of feature activity.
82	Ujt2-4-h4	24/04/2018	Swale	Surface Flow - Substantial	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	No Management Required	Poorly defined swale.
83	UJT2-4-H3	24/04/2018	No Defined Feature	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Mitigation required upstream - connectivity.
84	Ljt6-21-h1	27/04/2018	Swale	Surface Flow - Minimal	Wetland	Connected	Valued or Contributing	Important	Conservation	Protection	
85	Ljt5-h12A	23/04/2018	Swale	Surface Flow - Minimal	Meadow	Connected	Valued or Contributing	Valued	Mitigation	Mitigation	
86	Fct3-2h0a	27/04/2018	No Defined Feature	Interstitial Flow	Cropped Land	Not Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
87	Fct3-2h0c	27/04/2018	Swale	Surface Flow - Minimal	Cropped Land	Not Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Urban flow conveyance
88	F2-a-h1b	27/04/2018	Swale	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
89	F2-a-h1a	27/04/2018	Swale	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
90	F2ah1b	27/04/2018	Wetland	Surface Flow - Substantial	Scrubland	Connected	Valued or Contributing	Important	Conservation	Protection	GRCA-recommended updates 20181114
91	Gd-4a-h1	27/04/2018	Defined Natural Channel	Surface Flow - Substantial	Lawn	Connected	Valued or Contributing	Contributing	Mitigation	Mitigation	
92	Gdt1-2-h5a	27/04/2018	No Defined Feature	Surface Flow - Substantial	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
93	Fct3-2-h2	27/04/2018	No Defined Feature	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
94	Fct3-2-h1	27/04/2018	No Defined Feature	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
95		23/04/2018	No Defined Feature	Interstitial Flow	Meadow	Connected	Valued or Contributing	Valued	Mitigation	Mitigation	
96	Ljt5-h10A	27/04/2018	No Defined Feature	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
97	Ljt5-h10B	27/04/2018	Swale	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
98	Ljt5-h10c	27/04/2018	Swale	Interstitial Flow	Meadow	Connected	Valued or Contributing	Valued	Mitigation	Mitigation	
99	Ljt6-221a	27/04/2018	Wetland	Surface Flow - Minimal	Wetland	Connected	Important	Important	Protection	Protection	
100	Fct3-2h0d	23/04/2018	Swale	Interstitial Flow	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Urban flow conveyance
101	Fct3-2h0e	27/04/2018	Swale	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Urban flow conveyance
102		27/04/2018	Wetland	Surface Flow - Substantial	Scrubland	Connected	Valued or Contributing	Important	Conservation	Protection	GRCA-recommended updates 20181114
103		27/04/2018	Gully	Surface Flow - Substantial	Forest	Connected	Valued or Contributing	Important	Conservation	Conservation	
104		27/04/2018	Gully	Surface Flow - Substantial	Forest	Connected	Valued or Contributing	Important	Conservation	Conservation	
105	UJT2-6A	23/04/2018	Modified or Constrained	Surface Flow - Substantial	Cropped Land	Connected	Valued or Contributing	Important	Conservation	Conservation	
106	LJT6-2-H1	27/04/2018	Swale	Surface Flow - Minimal	Meadow	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
107	Ljt5-h8A	23/04/2018	No Defined Feature	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	No Management Required	No Management Required	
108	LJT4-H2A	23/04/2018	Modified or Constrained	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
109	LJT1-j	23/04/2018	No Defined Feature	Standing Water	Lawn	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Flow attenuation.
110	LJT1-e	23/04/2018	Swale	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Flow attenuation.
111	LJT1-f	23/04/2018	Swale	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Flow attenuation.
112	LJT1-g	23/04/2018	Swale	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Flow attenuation.
113	LJT1-i	23/04/2018	Swale	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Flow attenuation.
114	LJT1-i	23/04/2018	Swale	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Flow attenuation.
115	LJT1-h	23/04/2018	Swale	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Flow attenuation.
116	LJT1-c	23/04/2018	Swale	Standing Water	Wetland	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Flow attenuation.
117	LJT1-d	23/04/2018	No Defined Feature	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Flow attenuation.
118	Ljt1-h8a	23/04/2018	No Defined Feature	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
119	UJ3E	11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
120	NAME	24/04/2018	Wetland	Surface Flow - Substantial	Forest	Connected	Valued or Contributing	Important	Conservation	Conservation	
121	UJT2-8	24/04/2018	No Defined Feature	Surface Flow - Substantial	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
122	UJ2A	24/04/2018	No Defined Feature	Standing Water	Forest	Connected	Limited or Recharge	Important	No Management Required	Conservation	Mitigation required downstream; conservation required upstream.
123	UJ2A	24/04/2018	No Defined Feature	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Conservation	GRCA-recommended update 20181114

#	Name	Date (Survey 1)	Feature Type	Hydrological Evaluation	Riparian Evaluation	Connectivity	Hydrologic Classification	Riparian Classification	Protocol Management	Preliminary Management	Reasoning for Management Alteration (if applicable)
							FEATURES WITH LIMITED OR NO PROPERTY ACCESS (further assessment required)				
0	UJT2-3-H2	11/06/2018	Defined Natural Channel	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
1	UJT2-3-H3	11/06/2018	No Defined Feature	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
2	FCT2-H2	08/06/2018	Swale	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	
3	FCT2-H3	08/06/2018	Swale	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	
4	FCT2-H5	08/06/2018	Swale	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	
5	FCT2-H1	08/06/2018	Swale	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	
6	FCT2-H6	08/06/2018	Swale	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	
7	FCT2-H7	08/06/2018	Swale	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
8	UJ3E	11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
9	UJT2-3-H2	11/06/2018	Defined Natural Channel	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
10	UJT2-3-H2	11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Mitigation required upstream - connectivity.
11		08/06/2018	Swale	Standing Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	Mitigation	Mitigation required upstream - connectivity.
12		08/06/2018	Swale	No Surface Water	Cropped Land	Connected	Limited or Recharge	Limited	No Management Required	No Management Required	
13	FCT3-H2	08/06/2018	Swale	No Surface Water	Meadow	Connected	Limited or Recharge	Valued	No Management Required	No Management Required	
14	FCT3-H1	08/06/2018	Swale	No Surface Water	Meadow	Connected	Limited or Recharge	Valued	No Management Required	No Management Required	
15	FCT2-2	08/06/2018	Wetland	No Surface Water	Wetland	Connected	Valued or Contributing	Important	Conservation	Protection	GRCA recommended updates 20181114
16	FCT3	08/06/2018	Wetland	Surface Flow - Substantial	Scrubland	Connected	Valued or Contributing	Important	Conservation	Protection	GRCA-recommended updates 20181114
17	FCT2-1	08/06/2018	Wetland	No Surface Water	Wetland	Connected	Valued or Contributing	Important	Conservation	Protection	
18	UJT2-1	08/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
19		08/06/2018	Modified or Constrained	Surface Flow - Substantial	Cropped Land	Connected	Important	Limited	Conservation	Conservation	
20		08/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Conservation	GRCA-recommended updates 20181114
21		08/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
22		08/06/2018	Swale	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
23		08/06/2018	Wetland	No Surface Water	Wetland	Connected	Valued or Contributing	Important	Conservation	Protection	GRCA-recommended updates 20181114
24		08/06/2018	Swale	No Surface Water	Wetland	Connected	Valued or Contributing	Important	Conservation	Protection	GRCA-recommended updates 20181114
25		08/06/2018	Defined Natural Channel	Interstitial Flow	Scrubland	Connected	Valued or Contributing	Important	Conservation	Protection	GRCA-recommended updates 20181114
26		08/06/2018	Swale	No Surface Water	Wetland	Connected	Valued or Contributing	Important	Conservation	Protection	GRCA-recommended updates 20181114
27		08/06/2018	Wetland	Surface Flow - Minimal	Wetland	Connected	Valued or Contributing	Important	Conservation	Conservation	
28		08/06/2018	Wetland	Surface Flow - Minimal	Wetland	Connected	Valued or Contributing	Important	Conservation	Conservation	
29	FCT3	08/06/2018	Swale	Surface Flow - Substantial	Scrubland	Connected	Valued or Contributing	Valued	Mitigation	Conservation	Conservation upstream - connectivity.
30	FCT3	08/06/2018	Swale	No Surface Water	Meadow	Connected	Valued or Contributing	Valued	Mitigation	Protection	GRCA- recommended update 20181114
31		08/06/2018	Swale	Interstitial Flow	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
32		08/06/2018	Wetland	Surface Flow - Minimal	Wetland	Connected	Valued or Contributing	Important	Conservation	Conservation	
33	FCT3	08/06/2018	Wetland	Surface Flow - Substantial	Wetland	Connected	Valued or Contributing	Important	Conservation	Protection	GRCA-recommended updates 20181114
34		08/06/2018	Swale	Surface Flow - Minimal	Scrubland	Connected	Valued or Contributing	Important	Mitigation	Protection	Wetland. GRCA-recommended updates 20181114
35	FCT4	08/06/2018	No Defined Feature	Interstitial Flow	Scrubland	Connected	Valued or Contributing	Important	Mitigation	Protection	Wetland. GRCA-recommended updates 20181114
36	FCT4	08/06/2018	Swale	Interstitial Flow	Scrubland	Connected	Valued or Contributing	Important	Mitigation	Protection	Wetland. GRCA-recommended updates 20181114
37		08/06/2018	Swale	Surface Flow - Substantial	Scrubland	Connected	Valued or Contributing	Valued	Mitigation	Protection	GRCA-recommended updates 20181114
38	F2ah1b	27/04/2018	Wetland	Surface Flow - Substantial	Scrubland	Connected	Valued or Contributing	Important	Conservation	Protection	GRCA-recommended updates 20181114
39		27/04/2018	Defined Natural Channel	Interstitial Flow	Scrubland	Connected	Valued or Contributing	Important	Conservation	Conservation	
40		27/04/2018	No Defined Feature	No Surface Water	Meadow	Connected	Limited or Recharge	Valued	Mitigation	Protection	Wetland feature
41		27/04/2018	Wetland	Standing Water	Wetland	Connected	Limited or Recharge	Important	Conservation	Conservation	Wetland feature
42		27/04/2018	Wetland	Standing Water	Wetland	Connected	Limited or Recharge	Important	Conservation	Conservation	Wetland feature
43		27/04/2018	Modified or Constrained	Surface Flow - Minimal	Wetland	Connected	Valued or Contributing	Important	Conservation	Mitigation	Modified feature to stormwater pond
44		27/04/2018	Modified or Constrained	Surface Flow - Substantial	Wetland	Connected	Valued or Contributing	Important	Conservation	Conservation	
45		27/04/2018	Wetland	Surface Flow - Minimal	Wetland	Connected	Valued or Contributing	Important	Conservation	Protection	Wetland feature
46		27/04/2018	Swale	Surface Flow - Substantial	Wetland	Connected	Valued or Contributing	Important	Conservation	Conservation	
47		27/04/2018	No Defined Feature	Standing Water	Scrubland	Connected	Limited or Recharge	Important	Mitigation	Mitigation	
48		27/04/2018	No Defined Feature	Standing Water	Meadow	Connected	Limited or Recharge	Valued	Mitigation	Mitigation	
49		27/04/2018	Wetland	Standing Water	Wetland	Connected	Limited or Recharge	Important	Conservation	Mitigation	Outside of unevaluated wetland
50		27/04/2018	Wetland	Interstitial Flow	Scrubland	Connected	Valued or Contributing	Important	Conservation	Conservation	
51		27/04/2018	Swale	Surface Flow - Minimal	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
52		27/04/2018	Wetland	Surface Flow - Minimal	Wetland	Connected	Valued or Contributing	Important	Conservation	Protection	Wetland feature
53		27/04/2018	Wetland	Interstitial Flow	Scrubland	Connected	Valued or Contributing	Important	Conservation	Conservation	
54		27/04/2018	Wetland	Interstitial Flow	Scrubland	Connected	Valued or Contributing	Important	Conservation	Protection	Wetland feature
55		27/04/2018	Wetland	Standing Water	Wetland	Connected	Limited or Recharge	Important	Conservation	Conservation	
56		27/04/2018	Wetland	Standing Water	Wetland	Connected	Limited or Recharge	Important	Conservation	Conservation	
57	UJ3E	11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
58		11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
59		11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
60		11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
61		11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	

#	Name	Date (Survey 1)	Feature Type	Hydrological Evaluation	Riparian Evaluation	Connectivity	Hydrologic Classification	Riparian Classification	Protocol Management	Preliminary Management	Reasoning for Management Alteration (if applicable)
62		11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
63		11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
64		11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
65		11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
66		11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
67		11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
68		11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
69		11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
70		11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
71		11/06/2018	Swale	No Surface Water	Cropped Land	Connected	Valued or Contributing	Limited	Mitigation	Mitigation	
72		11/06/2018	Defined Natural Channel	Surface Flow - Substantial	Forest	Connected	Important	Important	Protection	Conservation	
73		11/06/2018	Defined Natural Channel	Surface Flow - Substantial	Forest	Connected	Important	Important	Protection	Conservation	
74		11/06/2018	Defined Natural Channel	Surface Flow - Substantial	Forest	Connected	Important	Important	Protection	Conservation	
75		11/06/2018	Defined Natural Channel	Surface Flow - Substantial	Forest	Connected	Important	Important	Protection	Conservation	
76		11/06/2018	Defined Natural Channel	Surface Flow - Substantial	Forest	Connected	Important	Important	Protection	Conservation	
77		11/06/2018	Wetland	Standing Water	Wetland	Connected	Limited or Recharge	Important	Conservation	Mitigation	Upstream of unevaluated wetland
78		11/06/2018	Swale	Surface Flow - Substantial	Wetland	Connected	Valued or Contributing	Important	Conservation	Mitigation	outside of wetland delineation

ATTACHMENT C
Photo Log of All HDF



Boundary Expansion Lands Master Plan

Feature Type

- Defined Natural Channel
- Gully
- Modified or Constrained
- No Defined Feature
- Swale
- Wetland

Feature Type*

- Defined Natural Channel
- Modified or Constrained
- No Defined Feature
- Swale
- Wetland
- Rill Erosion

- Watercourse
- Property Parcel
- General Photo Location & Feature Number

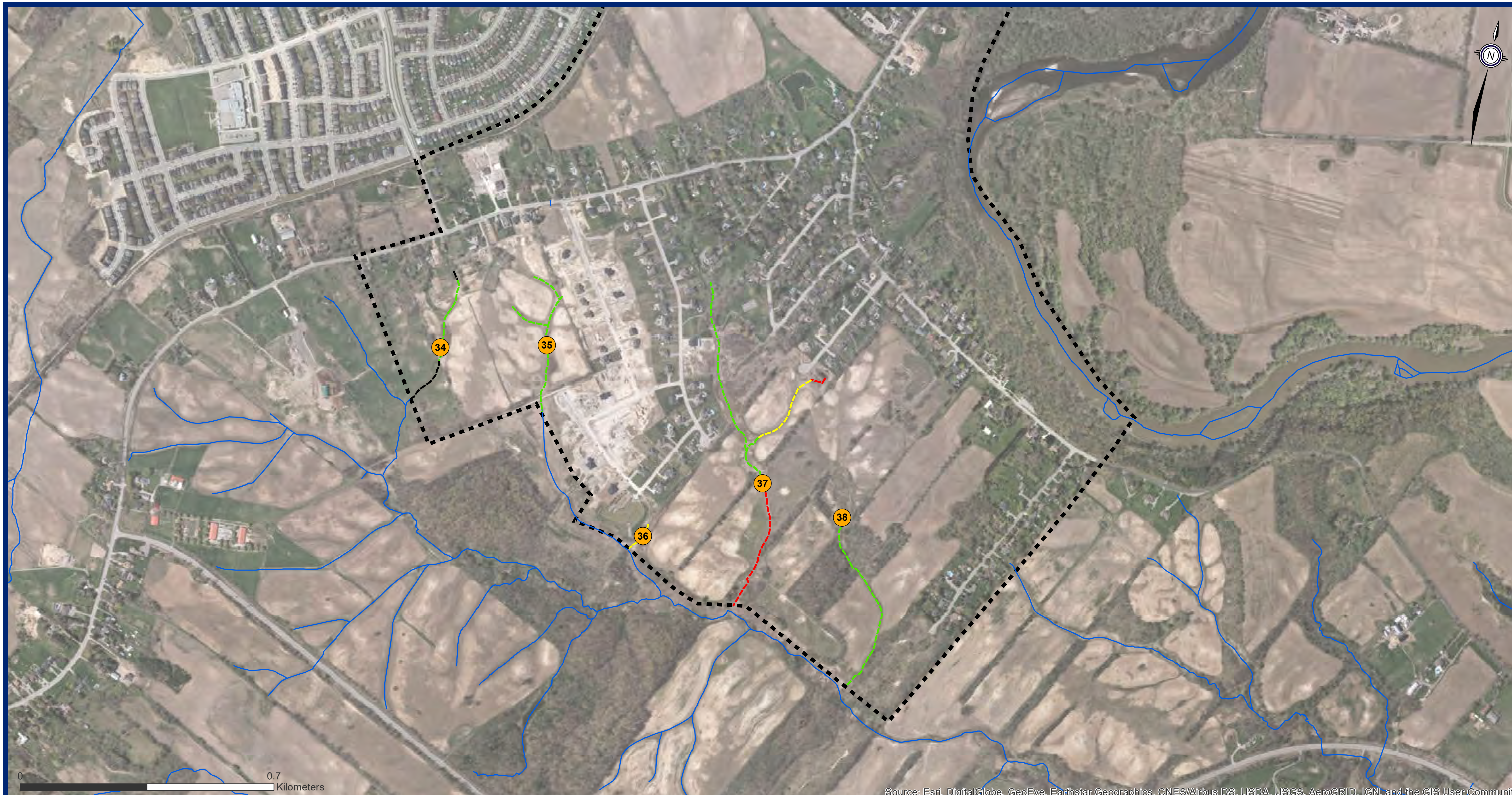
* Site access for these watercourses occurred after April 2018 and thus the full three season Headwater Drainage Feature Assessment was incomplete. Further assessment is required to confirm appropriate management strategy for these features.

Headwater Drainage Features

Photo Log Locations

Northern BEA

March, 2019
NAD 1983 UTM Zone 17N



THE CORPORATION OF THE CITY OF BRANTFORD

Boundary Expansion Lands Master Plan

Feature Type*

- Defined Natural Channel
- Modified or Constrained
- No Defined Feature
- Swale
- Wetland
- Rill Erosion
- Property Parcel
- Drainage Network
- General Photo Location & Feature Number

* Site access for these watercourses occurred after November 2018 and thus the full three season Headwater Drainage Feature Assessment was incomplete. Further assessment is required to confirm appropriate management strategy for these features.

Headwater Drainage Features

Photo Log Locations

Tutela Heights

ecosystem recovery inc. PROFESSIONAL ENGINEERS

March, 2019

NAD 1983 UTM Zone 17N

FEATURE 1: Northern BEA

CAPTION: Downstream view to Golf Road culvert.

Site visit #1 – April 2018

CAPTION: Downstream view towards Golf Road from landowner pedestrian bridge.
Site visit #1 – April 2018

CAPTION: Feature through forested area.

Site visit #1 – April 2018

CAPTION: Feature through forested area.

Site visit #1 – April 2018

FEATURE 2: Northern BEA

CAPTION: Roadside drainage feature along Golf Road, downstream view.
Site visit #1 – April 2018

CAPTION: Caption.

Site visit #1 – April 2018

CAPTION: Feature cut through fine sediment in agricultural field.

Site visit #1 – April 2018

CAPTION: Downstream view towards Golf Road, feature through plowed field.
Site visit #1 – April 2018

FEATURE 3: Northern BEA	
	
CAPTION: Caption. Site visit #1 – April 2018	**CAPTION:** Upstream view to Golf Road; feature well-defined, through plowed field. Site visit #1 – April 2018
	
CAPTION: Downstream view; feature dissipates in corn field. Site visit #1 – April 2018	**CAPTION:** Feature well-defined in downstream section. Site visit #1 – April 2018

FEATURE 4: Northern BEA

CAPTION: Small poorly-defined feature in agricultural field.

Site visit #1 – April 2018

CAPTION: Small poorly-defined feature in agricultural field; upstream view.
Site visit #1 – April 2018

CAPTION: Small poorly-defined feature in agricultural field, upstream view.
Site visit #1 – April 2018

CAPTION: Some rill formation in exposed soil material.

Site visit #1 – April 2018

FEATURE 5: Northern BEA

<table>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Poorly-defined feature through forested area; saturated soils.
Site visit #1 – April 2018</td><td>CAPTION: Poorly-defined feature through forested area; saturated soils.
Site visit #1 – April 2018</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Poorly-defined feature through forested area; saturated soils.
Site visit #1 – April 2018</td><td>CAPTION: Poorly-defined feature through agricultural field – upstream view.
Site visit #1 – April 2018</td></tr>
</table>

<table>
<tr><th colspan="2">FEATURE 7: Northern BEA</th></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Upstream view of rill/head cut formation.

Site visit #1 – April 2018</td><td>CAPTION: Upstream view – pooled water in drainage feature.

Site visit #1 – April 2018</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Upstream view of feature to head cut formation.
Site visit #1 – April 2018</td><td>CAPTION: Vegetation at upstream limit of drainage feature.
Site visit #1 – April 2018</td></tr>
</table>

FEATURE 8: Northern BEA	
	
CAPTION: Caption. Site visit #1 – April 2018	**CAPTION:** Caption. Site visit #1 – April 2018
	
CAPTION: Caption. Site visit #1 – April 2018	**CAPTION:** Caption. Site visit #1 – April 2018

FEATURE 8: Northern BEA

	
CAPTION: Caption. Site visit #1 – April 2018	**CAPTION:** Caption. Site visit #1 – April 2018
	
CAPTION: Caption. Site visit #1 – April 2018	**CAPTION:** Caption. Site visit #1 – April 2018

FEATURE 8: Northern BEA

	
CAPTION: Upstream view to Golf Road; no flow within feature. Site visit #1 – April 2018	**CAPTION:** Some sorting of sediment within drainage feature. Site visit #1 – April 2018
	
CAPTION: Upstream view – feature through agricultural field. Site visit #1 – April 2018	**CAPTION:** Multiple flow channels within feature - local. Site visit #1 – April 2018

FEATURE 9: Northern BEA

CAPTION: Downstream view to Golf Road; well-defined feature.

Site visit #1 – April 2018

CAPTION: Upstream view – feature narrows in width.

Site visit #1 – April 2018

CAPTION: Overview of riparian vegetation; feature located in agricultural field.
Site visit #1 – April 2018

CAPTION: Flowing condition of feature; narrow riparian corridor in agricultural field.
Site visit #1 – April 2018

FEATURE 10: Northern BEA	
	
CAPTION: Hickenbottom pond located at upstream limit of feature, adjacent to Golf Road. Site visit #1 – April 2018	**CAPTION:** Headcutting at outlet of hickenbottom pond. Site visit #1 – April 2018
	
CAPTION: Upstream view – some sediment sorting in feature. Site visit #1 – April 2018	**CAPTION:** Downstream view of feature, poorly-defined, into forested area from agricultural field (corn). Site visit #1 – April 2018

<table>
<tr><th colspan="2">FEATURE 11: Northern BEA</th></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Outlet pool at upstream limit of drainage feature.

Site visit #1 – April 2018</td><td>CAPTION: Pooling in feature at upstream limit at outlet pool.

Site visit #1 – April 2018</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Feature becomes poorly-defined through forested area; saturated soils in floodplaoin.
Site visit #1 – April 2018</td><td>CAPTION: Vegetation growing through poorly-defined feature; saturated soils.
Site visit #1 – April 2018</td></tr>
</table>

FEATURE 12: Northern BEA	
	
CAPTION: Drainage feature through agricultural (corn) field. Site visit #1 – April 2018	**CAPTION:** Outlet from Golf Road to drainage feature. Site visit #1 – April 2018
	
CAPTION: Standing water through drainage feature. Site visit #1 – April 2018	**CAPTION:** Drainage feature loses definition; downstream view. Site visit #1 – April 2018

FEATURE 13: Northern BEA

	
CAPTION: Upstream limit of drainage feature. Site visit #1 – April 2018	**CAPTION:** Pond feature located upstream of headwater feature. Site visit #1 – April 2018
	
CAPTION: Downstream limit of pond feature – upstream view. Site visit #1 – April 2018	**CAPTION:** Drainage feature dissipates downstream of pond. Site visit #1 – April 2018

<table>
<tr><td colspan="2">FEATURE 14: Northern BEA</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Upstream view of feature through vegetated area at downstream limit.
Site visit #1 – April 2018</td><td>CAPTION: Feature flow dissipates through vegetated area.

Site visit #1 – April 2018</td></tr>
</table>

FEATURE 15a: Northern BEA	
	
CAPTION: Upstream view of feature through agricultural (corn) field; no flow. Site visit #1 – April 2018	**CAPTION:** Downstream view of feature through agricultural (corn) field; no flow. Site visit #1 – April 2018
	
CAPTION: Feature loses definition in downstream direction. Site visit #1 – April 2018	**CAPTION:** Downstream view of feature at property line. Site visit #1 – April 2018

FEATURE 15b: Northern BEA

CAPTION: Upstream view of drainage feature to property line.
Site visit #1 – April 2018

CAPTION: Feature widens through agricultural field – upstream view.
Site visit #1 – April 2018

CAPTION: Potential groundwater/subsurface water interaction through feature.
Site visit #1 – April 2018

CAPTION: Upstream view of feature at confluence with Jones Creek tributary.
Site visit #1 – April 2018

FEATURE 16: Northern BEA

CAPTION: Upstream view of feature to Powerline Road.
Site visit #1 – April 2018

CAPTION: Downstream view of swale, some gravel substrate.
Site visit #1 – April 2018

CAPTION: Feature through agricultural field.

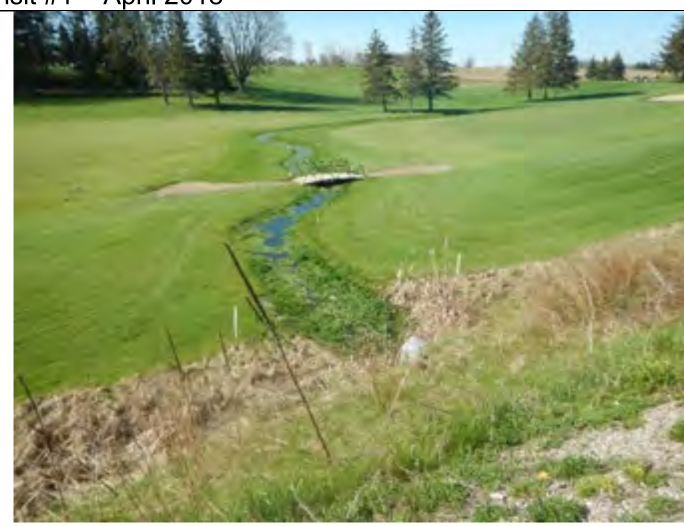
Site visit #1 – April 2018

CAPTION: Downstream view.

Site visit #1 – April 2018

<table>
<tr><td colspan="2">FEATURE 17: Northern BEA</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Upstream view – culvert under Powerline Road. Some gravel substrate present in feature.
Site visit #1 – April 2018</td><td>CAPTION: Downstream view – wide swale feature.
Site visit #1 – April 2018</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Downstream view – wide swale feature.
Site visit #1 – April 2018</td><td>CAPTION: Downstream view of feature at property line.
Site visit #1 – April 2018</td></tr>
</table>

FEATURE 18: Northern BEA

	
CAPTION: Downstream view of feature from Powerline Road. Site visit #1 – April 2018	**CAPTION:** Downstream view of feature from Powerline Road. Site visit #1 – April 2018
	
CAPTION: Rill erosion at upstream limit of feature at Powerline Road. Site visit #1 – April 2018	**CAPTION:** Upstream view of feature south of Powerline Road. Site visit #1 – April 2018

FEATURE 19: Northern BEA

CAPTION: Upstream view of flow in feature.

Site visit #1 – April 2018

CAPTION: Potential groundwater interaction with feature.

Site visit #1 – April 2018

CAPTION: Feature dissipates in downstream direction with loss of flow.
Site visit #1 – April 2018

CAPTION: Feature becomes fan-like in downstream limit.

Site visit #1 – April 2018

<table>
<tr><th colspan="2">FEATURE 20: Northern BEA</th></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Upstream view of feature; vegetation through feature.
Site visit #1 – April 2018</td><td>CAPTION: Well-defined feature; substantial flow.
Site visit #1 – April 2018</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Erosion along feature; exposed roots and undercutting

Site visit #1 – April 2018</td><td>CAPTION: Downstream limit of feature prior to dissipation in floodplain.
Site visit #1 – April 2018</td></tr>
</table>

<table>
<tr><td colspan="2">FEATURE 21: Northern BEA</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Downstream limit of feature prior to entering wooded area.
Site visit #1 – April 2018</td><td>CAPTION: Concrete culvert under agricultural/private crossing.
Site visit #1 – April 2018</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Wetland vegetation through feature.

Site visit #1 – April 2018</td><td>CAPTION: Overview of feature from upstream limit.

Site visit #1 – April 2018</td></tr>
</table>

FEATURE 22: Northern BEA

CAPTION: Downstream limit of feature at Park Road; pooling of flow.
Site visit #1 – April 2018

CAPTION: Feature through agricultural field.
Site visit #1 – April 2018

CAPTION: Upstream limit of feature at private crossing; feature dissipates in field.
Site visit #1 – April 2018

CAPTION: Rill features extent upwards from the feature through the hilly topography.
Site visit #1 – April 2018

FEATURE 23: Northern BEA	
	
CAPTION: Rill feature extending up slope from tributary. Site visit #1 – April 2018	**CAPTION:** Meandering rill feature. Site visit #1 – April 2018
	
CAPTION: Rill feature extending up slope from tributary (2). Site visit #1 – April 2018	**CAPTION:** Depositional nature of rill feature at downstream limit. Site visit #1 – April 2018

FEATURE 24: Northern BEA	
	
CAPTION: Upstream view of dredged feature through field. Site visit #1 – April 2018	**CAPTION:** Downstream view of dredged feature. Site visit #1 – April 2018
	
CAPTION: Feature enters wooded area in downstream limit. Site visit #1 – April 2018	**CAPTION:** Erosion and concrete slab protection at downstream limit of feature into wooded area. Site visit #1 – April 2018

<table>
<tr><td colspan="2">FEATURE 25: Northern BEA</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Downstream view of feature – linear wetland.
Site visit #1 – April 2018</td><td>CAPTION: Rill feature extending up slope from wetland.
Site visit #1 – April 2018</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Downstream view of feature – linear wetland.

Site visit #1 – April 2018</td><td>CAPTION: Wetland feature dissipates at upstream limit in somewhat wooded area.
Site visit #1 – April 2018</td></tr>
</table>

FEATURE 26: Northern BEA	
	
CAPTION: Downstream limit of feature – pooling of water in depression. Site visit #1 – April 2018	**CAPTION:** Upstream view of feature through crop field. Site visit #1 – April 2018
	
CAPTION: Upstream view of f. Site visit #1 – April 2018	**CAPTION:** Outfall at upstream limit of feature at Powerline Road. Site visit #1 – April 2018

<table>
<tr><td colspan="2">FEATURE 27: Northern BEA</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Upstream view of feature through private culvert crossing.
Site visit #1 – April 2018</td><td>CAPTION: Feature through agricultural field; downstream view.
Site visit #1 – April 2018</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Feature at upstream limit of accessible properties; pooling around fence line.
Site visit #1 – April 2018</td><td>CAPTION: Feature at downstream limit of accessible properties; culvert through fence line.
Site visit #1 – April 2018</td></tr>
</table>

<table>
<tr><th colspan="2">FEATURE 28: Northern BEA</th></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Upstream view of feature through grass vegetation.
Site visit #1 – April 2018</td><td>CAPTION: Upstream view of feature within agricultural fields; grass riparian vegetation.
Site visit #1 – April 2018</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Feature relatively well-defined.
Site visit #1 – April 2018</td><td>CAPTION: Features connect at pond in downstream limit.
Site visit #1 – April 2018</td></tr>
</table>

<table>
<tr><td colspan="2">FEATURE 29: Northern BEA</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Upstream view of feature from property access point.
Site visit #1 – April 2018</td><td>CAPTION: Upstream view – feature through culvert under driveway.
Site visit #1 – April 2018</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Downstream view of feature through culvert; dissipates in meadow-like setting.
Site visit #1 – April 2018</td><td></td></tr>
</table>

FEATURE 30: Northern BEA

CAPTION: Upstream limit of main feature; some pooling of water at fence line.
Site visit #1 – June 2018

CAPTION: Wide, vegetated feature through grazing pasture.
Site visit #1 – June 2018

CAPTION: Water pooled upstream of culvert under private crossing.
Site visit #1 – June 2018

CAPTION: Vegetated features extend up slope from main headwater.
Site visit #1 – June 2018

FEATURE 31: Northern BEA	
	
CAPTION: Grated outfall at upstream limit of feature. Site visit #1 – June 2018	**CAPTION:** Pooling of water at upstream limit of feature near outfall. Site visit #1 – June 2018
	
CAPTION: Feature densely vegetated. Site visit #1 – June 2018	**CAPTION:** Feature located within agricultural fields. Site visit #1 – June 2018

<table>
<tr><td colspan="2">FEATURE 32: Northern BEA</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Overview of tilled nature of agricultural field.
Site visit #1 – June 2018</td><td>CAPTION: Headcutting of feature; vegetated feature in downstream.
Site visit #1 – June 2018</td></tr>
<tr><td></td><td></td></tr>
<tr><td>CAPTION: Vegetated feature – upstream view.
Site visit #1 – June 2018</td><td>CAPTION: Vegetated feature up slope – upstream view.
Site visit #1 – June 2018</td></tr>
</table>

FEATURE 33: Garden Avenue

CAPTION: Downstream view of feature at property access limit.
Site visit #1 – April 2018

CAPTION: Pond constructed along feature in private property.
Site visit #1 – April 2018

CAPTION: Upstream view of feature; poorly defined depression with some flow.
Site visit #1 – April 2018

CAPTION: Upstream view of feature – dissipates through agricultural field.
Site visit #1 – April 2018

FEATURE 34: Tutela Heights

CAPTION: Downstream view of feature through dense vegetation.
Site visit #1 – November 2018

CAPTION: Upstream view of feature from culvert under private crossing; pooling located directly upstream of culvert.
Site visit #1 – November 2018

CAPTION: Thick vegetation (herbaceous/grasses) through feature.
Site visit #1 – November 2018

CAPTION: Thick vegetation (herbaceous/grasses) through feature; surrounded by corn fields.
Site visit #1 – November 2018

FEATURE 35: Tutela Heights	
	
CAPTION: Feature extends into corn fields. Site visit #1 –November 2018	**CAPTION:** Dense vegetation present through feature. Site visit #1 – November 2018
	
CAPTION: Some pooled water observed during assessment. Site visit #1 – November 2018	**CAPTION:** Wetland vegetation potentially present - unevaluated. Site visit #1 – November 2018

FEATURE 36: Tutela Heights	
	
CAPTION: Stormwater pond located at upstream limit of feature. Site visit #1 – November 2018	**CAPTION:** Stormwater pond located at upstream limit of feature. Site visit #1 – November 2018
	
CAPTION: Riprap lined outlet to drainage feature. Site visit #1 – November 2018	**CAPTION:** Outlet to drainage feature. Site visit #1 – November 2018

FEATURE 37: Tutela Heights

	
CAPTION: Downstream view of feature; potentially dredged along private laneway. Site visit #1 – November 2018	**CAPTION:** Feature piped through culvert under private laneway. Site visit #1 – November 2018
	
CAPTION: Aquatic vegetation through feature. Site visit #1 – November 2018	**CAPTION:** Riparian corridor relatively small in middle reaches of feature. Site visit #1 – November 2018

FEATURE 38: Tutela Heights

	
CAPTION: Upstream view of feature at property access point; dense vegetation through feature. Site visit #1 – November 2018	**CAPTION:** Upstream view of feature at property access point; dense vegetation through feature. Site visit #1 – November 2018

ATTACHMENT D

Fish and Terrestrial Habitat Assessment Results

Brantford Headwater - Amphibian Call Survey 2019

Stn.	Date	Start Time	End Time	Background Noise	Temp. (C)	Precipitation	Cloud Cover	Beaufort Scale	Species Observed within 100m of Station (count/code)	Species Observed within 200m of Station (count/code)	Notes
Round 1											
A	04-May-19	21:00	21:03	1 (distant traffic)	12	None/Dry	60%	0	AMTO (4-3), SPPE (10-3)	AMTO (1-2)	
B	04-May-19	21:22	21.25	1 (distant traffic)	10.6	None/Dry	70%	0	AMTO(5-3), SPPE (1-1), NLFR (1-1)	-	
C	04-May-19	21:43	21:46	1 (distant traffic)	9.1	None/Dry	70%	0	AMTO (3-3), SPPE (6-3)	SPPE (2-2)	No frogs calling at wetland, all on private property
D	04-May-19	22:24	22:27	2 (vehicle noise)	10.5	None/Dry	90%	0	AMTO (5-2)	SPPE (3-3)	
E	04-May-19	22:35	22:38	2 (vehicle noise)	9.5	None/Dry	90%	0	-	AMTO (1-1)	
F	04-May-19	22:59	23:02	2 (road noise, riser noise)	11.2	None/Dry	80%	0	-	AMTO (1-1)	
Round 2											
A	24-May-19	21:47	21:50	1 (distant traffic)	17.4	None/Dry	70%	0	AMTO (1-1), SPPE (4-2)	GRTR (1-1)	
B	24-May-19	22:06	22:09	3 (continuous traffic)	17.8	None/Dry	70%	1	AMTO (1-1), SPPE (1-1), CGTR (1-1)	AMTO (1-1)	
C	24-May-19	22:17	22:20	2 (vehicle noise)	16.4	None/Dry	70%	0	AMTO (1-1), SPPE (1-2), CGTR (4-3)	-	No frogs calling at wetland, all on private property
D	24-May-19	22:56	22:59	3 (vehicle traffic)	17.8	None/Dry	70%	1	-	SPPE (2-1), CGTR (3-1)	No amphibians calling within wetland, only in distance.
E	24-May-19	23:03	23:06	3 (vehicle traffic)	17.8	None/Dry	70%	1	-	-	No amphibians calling
F	24-May-19	23:30	23:33	3 (road noise, riser noise)	17.7	Damp/Haze	70%	1	-	AMTO (1-1)	No amphibians calling within the wetland
Round 3											
A	18-Jun-19	21:47	21:50	1 (road noise and wildlife in distance)	21.3	None/Dry	40%	1	GRFR (2-1), GRTR 4-1)	-	Coyotes calling, bats flying overhead, fireflies, high humidity
B	18-Jun-19	22:09	22:13	2 (traffic noise)	20	None/Dry	40%	1	GRFR(1-1), CGTR (1-1)	AMTO (2-1), CGTR (3-1)	Killdeer calling, fireflies, bats
C	18-Jun-19	22:20	22:23	1 (distant traffic)	19.4	None/Dry	40%	1	AMTO (1-1), CGTR (6-2)		All amphibians calling from private property
D	18-Jun-19	22:55	22:58	3 (vehicle traffic)	18.7	None/Dry	50%	2	-	CGTR (10-1)	Bats flying overhead
E	18-Jun-19	22:05	22:08	3 (vehicle traffic)	18.7	None/Dry	20%	2	-	-	No amphibians calling.
F	18-Jun-19	23:24	23:27	1 (traffic noise)	18.4	None/Dry	20%	2	-	-	

Brantford Headwater - Fisheries Assessment 2019

Powerline Road Pond 1					
Fish #	**Common Name**	**Scientific Name**	**Fork Length (cm)**	**Mass (g)**	**Comments**
1	Common Shiner	*Luxilus cornutus*	2.5	0	Minnowtrap 1
2	Common Shiner	*Luxilus cornutus*	6	3	Minnowtrap 1
3	Common Shiner	*Luxilus cornutus*	4.21	1	Minnowtrap 2
4	Common Shiner	*Luxilus cornutus*	4.75	1	Minnowtrap 2
5	Common Shiner	*Luxilus cornutus*	4.5	1	Minnowtrap 2
6	Common Shiner	*Luxilus cornutus*	4.7	1	Minnowtrap 2
7	Common Shiner	*Luxilus cornutus*	4.2	1	Minnowtrap 2
8	Common Shiner	*Luxilus cornutus*	4.8	1	Minnowtrap 2
9	Common Shiner	*Luxilus cornutus*	3.5	1	Minnowtrap 2
10	Common Shiner	*Luxilus cornutus*	4.4	1	Minnowtrap 2
11	Common Shiner	*Luxilus cornutus*	4.3	1	Minnowtrap 2
12	Common Shiner	*Luxilus cornutus*	3.5	1	Minnowtrap 2
13	Common Shiner	*Luxilus cornutus*	4.15	1	Minnowtrap 2
14	Common Shiner	*Luxilus cornutus*	4.1	1	Minnowtrap 2
15	Common Shiner	*Luxilus cornutus*	4.1	1	Minnowtrap 2
16	Common Shiner	*Luxilus cornutus*	4.2	1	Minnowtrap 2
17	Common Shiner	*Luxilus cornutus*	6.1	1	Minnowtrap 2
18	Common Shiner	*Luxilus cornutus*	4.2	1	Minnowtrap 2
19	Common Shiner	*Luxilus cornutus*	4.5	1	Minnowtrap 2
20	Common Shiner	*Luxilus cornutus*	3.5	1	Minnowtrap 2
21	Common Shiner	*Luxilus cornutus*	3.5	1	Minnowtrap 2
22	Common Shiner	*Luxilus cornutus*	5.2	1	Minnowtrap 2
23	Common Shiner	*Luxilus cornutus*	4.5	1	Minnowtrap 2
24	Fathead Minnow	*Pimephales promelas*	4.5	1	Minnowtrap 2
25	Fathead Minnow	*Pimephales promelas*	5.15	1	Minnowtrap 2
26	Common Shiner	*Luxilus cornutus*	4.1	1	Minnowtrap 2
27	Common Shiner	*Luxilus cornutus*	4.4	1	Minnowtrap 2
28	Common Shiner	*Luxilus cornutus*	3.2	1	Minnowtrap 2
29	Common Shiner	*Luxilus cornutus*	4.1	1	Minnowtrap 2
30	Common Shiner	*Luxilus cornutus*	3.5	1	Minnowtrap 2
31	Common Shiner	*Luxilus cornutus*	4	1	Minnowtrap 2
32	Common Shiner	*Luxilus cornutus*	4.5	1	Minnowtrap 2
33	Common Shiner	*Luxilus cornutus*	5.3	1	Minnowtrap 2
34	Common Shiner	*Luxilus cornutus*	4.1	1	Minnowtrap 2
35	Common Shiner	*Luxilus cornutus*	5.4	1	Minnowtrap 2
36	Common Shiner	*Luxilus cornutus*	3	1	Minnowtrap 2
37	Fathead Minnow	*Pimephales promelas*	3.5	1	Minnowtrap 2
38	Fathead Minnow	*Pimephales promelas*	4.2	1	Minnowtrap 2
39	Fathead Minnow	*Pimephales promelas*	4	1	Minnowtrap 2
40	Common Shiner	*Luxilus cornutus*	4	0	Minnowtrap 2
41	Common Shiner	*Luxilus cornutus*	4.5	0	Minnowtrap 2
42	Common Shiner	*Luxilus cornutus*	5.5	0	Minnowtrap 2
43	Common Shiner	*Luxilus cornutus*	6	0	Minnowtrap 2
44	Common Shiner	*Luxilus cornutus*	4	0	Minnowtrap 2
45	Common Shiner	*Luxilus cornutus*	2	0	Minnowtrap 2
46	Common Shiner	*Luxilus cornutus*	4.1	0	Minnowtrap 2

47	Common Shiner	*Luxilus cornutus*	4	0	Minnowtrap 2
48	Common Shiner	*Luxilus cornutus*	3.8	0	Minnowtrap 2
49	Common Shiner	*Luxilus cornutus*	3.6	54	Minnowtrap 2
50	Common Shiner	*Luxilus cornutus*	4	28	Minnowtrap 2
51	Fathead Minnow	*Pimephales promelas*	6	29	Minnowtrap 3
52	Common Shiner	*Luxilus cornutus*	3.6	29	Minnowtrap 3
53	Common Shiner	*Luxilus cornutus*	5	66	Minnowtrap 3
54	Common Shiner	*Luxilus cornutus*	5	38	Minnowtrap 3
55	Common Shiner	*Luxilus cornutus*	4.2	38	Minnowtrap 3
56	Common Shiner	*Luxilus cornutus*	5	41	Minnowtrap 3
57	Fathead Minnow	*Pimephales promelas*	4.6	64	Minnowtrap 3
58	Common Shiner	*Luxilus cornutus*	5	18	Minnowtrap 3
59	Common Shiner	*Luxilus cornutus*	4	32	Minnowtrap 3

Brantford Headwater - Fisheries Assessment 2019

Golf Road Pond 2					
Fish #	**Common Name**	**Scientific Name**	**Fork Length (cm)**	**Mass (g)**	**Comments**
1	Common Shiner	*Luxilus cornutus*	5.5	0	Minnow Trap 1
2	Common Shiner	*Luxilus cornutus*	4.7	3	Minnow Trap 1
3	Common Shiner	*Luxilus cornutus*	5.2	1	Minnow Trap 1
4	Common Shiner	*Luxilus cornutus*	5.6	2	Minnow Trap 1
5	Common Shiner	*Luxilus cornutus*	6.2	2	Minnow Trap 1
6	Common Shiner	*Luxilus cornutus*	6.4	2	Minnow Trap 1
7	Common Shiner	*Luxilus cornutus*	4.5	2	Minnow Trap 1
8	Common Shiner	*Luxilus cornutus*	5.5	2	Minnow Trap 1
9	Common Shiner	*Luxilus cornutus*	4.7	3	Minnow Trap 1
10	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 1
11	Common Shiner	*Luxilus cornutus*	6.2	2	Minnow Trap 1
12	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 1
13	Brook Stickleback	*Culaea inconstans*	6	3	Minnow Trap 1
14	Brook Stickleback	*Culaea inconstans*	6.4	3	Minnow Trap 1
15	Brook Stickleback	*Culaea inconstans*	6	3	Minnow Trap 1
16	Brook Stickleback	*Culaea inconstans*	6.4	3	Minnow Trap 1
17	Brook Stickleback	*Culaea inconstans*	5.5	3	Minnow Trap 1
18	Brook Stickleback	*Culaea inconstans*	6	3	Minnow Trap 1
19	Brook Stickleback	*Culaea inconstans*	5	3	Minnow Trap 1
20	Brook Stickleback	*Culaea inconstans*	5	3	Minnow Trap 1
21	Brook Stickleback	*Culaea inconstans*	6	3	Minnow Trap 1
22	Brook Stickleback	*Culaea inconstans*	4.5	3	Minnow Trap 1
23	Brook Stickleback	*Culaea inconstans*	5.5	3	Minnow Trap 1
24	Brook Stickleback	*Culaea inconstans*	6.2	3	Minnow Trap 1
25	Brook Stickleback	*Culaea inconstans*	6.2	3	Minnow Trap 1
26	Brook Stickleback	*Culaea inconstans*	6.2	3	Minnow Trap 1
27	Brook Stickleback	*Culaea inconstans*	5.2	3	Minnow Trap 1
28	Brook Stickleback	*Culaea inconstans*	6	3	Minnow Trap 1
29	Brook Stickleback	*Culaea inconstans*	6	3	Minnow Trap 1
30	Brook Stickleback	*Culaea inconstans*	5.4	3	Minnow Trap 1
31	Common Shiner	*Luxilus cornutus*	5.5	3	Minnow Trap 1
32	Common Shiner	*Luxilus cornutus*	6	3	Minnow Trap 1
33	Common Shiner	*Luxilus cornutus*	6	3	Minnow Trap 1
34	Common Shiner	*Luxilus cornutus*	6.4	3	Minnow Trap 1
35	Common Shiner	*Luxilus cornutus*	5	3	Minnow Trap 1
36	Common Shiner	*Luxilus cornutus*	6	3	Minnow Trap 1
37	Common Shiner	*Luxilus cornutus*	5	3	Minnow Trap 1
38	Fathead Minnow	*Pimpephales promelas*	6.4	3	Minnow Trap 1
39	Fathead Minnow	*Pimpephales promelas*	6.8	3	Minnow Trap 1
40	Common Shiner	*Luxilus cornutus*	5.5	3	Minnow Trap 1
41	Common Shiner	*Luxilus cornutus*	5	3	Minnow Trap 1
42	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 1
43	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 1
44	Common Shiner	*Luxilus cornutus*	7	2	Minnow Trap 1
45	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 1
46	Common Shiner	*Luxilus cornutus*	7	2	Minnow Trap 1
47	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 1

48	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 1
49	Common Shiner	*Luxilus cornutus*	7	2	Minnow Trap 1
50	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 1
51	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 1
52	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 1
53	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 1
54	Common Shiner	*Luxilus cornutus*	4.5	2	Minnow Trap 1
55	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 1
56	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 1
57	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 1
58	Common Shiner	*Luxilus cornutus*	7	2	Minnow Trap 1
59	Common Shiner	*Luxilus cornutus*	5.5	2	Minnow Trap 1
60	Common Shiner	*Luxilus cornutus*	6.5	2	Minnow Trap 1
61	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 1
62	Common Shiner	*Luxilus cornutus*	6.5	2	Minnow Trap 1
63	Common Shiner	*Luxilus cornutus*	6.5	2	Minnow Trap 1
64	Brook Stickleback	*Culaea inconstans*	6	2	Minnow Trap 2
65	Brook Stickleback	*Culaea inconstans*	6.2	2	Minnow Trap 2
66	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 2
67	Brook Stickleback	*Culaea inconstans*	6.2	2	Minnow Trap 2
68	Brook Stickleback	*Culaea inconstans*	4.5	2	Minnow Trap 2
69	Brook Stickleback	*Culaea inconstans*	6.4	2	Minnow Trap 2
70	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 2
71	Brook Stickleback	*Culaea inconstans*	6	2	Minnow Trap 2
72	Brook Stickleback	*Culaea inconstans*	6	2	Minnow Trap 2
73	Brook Stickleback	*Culaea inconstans*	6	2	Minnow Trap 2
74	Brook Stickleback	*Culaea inconstans*	6.2	2	Minnow Trap 2
75	Brook Stickleback	*Culaea inconstans*	5	2	Minnow Trap 2
76	Brook Stickleback	*Culaea inconstans*	4.5	2	Minnow Trap 2
77	Brook Stickleback	*Culaea inconstans*	5	2	Minnow Trap 2
78	Brook Stickleback	*Culaea inconstans*	5	2	Minnow Trap 2
79	Brook Stickleback	*Culaea inconstans*	6.5	2	Minnow Trap 2
80	Brook Stickleback	*Culaea inconstans*	6.2	2	Minnow Trap 2
81	Brook Stickleback	*Culaea inconstans*	6.5	2	Minnow Trap 2
82	Brook Stickleback	*Culaea inconstans*	6.5	2	Minnow Trap 2
83	Brook Stickleback	*Culaea inconstans*	6.4	2	Minnow Trap 2
84	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 2
85	Common Shiner	*Luxilus cornutus*	9	8	Minnow Trap 2
86	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 2
87	Brook Stickleback	*Culaea inconstans*	6	2	Minnow Trap 2
88	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 2
89	Brook Stickleback	*Culaea inconstans*	0.5	2	Minnow Trap 2
90	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 2
91	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 2
92	Fathead Minnow	*Pimpephales promelas*	6	2	Minnow Trap 2
93	Fathead Minnow	*Pimpephales promelas*	7	2	Minnow Trap 2
94	Fathead Minnow	*Pimpephales promelas*	5.5	2	Minnow Trap 2
95	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 2
96	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2

97	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
98	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
99	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
100	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
101	Common Shiner	*Luxilus cornutus*	5.5	2	Minnow Trap 2
102	Common Shiner	*Luxilus cornutus*	6.5	2	Minnow Trap 2
103	Common Shiner	*Luxilus cornutus*	6.5	2	Minnow Trap 2
104	Common Shiner	*Luxilus cornutus*	6.3	2	Minnow Trap 2
105	Common Shiner	*Luxilus cornutus*	4.7	2	Minnow Trap 2
106	Common Shiner	*Luxilus cornutus*	7	2	Minnow Trap 2
107	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 2
108	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 2
109	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 2
110	Common Shiner	*Luxilus cornutus*	0.5	2	Minnow Trap 2
111	Common Shiner	*Luxilus cornutus*	12	20	Minnow Trap 2
112	Common Shiner	*Luxilus cornutus*	3	2	Minnow Trap 2
113	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
114	Common Shiner	*Luxilus cornutus*	7	2	Minnow Trap 2
115	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
116	Common Shiner	*Luxilus cornutus*	7	2	Minnow Trap 2
117	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
118	Common Shiner	*Luxilus cornutus*	6.3	2	Minnow Trap 2
119	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
120	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 2

Brantford Headwater - Amphibian Call Survey 2019

Stn.	Date	Start Time	End Time	Background Noise	Temp. (C)	Precipitation	Cloud Cover	Beaufort Scale	Species Observed within 100m of Station (count/code)	Species Observed within 200m of Station (count/code)	Notes
Round 1											
A	04-May-19	21:00	21:03	1 (distant traffic)	12	None/Dry	60%	0	AMTO (4-3), SPPE (10-3)	AMTO (1-2)	
B	04-May-19	21:22	21.25	1 (distant traffic)	10.6	None/Dry	70%	0	AMTO(5-3), SPPE (1-1), NLFR (1-1)	-	
C	04-May-19	21:43	21:46	1 (distant traffic)	9.1	None/Dry	70%	0	AMTO (3-3), SPPE (6-3)	SPPE (2-2)	No frogs calling at wetland, all on private property
D	04-May-19	22:24	22:27	2 (vehicle noise)	10.5	None/Dry	90%	0	AMTO (5-2)	SPPE (3-3)	
E	04-May-19	22:35	22:38	2 (vehicle noise)	9.5	None/Dry	90%	0	-	AMTO (1-1)	
F	04-May-19	22:59	23:02	2 (road noise, riser noise)	11.2	None/Dry	80%	0	-	AMTO (1-1)	
Round 2											
A	24-May-19	21:47	21:50	1 (distant traffic)	17.4	None/Dry	70%	0	AMTO (1-1), SPPE (4-2)	GRTR (1-1)	
B	24-May-19	22:06	22:09	3 (continuous traffic)	17.8	None/Dry	70%	1	AMTO (1-1), SPPE (1-1), CGTR (1-1)	AMTO (1-1)	
C	24-May-19	22:17	22:20	2 (vehicle noise)	16.4	None/Dry	70%	0	AMTO (1-1), SPPE (1-2), CGTR (4-3)	-	No frogs calling at wetland, all on private property
D	24-May-19	22:56	22:59	3 (vehicle traffic)	17.8	None/Dry	70%	1	-	SPPE (2-1), CGTR (3-1)	No amphibians calling within wetland, only in distance.
E	24-May-19	23:03	23:06	3 (vehicle traffic)	17.8	None/Dry	70%	1	-	-	No amphibians calling
F	24-May-19	23:30	23:33	3 (road noise, riser noise)	17.7	Damp/Haze	70%	1	-	AMTO (1-1)	No amphibians calling within the wetland
Round 3											
A	18-Jun-19	21:47	21:50	1 (road noise and wildlife in distance)	21.3	None/Dry	40%	1	GRFR (2-1), GRTR 4-1)	-	Coyotes calling, bats flying overhead, fireflies, high humidity
B	18-Jun-19	22:09	22:13	2 (traffic noise)	20	None/Dry	40%	1	GRFR(1-1), CGTR (1-1)	AMTO (2-1), CGTR (3-1)	Killdeer calling, fireflies, bats
C	18-Jun-19	22:20	22:23	1 (distant traffic)	19.4	None/Dry	40%	1	AMTO (1-1), CGTR (6-2)		All amphibians calling from private property
D	18-Jun-19	22:55	22:58	3 (vehicle traffic)	18.7	None/Dry	50%	2	-	CGTR (10-1)	Bats flying overhead
E	18-Jun-19	22:05	22:08	3 (vehicle traffic)	18.7	None/Dry	20%	2	-	-	No amphibians calling.
F	18-Jun-19	23:24	23:27	1 (traffic noise)	18.4	None/Dry	20%	2	-	-	

Brantford Headwater - Fisheries Assessment 2019

Powerline Road Pond 1					
Fish #	**Common Name**	**Scientific Name**	**Fork Length (cm)**	**Mass (g)**	**Comments**
1	Common Shiner	*Luxilus cornutus*	2.5	0	Minnowtrap 1
2	Common Shiner	*Luxilus cornutus*	6	3	Minnowtrap 1
3	Common Shiner	*Luxilus cornutus*	4.21	1	Minnowtrap 2
4	Common Shiner	*Luxilus cornutus*	4.75	1	Minnowtrap 2
5	Common Shiner	*Luxilus cornutus*	4.5	1	Minnowtrap 2
6	Common Shiner	*Luxilus cornutus*	4.7	1	Minnowtrap 2
7	Common Shiner	*Luxilus cornutus*	4.2	1	Minnowtrap 2
8	Common Shiner	*Luxilus cornutus*	4.8	1	Minnowtrap 2
9	Common Shiner	*Luxilus cornutus*	3.5	1	Minnowtrap 2
10	Common Shiner	*Luxilus cornutus*	4.4	1	Minnowtrap 2
11	Common Shiner	*Luxilus cornutus*	4.3	1	Minnowtrap 2
12	Common Shiner	*Luxilus cornutus*	3.5	1	Minnowtrap 2
13	Common Shiner	*Luxilus cornutus*	4.15	1	Minnowtrap 2
14	Common Shiner	*Luxilus cornutus*	4.1	1	Minnowtrap 2
15	Common Shiner	*Luxilus cornutus*	4.1	1	Minnowtrap 2
16	Common Shiner	*Luxilus cornutus*	4.2	1	Minnowtrap 2
17	Common Shiner	*Luxilus cornutus*	6.1	1	Minnowtrap 2
18	Common Shiner	*Luxilus cornutus*	4.2	1	Minnowtrap 2
19	Common Shiner	*Luxilus cornutus*	4.5	1	Minnowtrap 2
20	Common Shiner	*Luxilus cornutus*	3.5	1	Minnowtrap 2
21	Common Shiner	*Luxilus cornutus*	3.5	1	Minnowtrap 2
22	Common Shiner	*Luxilus cornutus*	5.2	1	Minnowtrap 2
23	Common Shiner	*Luxilus cornutus*	4.5	1	Minnowtrap 2
24	Fathead Minnow	*Pimephales promelas*	4.5	1	Minnowtrap 2
25	Fathead Minnow	*Pimephales promelas*	5.15	1	Minnowtrap 2
26	Common Shiner	*Luxilus cornutus*	4.1	1	Minnowtrap 2
27	Common Shiner	*Luxilus cornutus*	4.4	1	Minnowtrap 2
28	Common Shiner	*Luxilus cornutus*	3.2	1	Minnowtrap 2
29	Common Shiner	*Luxilus cornutus*	4.1	1	Minnowtrap 2
30	Common Shiner	*Luxilus cornutus*	3.5	1	Minnowtrap 2
31	Common Shiner	*Luxilus cornutus*	4	1	Minnowtrap 2
32	Common Shiner	*Luxilus cornutus*	4.5	1	Minnowtrap 2
33	Common Shiner	*Luxilus cornutus*	5.3	1	Minnowtrap 2
34	Common Shiner	*Luxilus cornutus*	4.1	1	Minnowtrap 2
35	Common Shiner	*Luxilus cornutus*	5.4	1	Minnowtrap 2
36	Common Shiner	*Luxilus cornutus*	3	1	Minnowtrap 2
37	Fathead Minnow	*Pimephales promelas*	3.5	1	Minnowtrap 2
38	Fathead Minnow	*Pimephales promelas*	4.2	1	Minnowtrap 2
39	Fathead Minnow	*Pimephales promelas*	4	1	Minnowtrap 2
40	Common Shiner	*Luxilus cornutus*	4	0	Minnowtrap 2
41	Common Shiner	*Luxilus cornutus*	4.5	0	Minnowtrap 2
42	Common Shiner	*Luxilus cornutus*	5.5	0	Minnowtrap 2
43	Common Shiner	*Luxilus cornutus*	6	0	Minnowtrap 2
44	Common Shiner	*Luxilus cornutus*	4	0	Minnowtrap 2
45	Common Shiner	*Luxilus cornutus*	2	0	Minnowtrap 2
46	Common Shiner	*Luxilus cornutus*	4.1	0	Minnowtrap 2

47	Common Shiner	*Luxilus cornutus*	4	0	Minnowtrap 2
48	Common Shiner	*Luxilus cornutus*	3.8	0	Minnowtrap 2
49	Common Shiner	*Luxilus cornutus*	3.6	54	Minnowtrap 2
50	Common Shiner	*Luxilus cornutus*	4	28	Minnowtrap 2
51	Fathead Minnow	*Pimephales promelas*	6	29	Minnowtrap 3
52	Common Shiner	*Luxilus cornutus*	3.6	29	Minnowtrap 3
53	Common Shiner	*Luxilus cornutus*	5	66	Minnowtrap 3
54	Common Shiner	*Luxilus cornutus*	5	38	Minnowtrap 3
55	Common Shiner	*Luxilus cornutus*	4.2	38	Minnowtrap 3
56	Common Shiner	*Luxilus cornutus*	5	41	Minnowtrap 3
57	Fathead Minnow	*Pimephales promelas*	4.6	64	Minnowtrap 3
58	Common Shiner	*Luxilus cornutus*	5	18	Minnowtrap 3
59	Common Shiner	*Luxilus cornutus*	4	32	Minnowtrap 3

Golf Road Pond 2					
Fish #	**Common Name**	**Scientific Name**	**Fork Length (cm)**	**Mass (g)**	**Comments**
1	Common Shiner	*Luxilus cornutus*	5.5	0	Minnow Trap 1
2	Common Shiner	*Luxilus cornutus*	4.7	3	Minnow Trap 1
3	Common Shiner	*Luxilus cornutus*	5.2	1	Minnow Trap 1
4	Common Shiner	*Luxilus cornutus*	5.6	2	Minnow Trap 1
5	Common Shiner	*Luxilus cornutus*	6.2	2	Minnow Trap 1
6	Common Shiner	*Luxilus cornutus*	6.4	2	Minnow Trap 1
7	Common Shiner	*Luxilus cornutus*	4.5	2	Minnow Trap 1
8	Common Shiner	*Luxilus cornutus*	5.5	2	Minnow Trap 1
9	Common Shiner	*Luxilus cornutus*	4.7	3	Minnow Trap 1
10	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 1
11	Common Shiner	*Luxilus cornutus*	6.2	2	Minnow Trap 1
12	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 1
13	Brook Stickleback	*Culaea inconstans*	6	3	Minnow Trap 1
14	Brook Stickleback	*Culaea inconstans*	6.4	3	Minnow Trap 1
15	Brook Stickleback	*Culaea inconstans*	6	3	Minnow Trap 1
16	Brook Stickleback	*Culaea inconstans*	6.4	3	Minnow Trap 1
17	Brook Stickleback	*Culaea inconstans*	5.5	3	Minnow Trap 1
18	Brook Stickleback	*Culaea inconstans*	6	3	Minnow Trap 1
19	Brook Stickleback	*Culaea inconstans*	5	3	Minnow Trap 1
20	Brook Stickleback	*Culaea inconstans*	5	3	Minnow Trap 1
21	Brook Stickleback	*Culaea inconstans*	6	3	Minnow Trap 1
22	Brook Stickleback	*Culaea inconstans*	4.5	3	Minnow Trap 1
23	Brook Stickleback	*Culaea inconstans*	5.5	3	Minnow Trap 1
24	Brook Stickleback	*Culaea inconstans*	6.2	3	Minnow Trap 1
25	Brook Stickleback	*Culaea inconstans*	6.2	3	Minnow Trap 1
26	Brook Stickleback	*Culaea inconstans*	6.2	3	Minnow Trap 1
27	Brook Stickleback	*Culaea inconstans*	5.2	3	Minnow Trap 1
28	Brook Stickleback	*Culaea inconstans*	6	3	Minnow Trap 1
29	Brook Stickleback	*Culaea inconstans*	6	3	Minnow Trap 1
30	Brook Stickleback	*Culaea inconstans*	5.4	3	Minnow Trap 1
31	Common Shiner	*Luxilus cornutus*	5.5	3	Minnow Trap 1
32	Common Shiner	*Luxilus cornutus*	6	3	Minnow Trap 1
33	Common Shiner	*Luxilus cornutus*	6	3	Minnow Trap 1
34	Common Shiner	*Luxilus cornutus*	6.4	3	Minnow Trap 1
35	Common Shiner	*Luxilus cornutus*	5	3	Minnow Trap 1
36	Common Shiner	*Luxilus cornutus*	6	3	Minnow Trap 1
37	Common Shiner	*Luxilus cornutus*	5	3	Minnow Trap 1
38	Fathead Minnow	*Pimpephales promelas*	6.4	3	Minnow Trap 1
39	Fathead Minnow	*Pimpephales promelas*	6.8	3	Minnow Trap 1
40	Common Shiner	*Luxilus cornutus*	5.5	3	Minnow Trap 1
41	Common Shiner	*Luxilus cornutus*	5	3	Minnow Trap 1
42	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 1
43	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 1
44	Common Shiner	*Luxilus cornutus*	7	2	Minnow Trap 1
45	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 1
46	Common Shiner	*Luxilus cornutus*	7	2	Minnow Trap 1
47	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 1

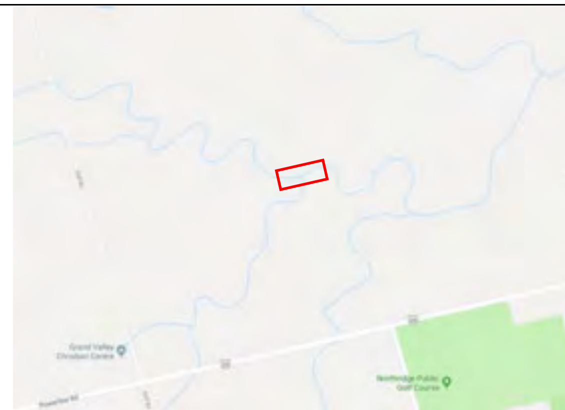
48	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 1
49	Common Shiner	*Luxilus cornutus*	7	2	Minnow Trap 1
50	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 1
51	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 1
52	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 1
53	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 1
54	Common Shiner	*Luxilus cornutus*	4.5	2	Minnow Trap 1
55	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 1
56	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 1
57	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 1
58	Common Shiner	*Luxilus cornutus*	7	2	Minnow Trap 1
59	Common Shiner	*Luxilus cornutus*	5.5	2	Minnow Trap 1
60	Common Shiner	*Luxilus cornutus*	6.5	2	Minnow Trap 1
61	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 1
62	Common Shiner	*Luxilus cornutus*	6.5	2	Minnow Trap 1
63	Common Shiner	*Luxilus cornutus*	6.5	2	Minnow Trap 1
64	Brook Stickleback	*Culaea inconstans*	6	2	Minnow Trap 2
65	Brook Stickleback	*Culaea inconstans*	6.2	2	Minnow Trap 2
66	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 2
67	Brook Stickleback	*Culaea inconstans*	6.2	2	Minnow Trap 2
68	Brook Stickleback	*Culaea inconstans*	4.5	2	Minnow Trap 2
69	Brook Stickleback	*Culaea inconstans*	6.4	2	Minnow Trap 2
70	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 2
71	Brook Stickleback	*Culaea inconstans*	6	2	Minnow Trap 2
72	Brook Stickleback	*Culaea inconstans*	6	2	Minnow Trap 2
73	Brook Stickleback	*Culaea inconstans*	6	2	Minnow Trap 2
74	Brook Stickleback	*Culaea inconstans*	6.2	2	Minnow Trap 2
75	Brook Stickleback	*Culaea inconstans*	5	2	Minnow Trap 2
76	Brook Stickleback	*Culaea inconstans*	4.5	2	Minnow Trap 2
77	Brook Stickleback	*Culaea inconstans*	5	2	Minnow Trap 2
78	Brook Stickleback	*Culaea inconstans*	5	2	Minnow Trap 2
79	Brook Stickleback	*Culaea inconstans*	6.5	2	Minnow Trap 2
80	Brook Stickleback	*Culaea inconstans*	6.2	2	Minnow Trap 2
81	Brook Stickleback	*Culaea inconstans*	6.5	2	Minnow Trap 2
82	Brook Stickleback	*Culaea inconstans*	6.5	2	Minnow Trap 2
83	Brook Stickleback	*Culaea inconstans*	6.4	2	Minnow Trap 2
84	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 2
85	Common Shiner	*Luxilus cornutus*	9	8	Minnow Trap 2
86	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 2
87	Brook Stickleback	*Culaea inconstans*	6	2	Minnow Trap 2
88	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 2
89	Brook Stickleback	*Culaea inconstans*	0.5	2	Minnow Trap 2
90	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 2
91	Brook Stickleback	*Culaea inconstans*	5.5	2	Minnow Trap 2
92	Fathead Minnow	*Pimpephales promelas*	6	2	Minnow Trap 2
93	Fathead Minnow	*Pimpephales promelas*	7	2	Minnow Trap 2
94	Fathead Minnow	*Pimpephales promelas*	5.5	2	Minnow Trap 2
95	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 2
96	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2

97	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
98	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
99	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
100	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
101	Common Shiner	*Luxilus cornutus*	5.5	2	Minnow Trap 2
102	Common Shiner	*Luxilus cornutus*	6.5	2	Minnow Trap 2
103	Common Shiner	*Luxilus cornutus*	6.5	2	Minnow Trap 2
104	Common Shiner	*Luxilus cornutus*	6.3	2	Minnow Trap 2
105	Common Shiner	*Luxilus cornutus*	4.7	2	Minnow Trap 2
106	Common Shiner	*Luxilus cornutus*	7	2	Minnow Trap 2
107	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 2
108	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 2
109	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 2
110	Common Shiner	*Luxilus cornutus*	0.5	2	Minnow Trap 2
111	Common Shiner	*Luxilus cornutus*	12	20	Minnow Trap 2
112	Common Shiner	*Luxilus cornutus*	3	2	Minnow Trap 2
113	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
114	Common Shiner	*Luxilus cornutus*	7	2	Minnow Trap 2
115	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
116	Common Shiner	*Luxilus cornutus*	7	2	Minnow Trap 2
117	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
118	Common Shiner	*Luxilus cornutus*	6.3	2	Minnow Trap 2
119	Common Shiner	*Luxilus cornutus*	6	2	Minnow Trap 2
120	Common Shiner	*Luxilus cornutus*	5	2	Minnow Trap 2

Detailed Geomorphological Assessment Summary

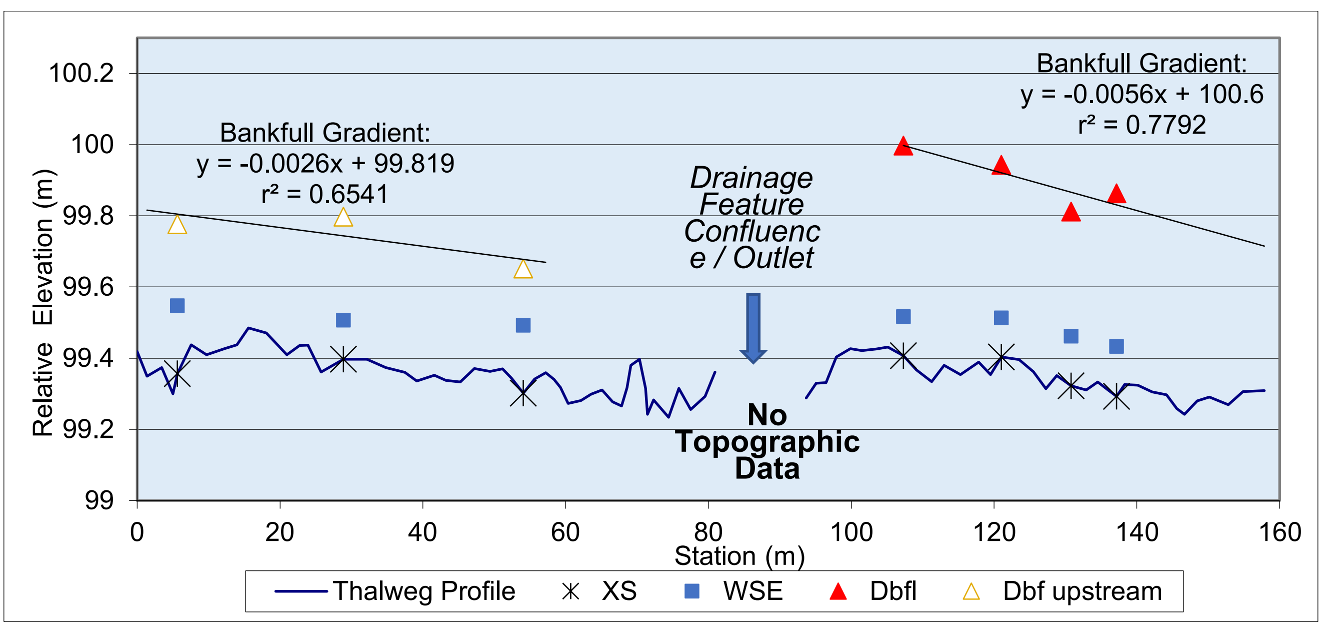
Project:	1706 – Brantford	**Date:**	October 11, 2018
Watercourse:	Lower Jones/Golf Road Tributary	**Length surveyed (m):**	158 m
Reach:	-	**# of Cross-sections:**	7
Site Access:	Golf Road		

Reach Characteristics	
Surrounding Land Use:	Agricultural (corn)
Valley Setting:	Unconfined
General Riparian Vegetation:	**Type:** herbaceous
	Width: 75 m (right bank); 15 m (left bank)
Existing Disturbances:	Agricultural plowing; drain/tile outlet at upstream limit
Woody Debris Occurrence:	Minimal



Profile Characteristics	
Bankfull Gradient (%)	0.26 (upstream) 0.56 (downstream)
Channel Bed Gradient (%)	0.05
Maximum Low Flow Pool Depth (m)	0.25 (upstream) 0.18 (downstream)
Maximum Residual Pool Depth (m)	0.19 (upstream)
Pool-pool Spacing (m)	N/A

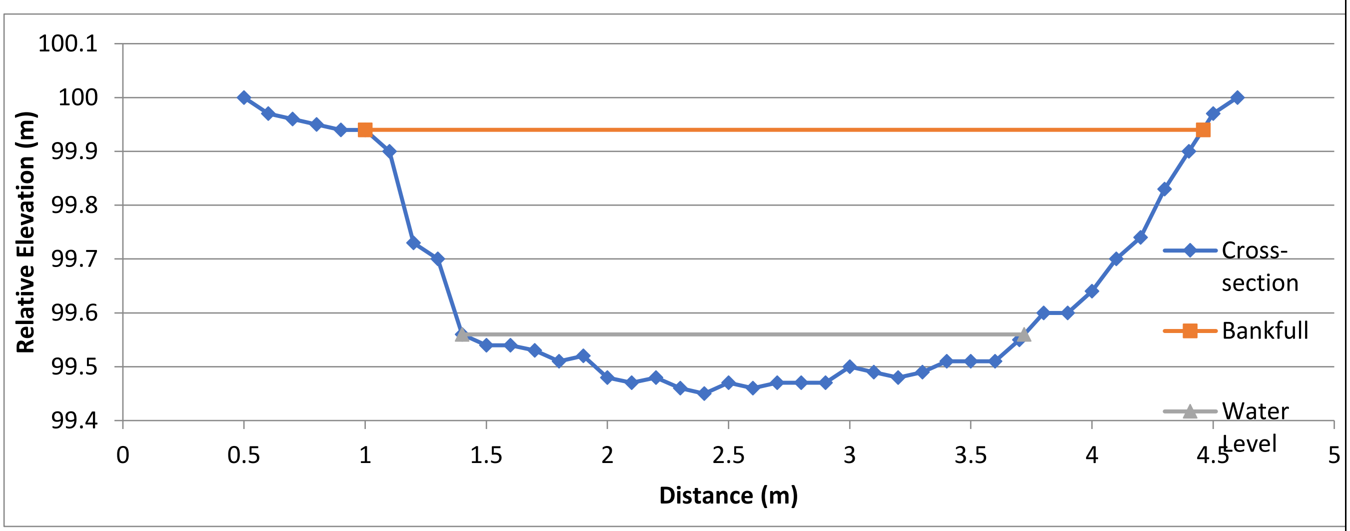
Planform Characteristics	
Sinuosity	N/A
Meander Belt Width (m)	N/A
Meander Wavelength (m)	N/A
Note: Channel is altered/straightened	



Bankfull Channel Characteristics			
	Minimum	**Maximum**	**Average**
Bank Heights	0.34	0.57	0.44
Bank Angles	0.72	57.99	20.72
Undercutting (m) Location:	N/A		
Horizontal: Vertical Ratio	0.6	80.0	2.4
Bank Material(s)	Cl, SI		

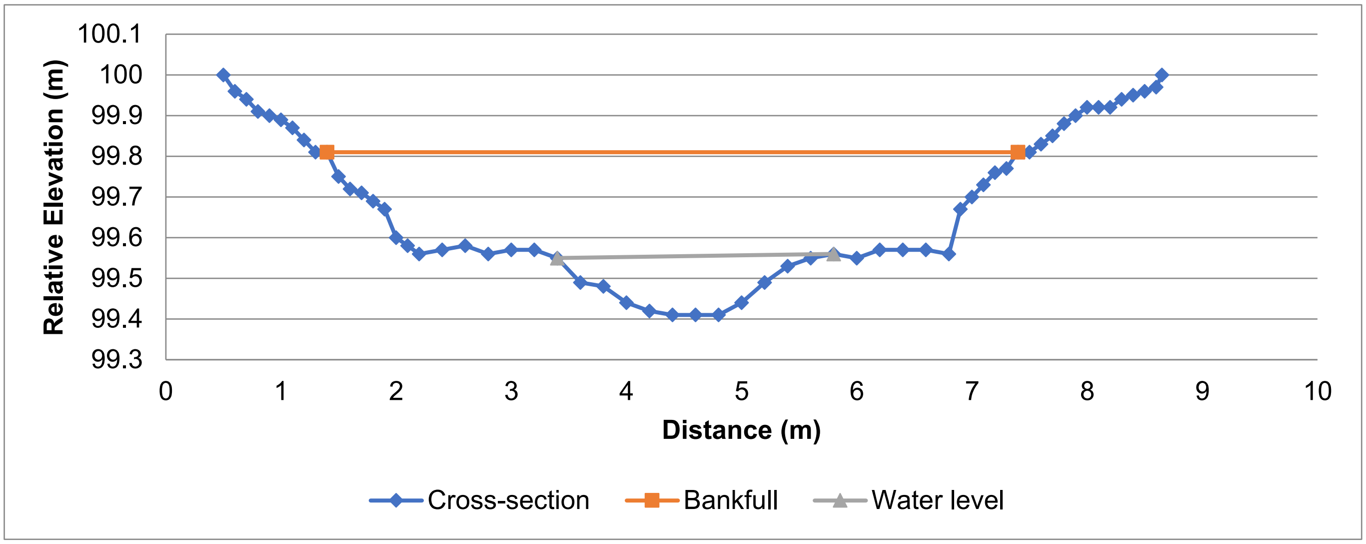
Bank Stratigraphy

Cross-Sectional Characteristics - Downstream			
	Minimum	**Maximum**	**Average**
Bankfull Width (m)	2.68	3.46	3.10
Max. Bankfull Depth (m)	0.48	0.57	0.52
Avg. Bankfull Depth (m)	0.33	0.40	0.37
Bankfull Area (m^2)	0.87	1.27	1.16
Hydraulic Radius (m)	0.28	0.34	0.33
Width:Depth Ratio (m/m)	7.71	9.43	8.33
Wetted Width (m)	1.60	2.32	2.06
Water Depth (m)	0.11	0.19	0.15
Wetted Width: Depth (m/m)	20.81	35.41	25.90
Wetted Perimeter (m)	1.84	2.47	2.21



Hydrogeomorphology – Downstream			
Calculated Average Bankfull Discharge (cms)	0.97	**Maximum Shear Stress (N/m^2)**	28.56
Calculated Average Bankfull Velocity (m/s)	1.07	**Average Shear Stress (N/m^2)**	20.45
Total Stream Power (W/m^2)	53.387	**Mannings *n***	0.05
Unit Stream Power (W/m)	17.25		

Cross-Sectional Characteristics - Upstream				
	Minimum	Maximum	Average	
Bankfull Width (m)	6.00	6.07	6.02	
Max. Bankfull Depth (m)	0.35	0.42	0.39	
Avg. Bankfull Depth (m)	0.24	0.26	0.25	
Bankfull Area (m^2)	1.43	1.57	1.51	
Hydraulic Radius (m)	0.23	0.26	0.24	
Width: Depth (m/m)	22.92	25.78	24.14	
Wetted Width (m)	2.40	4.40	3.49	
Water Depth (m)	0.14	0.14	0.14	
Wetted Width: Depth (m/m)	29.39	62.65	51.00	
Wetted Perimeter (m)	2.23	4.47	3.48	



Hydrogeomorphology – Upstream			
Measured Low Flow Discharge (cms)	-	Total Stream Power (W/m^2)	21.66
Corresponding Average Velocity (m/s)	-	Unit Stream Power (W/m)	3.6
		Maximum Shear Stress (N/m^2)	9.94
Calculated Average Bankfull Discharge (cms)	0.85	Average Shear Stress (N/m^2)	6.38
Calculated Average Bankfull Velocity (m/s)	0.98	Mannings *n*	0.05

Substrate Characteristics				
	Particle Size (mm)		Subpavement	Silty clay
D_{10}	-		Particle Shape	-
D_{50}	-		Embeddedness	100%
D_{90}	-		Substrate (no distinction between undulating features	Silty clay (loose/soft)

Bed material is fine grained – no hydrometer grain size analyses completed.

General Field Observations

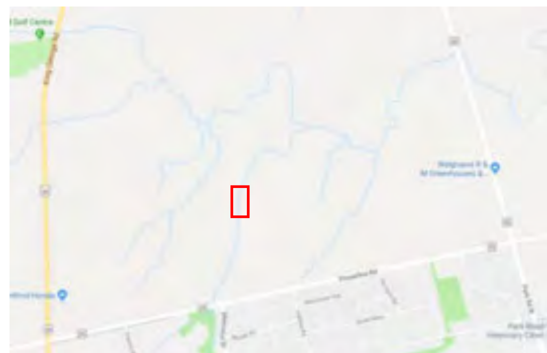
- Jones Creek tributary
- Soft clay banks
- Located in agricultural setting with relatively narrow riparian corridor (left bank)
- Overhanging vegetation (herbaceous)
- Vegetation in channel (grasses; submergent aquatic vegetation)
- Relatively steep banks in upstream cross-sections; bank angles more gradual slope in downstream
- Channel becomes less defined in downstream section
- Saturation through floodplain; good floodplain access
- Very minimal flow – backwater-like conditions
- Outlet of a tile drain at upstream limit of the site

Cross-section 3 - Looking Upstream in downstream portion of reach

Detailed Geomorphological Assessment Summary

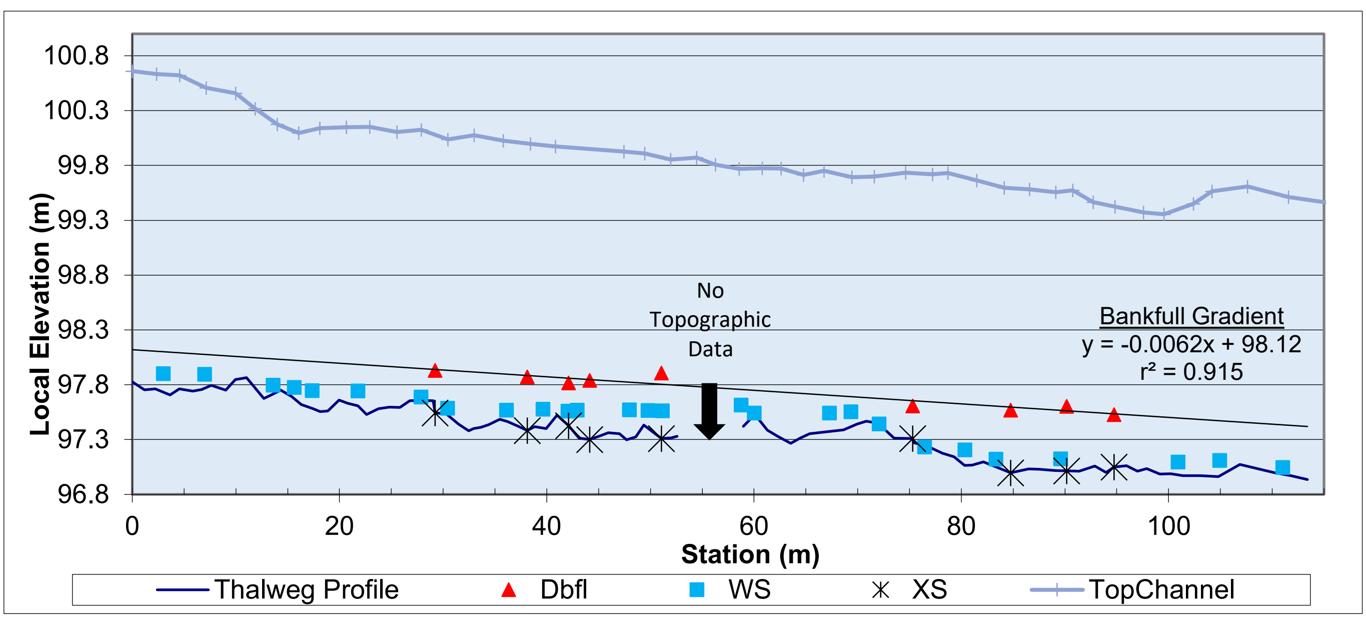
Project:	1706 – Brantford	**Date:**	October 10, 2018
Watercourse:	Tributary K	**Length surveyed (m):**	114 m
Reach:	N/A	**# of Cross-sections:**	9
Site Access:	Powerline Road		

Reach Characteristics	
Surrounding Land Use:	Agricultural (soy)
Valley Setting:	Unconfined
General Riparian Vegetation:	**Type:** shrubs; grasses
	Width: 5 – 15 m
Existing Disturbances:	Powerline Road SWM outfall; agricultural plowing
Woody Debris Occurrence:	Minimal



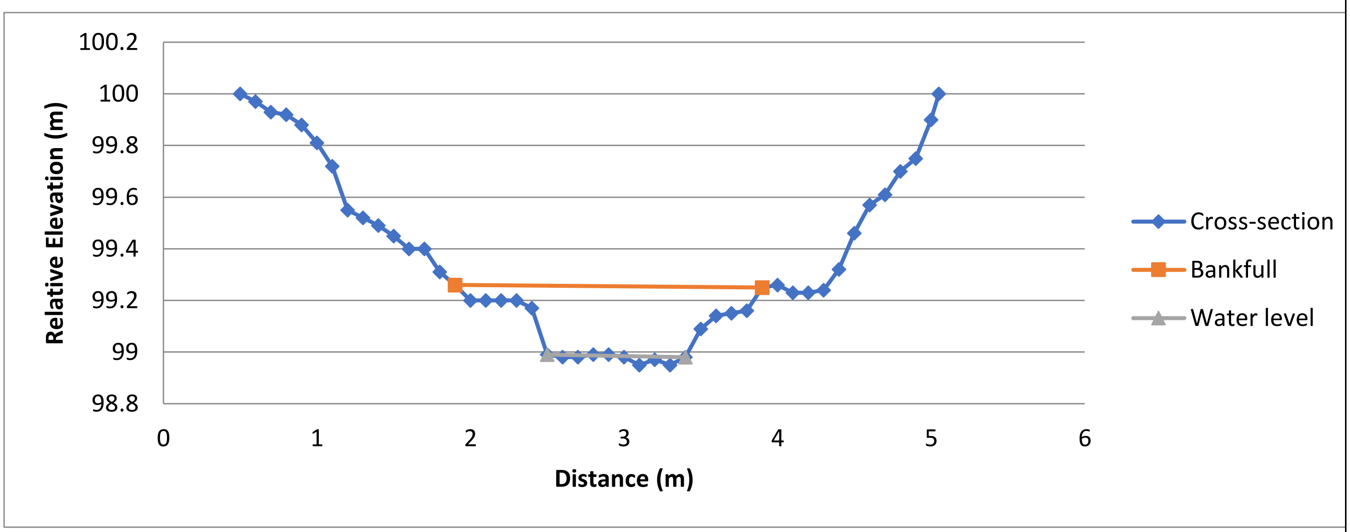
Profile Characteristics	
Bankfull Gradient (%)	0.60
Channel Bed Gradient (%)	0.70
Maximum Low Flow Pool Depth (m)	0.29
Maximum Residual Pool Depth (m)	0.20
Pool-pool Spacing (m)	N/A

Planform Characteristics	
Sinuosity	N/A
Meander Belt Width (m)	N/A
Meander Wavelength (m)	N/A
Note: Channel is altered/straightened	



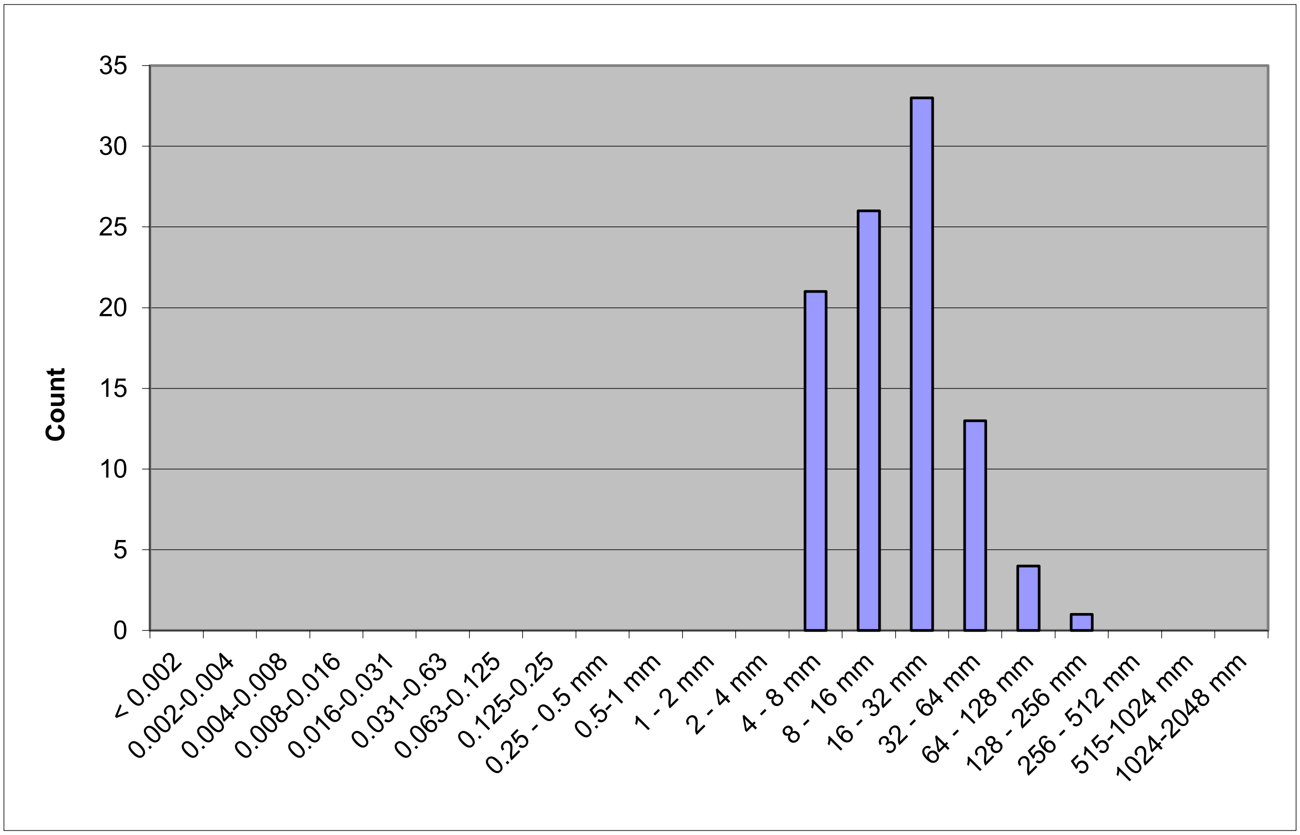
Bankfull Channel Characteristics				Bank Stratigraphy
	Minimum	Maximum	Average	
Bank Heights	0.64	1.22	0.96	
Bank Angles	16.70	78.23	68.83	
Undercutting (m) Location:	N/A			
Horizontal: Vertical Ratio	0.2	3.33	2	
Bank Material(s)	Cl, SI, FS (minimal)			

Cross-Sectional Characteristics				
	Minimum	Maximum	Average	
Bankfull Width (m)	0.88	2.4	1.82	
Max. Bankfull Depth (m)	0.30	0.60	0.48	
Avg. Bankfull Depth (m)	0.18	0.44	0.31	
Width: Depth (m/m)	2.03	11.33	6.49	
Bankfull Area (m^2)	0.26	0.89	0.56	
Hydraulic Radius (m)	0.11	0.33	0.22	
Wetted Width (m)	0.25	1.50	0.89	
Avg. Water Depth (m)	0.02	0.25	0.10	
Wetted Width: Depth (m/m)	3.18	57.86	14.88	
Wetted Perimeter (m)	0.39	1.91	1.06	



Hydrogeomorphology			
Measured Low Flow Discharge (cms)	-	**Total Stream Power (W/m^2)**	32.90
Corresponding Average Velocity (m/s)	-	**Unit Stream Power (W/m)**	18.11
		Maximum Shear Stress (N/m^2)	29.39
Calculated Average Bankfull Discharge (cms)	0.54	**Average Shear Stress (N/m^2)**	19.05
Calculated Average Bankfull Velocity (m/s)	1.01	**Mannings *n***	0.032

Substrate Characteristics				
	Particle Size (mm)		**Subpavement**	Glacial till / clay
D_{10}	5		**Particle Shape**	Angular
D_{50}	20		**Embeddedness**	None
D_{90}	50		**Particle range (riffle)**	5 – 70 mm
			Particle range (pool)	Clay/till



General Field Observations

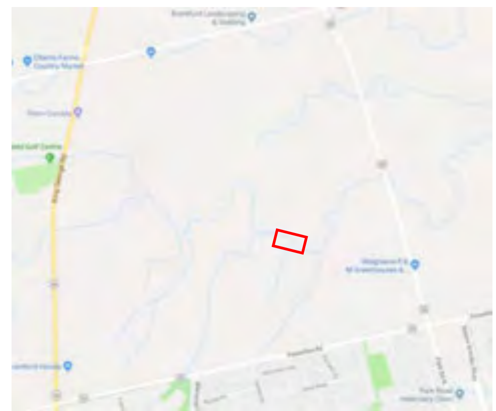
- Incised channel – depth of channel from tablelands to channel bottom ranges from 2 – 4 m in depth, whereas bankfull depths were measured at less than 1 m
- Steep gradient
- Near vertical banks
- Channel carved into red-brown clay and grey till; sculpted native material; fallen blocks / pieces of native material in channel; clay/till ledges exposed under water
- Till contains small gravel/pebbles
- Slumping within channel – vegetated blocks from top of channel
- Substrate: coarse sand and pea gravel; some soft silt deposits
- Tile drain outlet into channel
- Gully formations along top of channel/valley banks
- Channel shallows in upstream direction
- Narrow riparian corridor (herbaceous)

Cross-section 3 - Looking Upstream


Detailed Geomorphological Assessment Summary

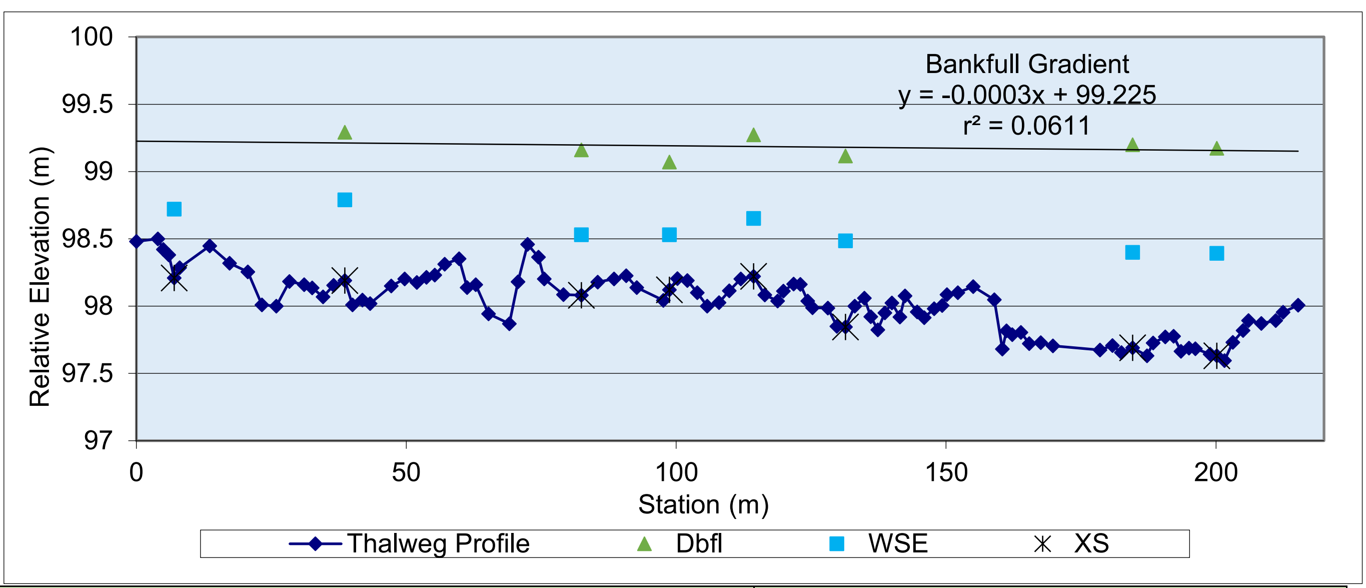
Project:	1706 – Brantford	**Date:**	November 15, 2018
Watercourse:	Jones Creek	**Length surveyed (m):**	215 m
Reach:	JC-H	**# of Cross-sections:**	8
Site Access:	Governors Road – Private Property Access		

Reach Characteristics		
Surrounding Land Use:	Natural forest & agriculture (soy)	
Valley Setting:	Confined valley setting	
General Riparian Vegetation:	**Type:** trees; herbaceous	
	Width: 6 – 70 m	
Existing Disturbances:	Pedestrian crossing; agricultural plowing	
Woody Debris Occurrence:	Minimal	



Profile Characteristics	
Bankfull Gradient (%)	0.03
Channel Bed Gradient (%)	0.28
Maximum Low Flow Pool Depth (m)	0.92
Residual Pool Depth (m)	0.59
Pool-pool Spacing (m)	20 – 40

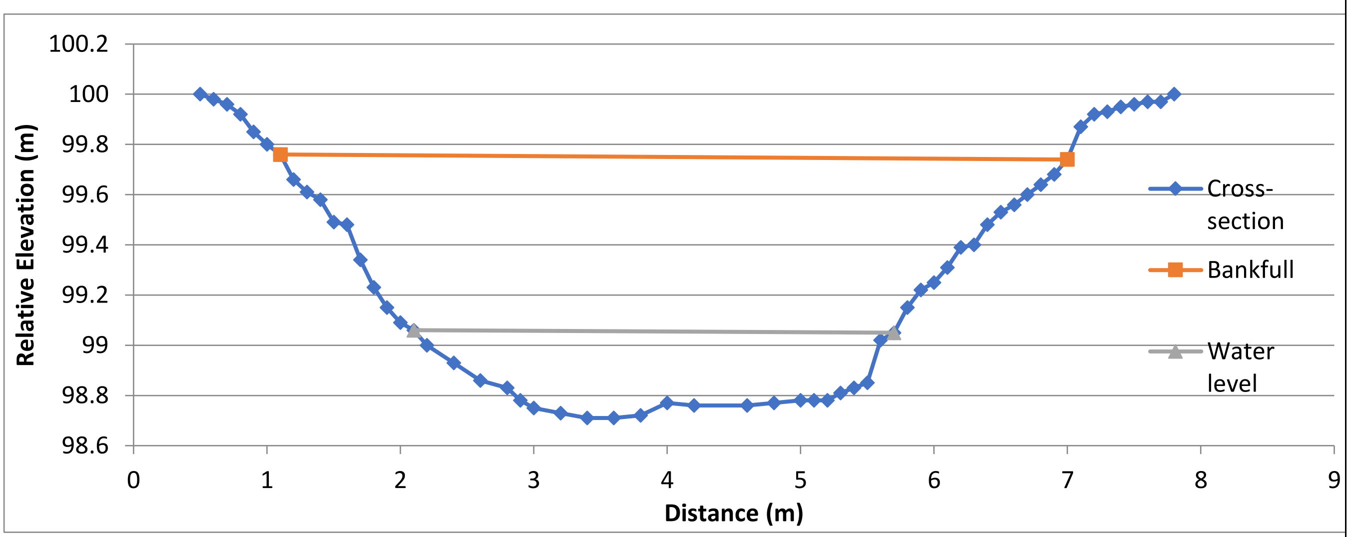
Planform Characteristics	
Sinuosity	1.27
Meander Belt Width (m)	N/A
Meander Wavelength (m)	20



Bankfull Channel Characteristics	**Bank Stratigraphy**

	Minimum	Maximum	Average
Bank Heights	0.43	1.22	0.82
Bank Angles	9.46	51.63	30.13
Undercutting (m) **Location:**		0.35 Root depth (0.4 m)	
Horizontal: Vertical Ratio	6.00	0.41	2.05
Bank Material(s)	Cl, Sl		

Cross-Sectional Characteristics			
	Minimum	**Maximum**	**Average**
Bankfull Width (m)	5.10	7.20	6.01
Max. Bankfull Depth (m)	0.95	1.54	1.21
Avg. Bankfull Depth (m)	0.57	0.86	0.72
Width: Depth (m/m)	6.74	10.63	8.44
Bankfull Area (m^2)	3.22	6.18	4.38
Hydraulic Radius (m)	0.38	0.74	0.62
Wetted Width (m)	3.00	4.00	3.36
Water Depth (m)	0.41	0.76	0.57
Wetted Width: Depth (m/m)	7.65	10.56	9.13
Wetted Perimeter (m)	3.32	4.58	3.95



Hydrogeomorphology			
Measured Discharge (cms)	0.06	**Total Stream Power (W/m^2)**	6.63
Corresponding Average Velocity (m/s)	0.11	**Unit Stream Power (W/m)**	1.10
		Maximum Shear Stress (N/m^2)	3.57
Calculated Average Bankfull Discharge (cms)	2.25	**Average Shear Stress (N/m^2)**	2.13
Calculated Average Bankfull Velocity (m/s)	0.87	**Mannings *n***	0.030

Substrate Characteristics				
	Particle Size (mm)		**Subpavement**	Glacial till / clay
D_{10}	-		**Particle Shape**	
D_{50}	-		**Embeddedness**	100%
D_{90}	-		**Substrate (no distinction between undulating features**	Silty clay(loose/soft)
Bed material is fine grained – no hydrometer grain size analyses completed.				

General Field Observations

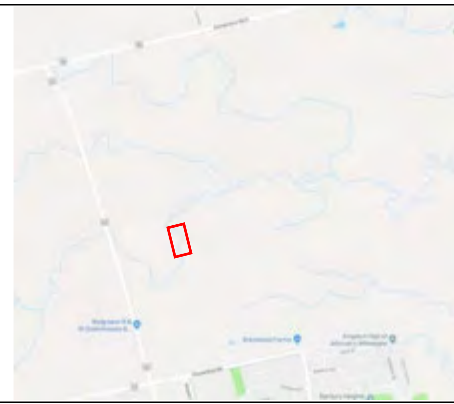
- Riparian herbaceous & trees
- Bank heights increase in downstream direction
- Mostly soft clay/silt – some areas of firm bed
- Elevated tributary (Tributary K) outlet- upstream
- Some gravel in channel near landowner pedestrian bridge crossing – source of material may be bank protection under the bridge crossing
- Fallen/leaning trees along channel
- Upstream section of site may have been altered previously; mowing to top of channel bank

Cross-section 5 - Looking Downstream

Detailed Geomorphological Assessment Summary

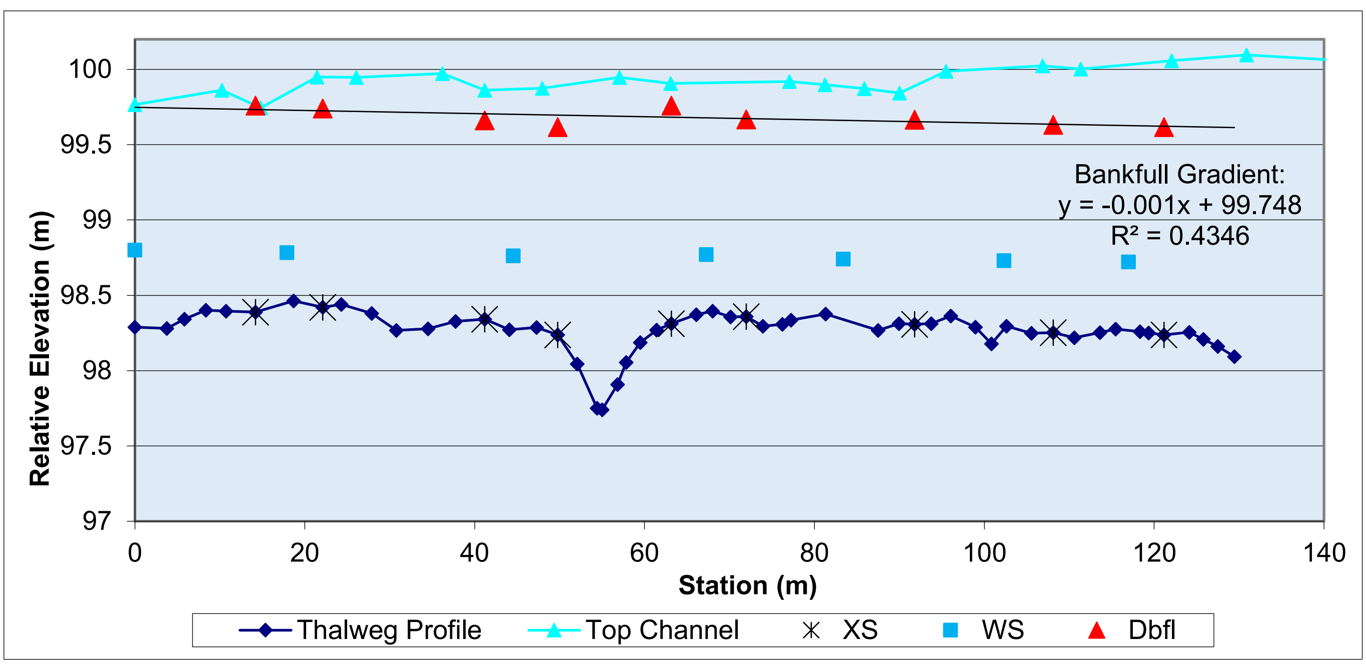
Project:	1706 – Brantford	**Date:**	November 19, 2018
Watercourse:	Jones Creek	**Length surveyed (m):**	130 m
Reach:	JC-F	**# of Cross-sections:**	9
Site Access:	Park Road		

Reach Characteristics	
Surrounding Land Use:	Natural forest
Valley Setting:	Confined valley setting
General Riparian Vegetation:	**Type:** trees; herbaceous
	Width: > 50 m
Existing Disturbances:	Pedestrian crossing
Woody Debris Occurrence:	Minimal



Profile Characteristics	
Bankfull Gradient (%)	0.10
Channel Bed Gradient (%)	0.08
Maximum Low Flow Pool Depth (m)	1.03
Maximum Residual Pool Depth (m)	0.65
Pool-pool Spacing (m)	N/A

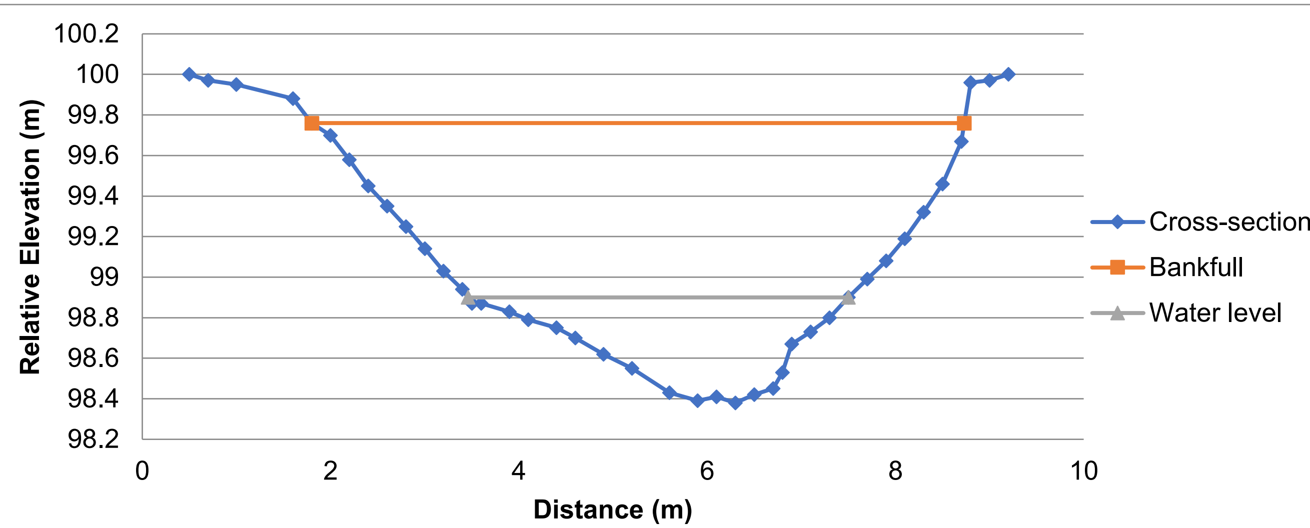
Planform Characteristics	
Sinuosity	1.95
Meander Belt Width (m)	N/A
Meander Wavelength (m)	20 – 30
Meander Amplitude (m)	30



Bankfull Channel Characteristics			
	Minimum	**Maximum**	**Average**
Bank Heights	0.77	1.54	1.05
Bank Angles	5.98	83.13	30.84
Undercutting (m) **Location:**		0.10 Top of bank	
Horizontal: Vertical Ratio	0.98	4.77	1.92
Bank Material(s)	Cl, Sl		

Bank Stratigraphy

Cross-Sectional Characteristics			
	Minimum	**Maximum**	**Average**
Bankfull Width (m)	4.66	6.93	5.84
Max. Bankfull Depth (m)	1.21	1.45	1.34
Avg. Bankfull	0.64	0.93	0.84
Width: Depth (m/m)	5.13	9.51	7.05
Bankfull Area (m^2)	3.91	5.95	4.89
Hydraulic Radius (m)	0.56	0.81	0.73
Wetted Width (m)	2.90	4.20	3.40
Water Depth (m)	0.40	1.46	0.59
Wetted Width: Depth (m/m)	1.94	14.43	10.68
Wetted Perimeter (m)	3.29	7.02	4.06



Hydrogeomorphology			
Measured Discharge (cms)	0.12	**Total Stream Power (W/m^2)**	39.26
Maximum Measured Velocity (m/s)	0.09	**Unit Stream Power (W/m)**	6.72
		Maximum Shear Stress (N/m^2)	13.18
Calculated Average Bankfull Discharge (cms)	4.00	**Average Shear Stress (N/m^2)**	8.23
Calculated Average Bankfull Velocity (m/s)	1.39	**Mannings *n***	0.035

Substrate Characteristics				
	Particle Size (mm)		**Subpavement**	Silty- clay (firm)
D_{10}	-		**Particle Shape**	-
D_{50}	-		**Embeddedness**	100%
D_{90}	-		**Substrate (no distinction between undulating features**	Silty clay(loose/soft)
Bed material is fine grained – no hydrometer grain size analyses completed.				

General Field Observations
- Steep banks – very soft silt/clay mixture - LWD in channel - Soft clay/silt shelves on bed - Exposed tree roots - Planform change – gradual – incision - Till is firm where there is little soft silt coverage (holes and cavities in hard till/clay) - Planform & profile consistent with downstream reaches

Cross-section 5 - Looking Downstream

APPENDIX E:
HYRDOGEOLOGY APPENDIX

Table 1: Summary of Water Well Records

MECP Well ID	Address	Lot	Conc.	Easting	Northing	Township	Well Use	Bedrock/ Overburden	Depth to Bedrock (m)	Total Depth of Well (m)	Static Water Level (m)	Year Drilled	Pumping Rate (GPM)	Water Column	Notes
Wells Records Within the Northern Expansion Area															
1300114	~	25	1	555484	4782703	Brantford	Domestic	Bedrock	29.3	32	10.7	1964	5	21.3	
1305028	~	24	1	555394	4782073	Brantford	Domestic	Overburden	~	15.2	3.7	1996	~	11.5	
1302220	~	21	1	554589	4780879	Brantford	Domestic	Overburden	~	26.2	23.2	1975	3	3	Coarse Gravel and sand
1300139	~	40	1	561984	4782563	Brantford	Domestic	Overburden	~	21.9	12.2	1965	3	9.7	
1300122	~	31	1	558334	4782143	Brantford	Domestic	Bedrock	25.6	30.5	7.3	1905	~	23.2	
1300120	~	31	1	558183	4782728	Brantford	Domestic	Overburden	25	27.4	7.6	1948	10	19.8	
1301358	~	21	1	554564	4780983	Brantford	Domestic	Overburden	~	47.2	40.5	1969	3	6.7	Alternating Coarse and fine layers
1304601	~	44	2	564042	4780948	Brantford	Domestic	Overburden	~	18.3	4.6	1993	3	13.7	
1301691	~	23	2	555379	4780523	Brantford	Commercial	Overburden	~	21.6	15.2	1971	20	6.4	Coarse Gravel
1300233	~	44	3	564414	4780983	Brantford	Domestic	Overburden	~	18.3	6.1	1965	2	12.2	
1301924	~	26	1	556604	4781353	Brantford	Domestic	Bedrock	31.4	39.3	9.8	1973	20	29.5	
1300181	~	42	2	562744	4782533	Brantford	Domestic	Overburden	~	24.4	20.7	1966	3	3.7	
3802097	~	41	~	556454	4781073	Niagara	Domestic	Overburden	~	12.5	0.6	1971	6	11.9	Sand & gravel at 11.3 m
1304616	~	25	1	555524	4782577	Brantford	Domestic	Overburden	~	12.2	~	1993	3	~	
1301367	~	22	1	555014	4780993	Brantford	Domestic	Overburden	~	25.3	15.2	1968	10	10.1	Gravel starting at 0.61 m
1301956	~	40	1	561864	4782563	Brantford	Domestic	Overburden	~	24.4	6.1	1973	8	18.3	
1300113	~	24	1	555634	4781908	Brantford	Livestock	Bedrock	37.8	41.1	21.3	1964	20	19.8	
1303433	~	45	3	564884	4780341	Brantford	Domestic	Overburden	~	19.2	4.6	1986	2	14.6	
1303624	~	22	2	555006	4780892	Brantford	Domestic	Overburden	~	25.3	19.5	1987	15	5.8	Coarse Gravel and sand
1305378	~	21	1	554224	4781792	Brantford	Public	Bedrock	44.2	48.8	23.8	1999	20	25	
1300165	~	25	2	556154	4780333	Brantford	Domestic	Overburden	~	23.5	7.6	1965	10	15.9	Sand at 22 m
1302488	~	27	1	556774	4781423	Brantford	Domestic	Bedrock	30.8	32	7.6	1977	20	24.4	
1300231	~	43	3	563784	4780803	Brantford	Domestic	Overburden	~	13.4	7.3	1966	3	6.1	
1302373	~	21	1	554514	4780873	Brantford	Domestic	Overburden	~	30.2	23.5	1976	20	6.7	Sand at 24 m
1301250	~	22	2	555054	4780703	Brantford	Domestic	Overburden	~	24.7	18.9	1968	10	5.8	Sand at 18.5 m
1300115	~	25	1	555474	4782693	Brantford	Domestic	Overburden	~	15.8	9.1	1964	4	6.7	
1300125	~	31	1	558424	4782223	Brantford	Irrigation	Bedrock	25.3	61	8.5	1959	8	52.5	
1303872	~	37	1	560662	4782625	Brantford	Commercial	Bedrock	32.3	63.4	12.2	1988	16	51.2	
1300232	~	44	3	564254	4780943	Brantford	Domestic	Overburden	~	24.4	6.1	1964	3	18.3	
1300119	~	30	1	557974	4781773	Brantford	Domestic	Bedrock	23.8	30.5	2.4	1955	5	28.1	
1302074	~	42	1	562909	4782847	Brantford	Domestic	Overburden	~	27.4	~	1974	6	~	
1301688	~	30	1	558009	4781773	Brantford	Domestic	Overburden	~	18.3	7.6	1971	5	10.7	
1302623	~	43	2	563434	4782843	Brantford	Domestic	Overburden	~	19.2	6.1	1978	6	13.1	
1301245	~	21	1	554534	4780883	Brantford	Not used	Overburden	~	34.4	25.6	1968	4	8.8	
1300112	~	23	1	555274	4781113	Brantford	Livestock	Bedrock	40.2	40.8	19.8	1963	20	21	Sand and Gravel at 21 m
1303287	~	23	2	555328	4780522	Brantford	Commercial	Overburden	~	22.9	15.2	1984	15	7.7	
1301776	~	46	3	565374	4780033	Brantford	Domestic	Overburden	~	21.3	6.1	1972	~	15.2	
7114368	701 Powerline Road.	~	~	554340	4780805	Paris	Monitoring	Overburden	~	21	~	2008	~	~	Entirely Sand and Gravel
7263019	459 Paris Road	21	1	554314	4780977	Brantford	Commercial	Overburden	~	53	41.1	2016	5	11.9	Sand and Gravel at 14 m
1300128	~	31	1	558804	4782453	Brantford	Domestic	Bedrock	29.9	43	15.2	1963	~	27.8	
1300166	~	25	2	556174	4780338	Brantford	Domestic	Overburden	~	25	12.2	1965	12	12.8	Sand at 23 m
1303432	~	46	3	565145	4780096	Brantford	Domestic	Overburden	~	16.8	4.6	1986	2	12.2	
1300137	~	39	1	561704	4782533	Brantford	Livestock	Bedrock	38.4	40.5	13.7	1965	30	26.8	
1300111	~	23	1	555054	4781183	Brantford	Livestock	Overburden	~	24.4	12.2	1958	1	12.2	Stone and quick sand
1300129	~	32	1	558954	4781973	Brantford	Livestock	Bedrock	28.7	34.1	11	1949	1	23.1	
1301833	~	40	1	562034	4782603	Brantford	Domestic	Bedrock	30.8	43.6	13.4	1972	1	30.2	
1300163	~	24	2	556164	4780173	Brantford	Commercial	Bedrock	38.4	47.2	12.8	1960	4	34.4	Sand at 18.3 m
1306460	389 Brant Road	~	~	558265	4781945	Brantford	Monitoring	Overburden	~	4.5	~	2005	~	~	
1303562	~	45	3	564572	4780726	Brantford	Domestic	Overburden	~	15.2	4.6	1987	2	10.6	
1304075	~	20	1	554351	4781112	Brantford	Domestic	Overburden	~	17.4	11.3	1989	12	6.1	
1300121	~	31	1	558364	4782143	Brantford	Domestic	Bedrock	25.3	27.4	8.5	1950	1	18.9	
1303074	~	21	1	554615	4780888	Brantford	Commercial	Overburden	~	25.9	20.7	1982	20	5.2	
1303697	~	37	1	560662	4782625	Brantford	Commercial	Bedrock	27.4	32.3	10.7	1988	10	21.6	
7108893	250 Golf Road	25	2	556448	4780563	Brantford	Not used	Overburden	~	~	8.8	2008	~	~	
7282596	394 Landen Road	~	~	564551	4780715	Brantford	Unknown	Overburden	~	~	~	2016	~	~	
1303202	~	21	1	554546	4780834	Brantford	Domestic	Overburden	~	28.3	24.1	1983	2	4.2	Sand at 23 m
7108892	250 Golf Road	25	2	556448	4780563	Brantford	Not used	Overburden	~	~	~	2008		~	
1301439	~	~	JJG 02	565614	4779973	Brantford	Domestic	Overburden	~	7.6	4.6	1969	30	3	
1301252	~	44	2	564194	4780983	Brantford	Domestic	Bedrock	36.9	40.5	8.2	1968	1	32.3	
1300109	~	21	1	554554	4780853	Brantford	Domestic	Bedrock	40.8	54.9	40.8	1965	20	14.1	
1300123	~	31	1	558364	4782273	Brantford	Domestic	Bedrock	25.3	25.9	7.6	1950	8	18.3	
1301287	~	43	2	563354	4782803	Brantford	Domestic	Overburden	~	30.8	19.8	1968	3	11	
1301737	~	43	1	563294	4782883	Brantford	Domestic	Bedrock	31.1	34.7	13.7	1971	2	21	
1300136	~	39	1	561604	4782468	Brantford	Unknown	Overburden	~	25	~	1964	~	~	
7212439	407 Paris Road	22	2	555048	4780679	Brantford	Domestic	Overburden	~	23.8	18.9	2013	15	4.9	Sand and gravel throughout
7041625	299 Lynden Road	~	2	563490	4781212	Brantford	Not used	Overburden	~	7.6	~	2007	~	~	
1302888	~	24	1	555294	4782523	Brantford	Domestic	Overburden	~	15.2	4.6	1980	6	10.6	
1302347	~	43	1	563114	4782823	Brantford	Domestic	Bedrock	28	36	11.3	1976	7	24.7	
1300134	~	37	1	560634	4782523	Brantford	Domestic	Overburden	~	20.4	9.1	1966	10	11.3	
1300133	~	37	1	560854	4782383	Brantford	Domestic	Overburden	~	16.8	12.2	1964	3	4.6	
1305725	~	23	2	555589	4780321	South Dumfries	Commercial	Overburden	~	25	14	2001	10	11	Sand & gravel at 3.6 m
1304959	~	22	2	554922	4780871	Brantford	Domestic	Overburden	~	29	19.8	1995	15	9.2	
1302197	~	37	1	560617	4782696	Brantford	Commercial	Overburden	~	12.2	4.6	1975	6	7.6	
1300124	~	31	1	558394	4782303	Brantford	Domestic	Bedrock	24.7	31.7	9.1	1954	1	22.6	
1304407	~	31	1	558304	4782134	Brantford	Domestic	Bedrock	18.3	31.7	4.6	1991	10	27.1	
1301389	~	22	1	554934	4780898	Brantford	Domestic	Overburden	~	26.8	19.8	1969	5	7	
1301248	~	21	1	554314	4780803	Brantford	Industrial	Overburden	~	32.6	15.2	1968	4	17.4	Sand at 27.5 m
1302224	~	21	1	554582	4780930	Brantford	Domestic	Overburden	~	30.5	24.1	1975	5	6.4	
1301844	~	24	1	555464	4782363	Brantford	Domestic	Overburden	~	18.9	11.6	1972	8	7.3	
1300126	~	31	1	558564.00	4782843	Brantford	Domestic	Bedrock	17.7	25	0.9	1962	10	24.1	
1300164	~	25	2	556389.00	4780643	Brantford	Domestic	Bedrock	41.1	46.3	12.2	1961	2	34.1	
1300108	~	21	1	554234.00	4781023	Brantford	Commercial	Bedrock	45.7	51.8	39.6	1963	13	12.2	
1300185	~	44	2	564314.00	4781003	Brantford	Domestic	Overburden	~	23.5	4.6	1967	2	18.9	
1302662	~	21	2	554674.00	4780823	Brantford	Domestic	Overburden	~	26.5	19.8	1978	20	6.7	
7212440	407 Paris Road	22	2	555050.00	4780673	Brantford	Domestic	Overburden	~	~	20.7	2013	8	~	
1301246	~	21	1	554574.00	4780883	Brantford	Not used	Overburden	~	27.4	26.8	1968	1	0.6	Sand & gravel at 17 m
7108891	250 Golf Road	25	2	556445.00	4780568	Brantford	Not used	Overburden	~	~	0.8	2008	~	~	
7200686	645 Powerline Road	23	1	555247.00	4781232	Brantford	Livestock	Overburden	~	43.6	21.3	2013	8	22.3	
1306678	374 Lynden Road	~	~	564524.00	4780714	Brantford	Monitoring	Overburden	~	~	~	2006	~	~	
1302314	~	21	1	554464.00	4780823	Brantford	Domestic	Overburden	~	30.5	23.2	1975	5	7.3	
1304173	~	23	2	555676.00	4780310	Brantford	Domestic	Overburden	~	10.4	5.2	1990	3	5.2	
1304442	~	37	1	560632.00	4782659	Brantford	Domestic	Overburden	~	26.5	1.8	1992	1	24.7	
1301247	~	21	1	554494.00	4780943	Brantford	Domestic	Bedrock	43.6	54.9	42.7	1968	6	12.2	
1302580	~	25	1	555474.00	4782643	Brantford	Domestic	Overburden	~	12.2	3	1978	6	9.2	
1300116	~	28	1	557374.00	4781523	Brantford	Domestic	Bedrock	21.3	28	11.3	1962	4	16.7	
Wells Records Within the Tutela Heights Study Area															
7212219	~	~	~	557871	4772811	Brantford	Unknown	Overburden	~	~	~	2013	~	~	
7229614	~	~	~	557952	4773056	Brantford	Unknown	Overburden	~	~	~	2014	~	~	
1300460	~	~	~	558334	4773223	Brantford	Domestic	Bedrock	70.1	72.2	8.8	1952	15	63	
1302903	~	13	1	558414	4771583	Brantford	Domestic	Bedrock	54.9	59.1	27.7	1980	7	31	
1300043	~	~	~	557394	4772863	Brantford	Not used	Bedrock	74.7	76.2	22.9	1964	0	53	
1301740	~	~	~	558974	4774113	Brantford	Domestic	Overburden	~	13.7	9.8	1972	80	4	Sand at 6.7 m
1300463	~	~	~	558714	4772923	Brantford	Unknown	Bedrock	55.2	55.8	~	1958	~	~	Sand at 40 m and 51.5 m. Gravel at 55 m.
7293556	~	~	~	558363	4772534	Brantford	Irrigation	Bedrock	52.7	60	4.3	2017	9	56	
1301355	~	~	~	558994	4774063	Brantford	Domestic	Overburden	~	10.7	4.8	1968	1	6	
7220629	~	~	~	557997	4773002	Brantford	Unknown	Overburden	~	~	~	2014	~	~	
7237662	81 Tutela Heights	~	~	559156	4772826	Brantford	Domestic	Overburden	~	6.1	~	2014	~	~	
1300461	~	~	~	558674	4773213	Brantford	Not used	Overburden	~	29.9	~	1957	~	~	
1302819	~	~	~	559014	4774183	Brantford	Domestic	Overburden	~	13.7	10.7	1979	10	3	Sand at 5.5 m
7159761	~	~	~	558549	4771615	Brantford	Monitoring	Overburden	~	~	~	2011	~	~	
7168111	~	~	~	559319	4773092	Brantford	Unknown	Overburden	~	~	~	2011	~	~	
1300462	~	~	~	558734	4772923	Brantford	Not used	Bedrock	57.3	58.2	~	1957	30	~	Sand at 26.8 m
7295207	228 Mt. Pleasant St.	~	~	559028	4774390	Brantford	Domestic	Overburden	~	~	~	2016	~	~	

Table 1: Summary of Water Well Records

MECP Well ID	Address	Lot	Conc.	Easting	Northing	Township	Well Use	Bedrock/ Overburden	Depth to Bedrock (m)	Total Depth of Well (m)	Static Water Level (m)	Year Drilled	Pumping Rate (GPM)	Water Column	Notes
1306342	205,207,209 Mt. Pleasant St.	~	~	558643	4774380	Brantford	Unknown	Overburden	~	5	~	2005	~	~	Sand at 1.1 m
7215905	~	~	~	557917	4773063	Brantford	Unknown	Overburden	~	~	~	2014	~	~	
7149419	292 Mt. Pleasant Rd.	~	~	558953	4773804	Brantford	Monitoring	Overburden	~	6.5	~	2010	~	~	
1302392	~	13	1	558464	4771823	Brantford	Domestic	Overburden	~	18.3	~	1976	~	~	
1300464	~	~	~	558074	4773423	Brantford	Unknown	Bedrock	67.4	68	~	1958	~	~	
7111763	2 Rue Chateau Terr.	~	~	558964	4773136	Brantford	Irrigation	Overburden	~	64.9	20	2008	205	45	Sand and Gravel at 61 m
7251806	422 Mt. Pleasant Rd.	~	~	557919	4772940	Brantford	Monitoring	Overburden	~	12.2	~	2015	~	~	
7110586	286 Mt. Pleasant Rd.	~	~	558975	4773815	Brantford	Irrigation	Overburden	~	32.6	~	2008	~	~	Sand at 16.8 m
7262429	94 Tutela Heights Rd.	~	~	559463	4772974	Brantford	Monitoring	Overburden	~	6.1	~	2016	~	~	
7103729	82 Morrell St.	~	~	557944	4772023	Brantford	Monitoring	Overburden	~	4.6	1.8	2008	~	3	
7116601	400 Mt. Pleasant Rd,	25	~	558284	4773131	Brantford	Unknown	Overburden	~	~	~	2008	~	~	
7293555	56 Ruijs Blvd.	~	~	558443	4772540	Brantford	Domestic	Bedrock	47.6	100.9	~	2017	~	~	
1300465	~	~	~	558484	4773753	Brantford	Not used	Overburden	~	39.9	11.3	1958	~	29	Sand and Gravel at 29.6 m and 31.4 m
1302145	~	~	~	558279	4773215	Brantford	Domestic	Overburden	~	15.2	~	1974	~	~	Sand at 3.6 m
1300466	~	~	~	558484	4773753	Brantford	Monitoring	Bedrock	42.7	43.9	~	1958	~	~	Sand and Gravel at 29.6 m, 32 m, and 42 m
1303255	~	~	~	558459	4773460	Brantford	Domestic	Overburden	~	13.4	11	1984	25	2	Sand throughout
7228732	~	~	~	558366	4773268	Brantford	Domestic	Bedrock	~	80.8	19.5	2013	10	61	
7281381	687 Front Rd.	~	~	558418	4772004	Brantford	Domestic	Overburden	~	14.3	9.15	2016	10	5	Sand throughout
7238701	429 Mt. Pleasant Rd.	~	~	557837	4773190	Brantford	Not used	Overburden	~	~	~	2015	~	~	
7158315	94 Tutela Heights Rd.	~	~	559319	4773092	Brantford	Monitoring	Overburden	~	6	~	2010	~	~	

Table 2: Summary of Permits to Take Water Within the Sub-Watershed

Permit Number	Client Name	Lot	Conc.	Easting	Northing	Township	Purpose of Permit	Issue Date	Expiry Date	Water Taking Source	Water Taking Source ID	Active
Permits Within Primary Study Area												
66-P-0016	Brantford, City of	29	2	558015	4781030	Brantford	Water Supply: Golf Course Irrigation	3/29/1966	12/31/2006	Ground Water	Well 1	No
03-P-2334T	King & Benton Development Group	21	2	554688	4780409	Brantford	Miscellaneous: Pumping Test	11/25/2003	12/31/2003	Ground Water	Well TW2	No
7511-A4SPUR	Thomas W. Pate	39	1	561236	4783489	Brantford	Agricultural: Farm	12/22/2015	1/31/2026	Surface Water	Jones Creek	Yes
3142-A4CLJT	CRH Canada Group Inc.	31~13~2~6~11~7~1	1 Brantford~	558330	4782810	Brantford	Dewatering Construction	11/17/2015	11/30/2016	Surface and Ground Water	Site No. -204/C(53)	No
1142-7VHQSJ	The Corporation of the City of Brantford	32	2	559149	4781610	Brantford	Dewatering Construction	9/14/2009	8/31/2010	Surface Water	Municipal Storm Sewer/East Channel	No
64-P-0113	Brantford Landscaping & Sodding	35	1	559778	4782679	Brantford	Agricultural: Farm	5/20/1964	3/31/2005	Surface Water	Fairchild Creek(a tributay of)	No
0545-ABDQJF	The Corporation of the City of Brantford	29	2	557972	4781203	Brantford	Commercial: Golf Course Irrigation	6/29/2016	2/28/2026	Ground Water	Well # 1	Yes
0453-6B6PPD	Braund, Ernie	40	1	562340	4783347	Brantford	Agricultural: Farm	4/29/2005	10/31/2010	Surface Water	Jane Creek	No
7411-6FYHM7	Pate, Thomas W.	39	1	561236	4783489	Brantford	Agricultural: Farm	1/22/2006	12/31/2015	Surface Water	Jones Creek	No
3142-A4CLJT	CRH Canada Group Inc.	31~13~2~6~11~7~1	1	558546	4781039	Brantford	Dewatering Construction	11/17/2015	11/30/2016	Surface and Ground Water	Site No. 1-205/C(54)	No
6054-6RNHEW	The Corporation of the City of Brantford	29	2	557972	4781203	Brantford	Commercial: Golf Course Irrigation	7/26/2006	2/28/2016	Ground Water	Well # 1	No
1535-9TUKEG	Holcim (Canada) Inc.	31~13~2~6~11~7~1	1	558330	4782810	Brantford	Dewatering Construction	6/22/2015	11/30/2016	Surface and Ground Water	Site No. -204/C(53)	No
00-P-2061	Brantwod Farm c/o Tom Pate	39	1	561236	4783489	Brantford	Agricultural: Farm	4/11/2000	3/31/2005	Surface Water	Jones Creek	No
7271-6EHKJ3	Brantford Landscaping & Sodding Ltd.	35	1	559781	4782692	Brantford	Agricultural: Farm	7/29/2005	12/31/2014	Surface Water	Tributary of Fairchild Creek	No
1535-9TUKEG	Holcim (Canada) Inc.	31~13~2~6~11~7~1	1	558546	4781039	Brantford	Dewatering Construction	6/22/2015	11/30/2016	Surface and Ground Water	Site No. 1-205/C(54)	No
3770-6APQBL	Ross Knill	2	1	554998	4780169	Brantford	Agricultural: Farm	4/5/2005	10/31/2014	Surface and Ground Water	Trib. of Nith River	No

V's within Primary study Area

GM BluePlan Engineering Ltd.
Guelph, Owen Sound, Listowel, Kitchener, London, Hamilton, GTA
650 Woodlawn Rd. W. Block C, Unit 2, Guelph, ON N1K 1B8
www.GMBluePlan.ca

PROJECT: 717003
BRANTFORD
GROWTH
PLAN

N

LEGEND

WELL

800 400 0 1000 2000 3000

1:60000 (m)

HYDROGEOLOGICAL
CROSS-SECTIONS

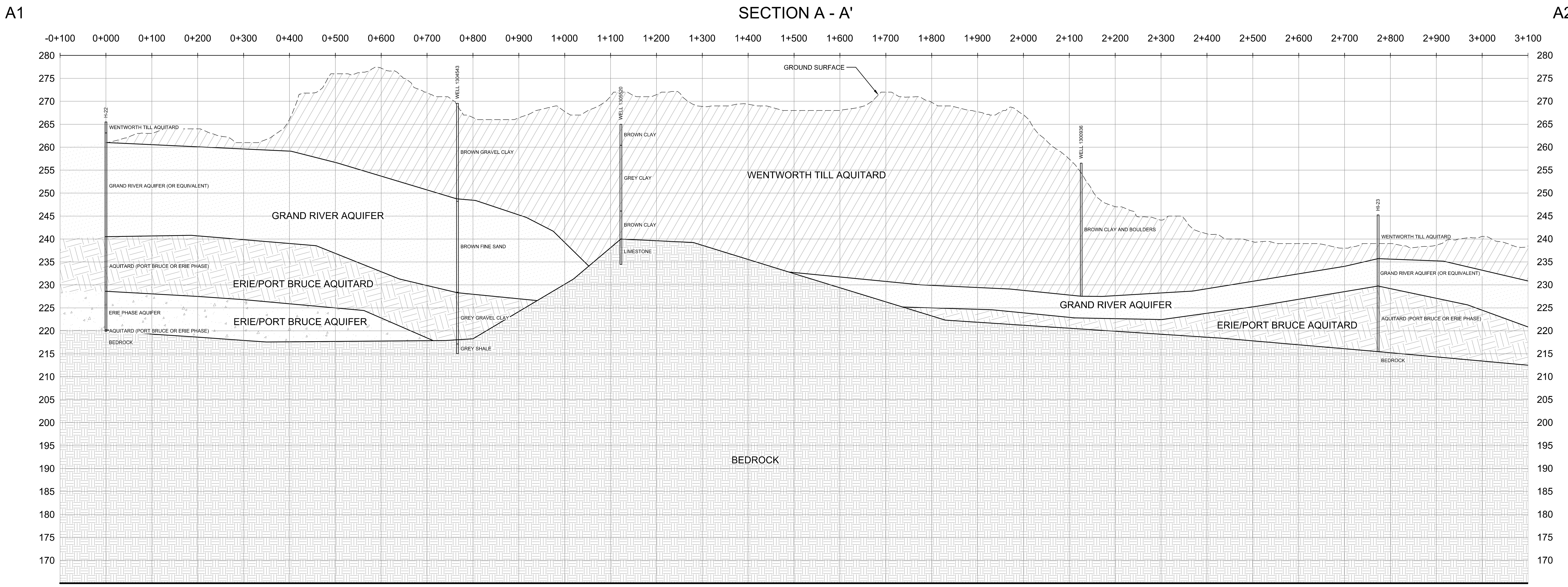
Figure No. 1

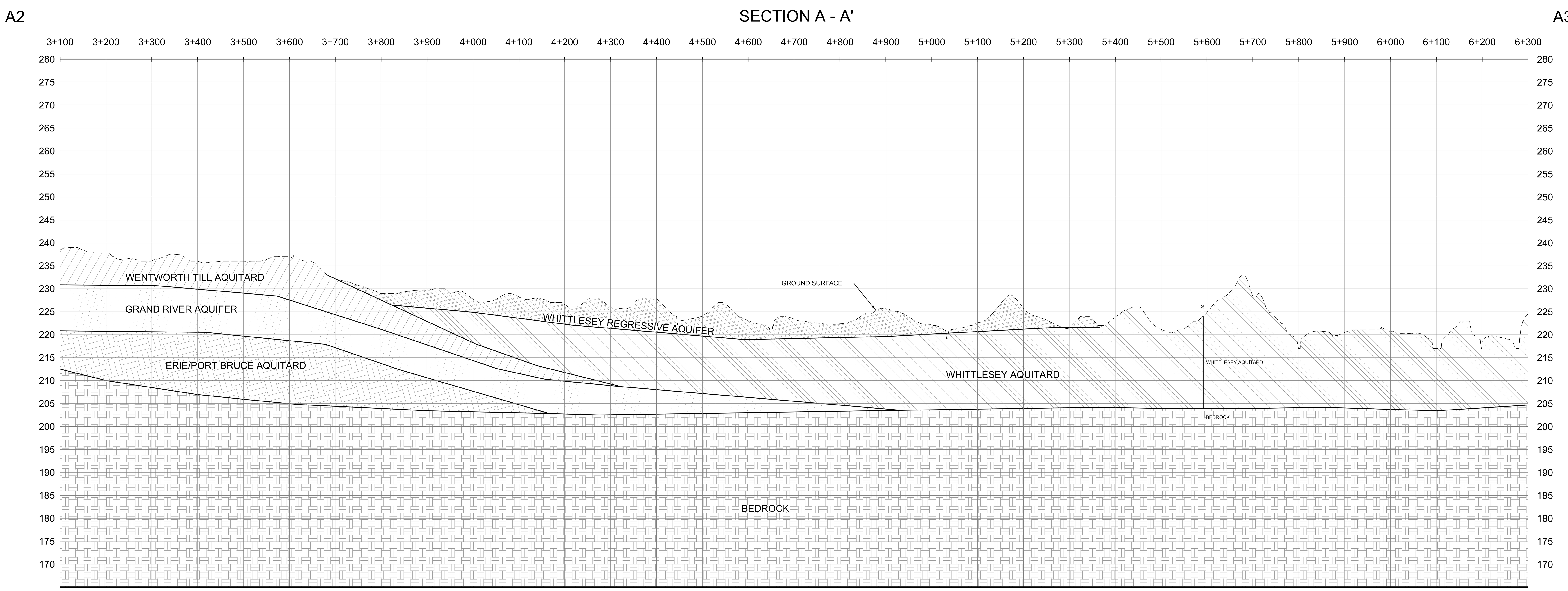
GM BluePlan
ENGINEERING

717003
NOVEMBER 2018
Scale: 1:10000 | NAD 1983 UTM Zone 17N

FILE:W:\GTA\717000\717003 Brantford Growth Plan\5 Work In Progress\Hydrogeology\717003-Hydrogeological Study Plan View.dwg LAYOUT:FIG 1 PLAN
LAST SAVED BY:Sgasior, 1/17/2019 9:30:59 AM PLOTTED BY:Steve Gasior - GM BluePlan 1/17/2019 9:31:41 AM

PROJECT: 717003
BRANTFORD
GROWTH
PLAN





HORIZONTAL
75 0 50 100 200
1:5000 (m)

VERTICAL
5 0 5 10 20
1:500 (m)

HYDROGEOLOGICAL
CROSS-SECTIONS

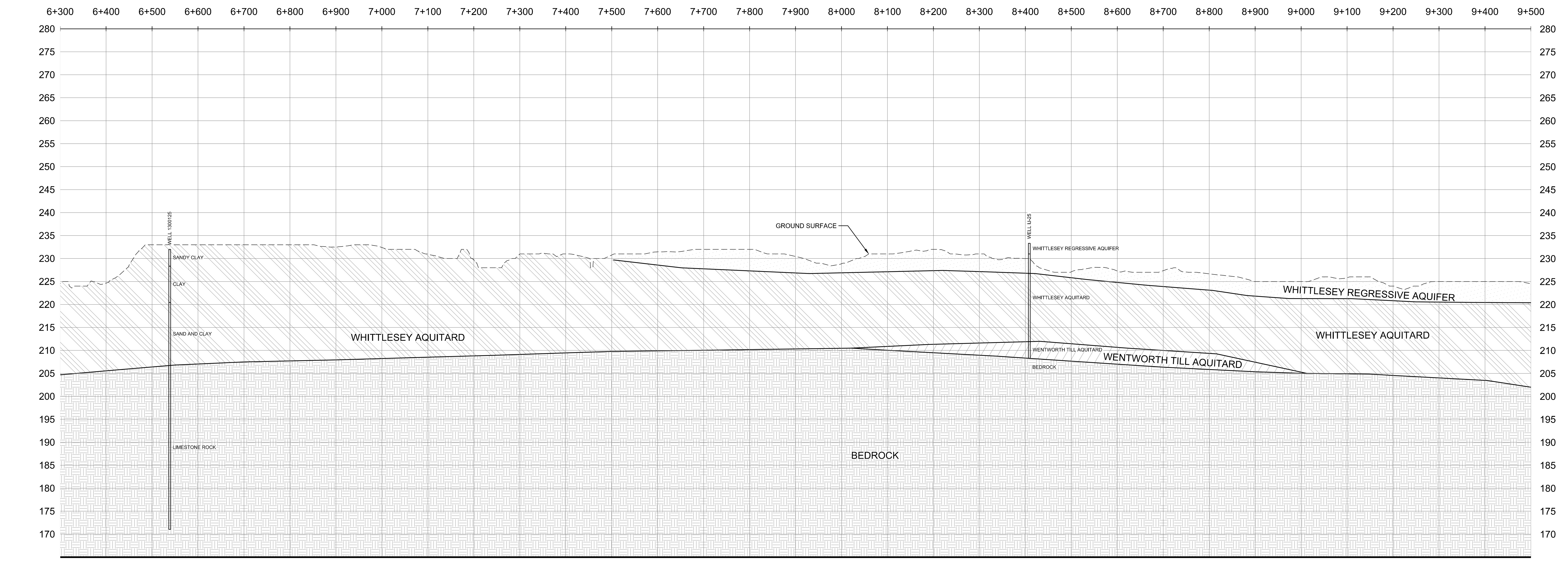
Figure No. 2

717003
NOVEMBER 2018
Scale: 1:5000 | NAD 1983 UTM Zone 17N

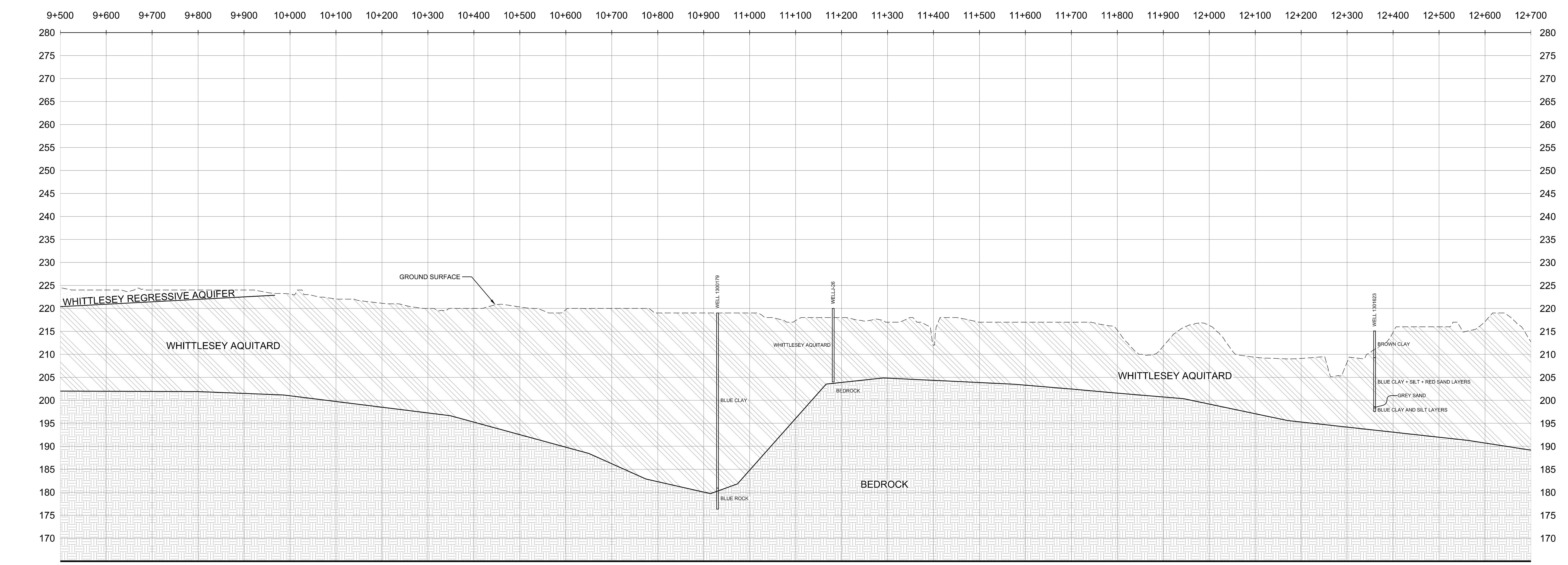
NOTE: WELLS H-22, HI-23, & I-24 ARE FORMALLY REFERRED TO AS "VIRTUAL WELLS".
STRATIGRAPHY AT THIS LOCATION TAKEN FROM ONTARIO GEOLOGICAL SURVEY GROUNDWATER RESOURCES STUDY 10:
THREE-DIMENSIONAL MAPPING OF SURFICIAL DEPOSITS IN THE BRANTFORD-WOODSTOCK AREA, SOUTHWESTERN ONTARIO

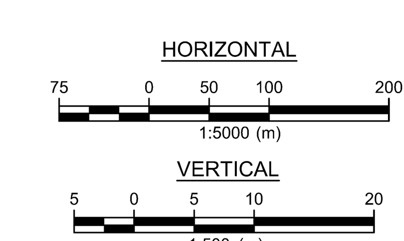
PROJECT: 717003
BRANTFORD
GROWTH
PLAN

SECTION A - A'



SECTION A - A'





HYDROGEOLOGICAL
CROSS-SECTIONS

Figure No. 3

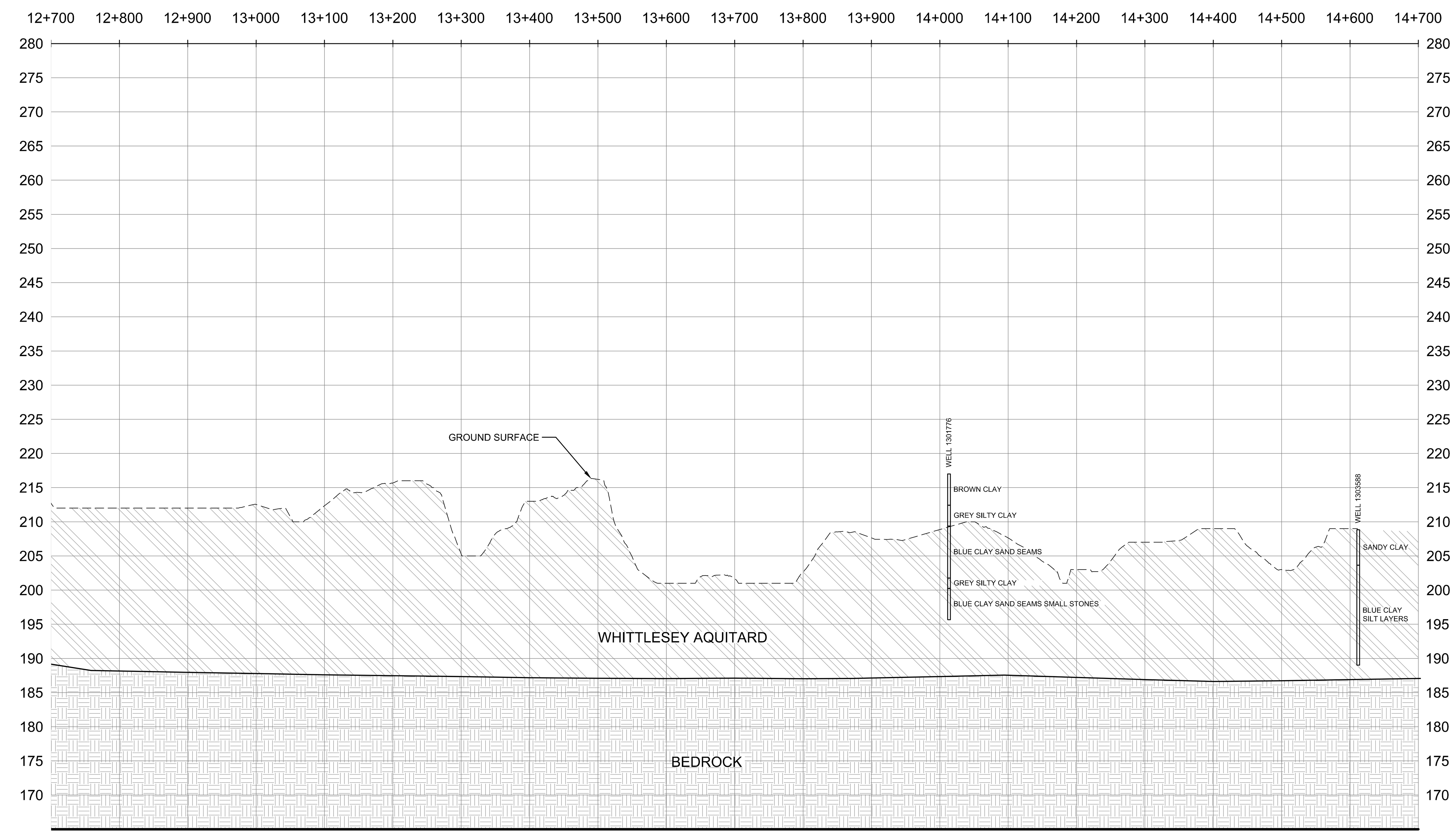
BluePlan
ENGINEERING

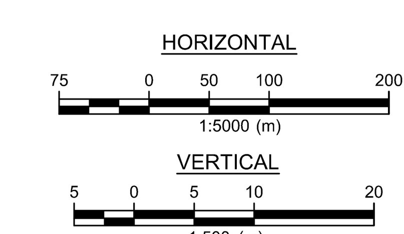
717003
NOVEMBER 2018
Scale: 1:5000 | NAD 1983 UTM Zone 17N

NOTE: WELLS IJ-25, & J-26 ARE FORMALLY REFERRED TO AS "VIRTUAL WELLS".
STRATIGRAPHY AT THIS LOCATION TAKEN FROM ONTARIO GEOLOGICAL SURVEY GROUNDWATER RESOURCES STUDY 10:
THREE-DIMENSIONAL MAPPING OF SURFICIAL DEPOSITS IN THE BRANTFORD-WOODSTOCK AREA, SOUTHWESTERN ONTARIO

PROJECT: 717003
BRANTFORD
GROWTH
PLAN

A5 SECTION A - A' A6





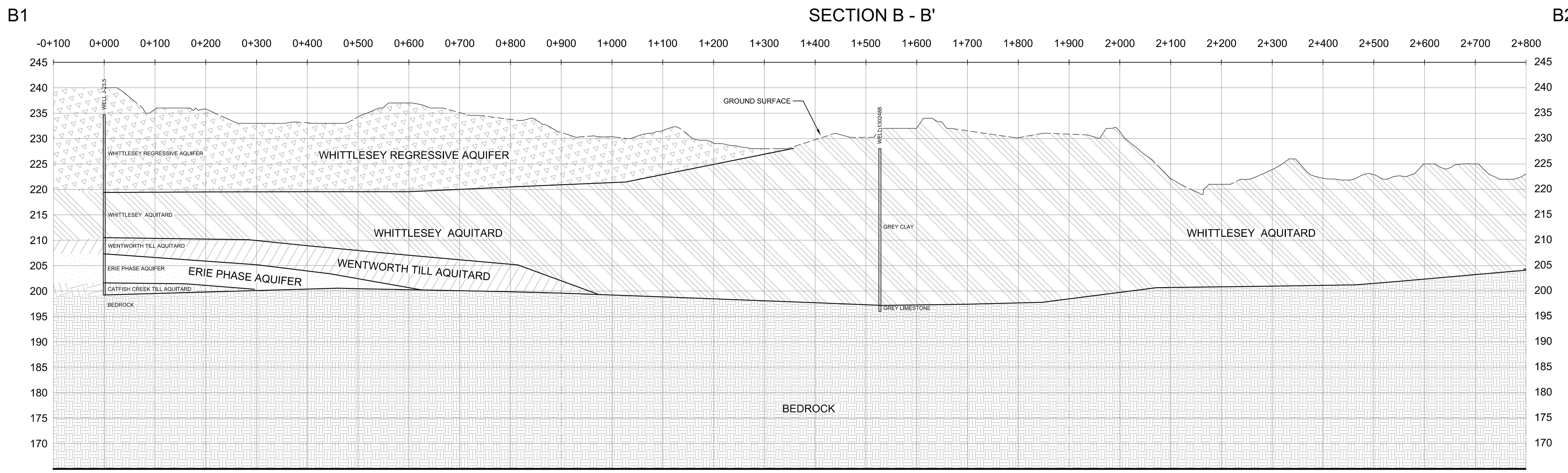
HYDROGEOLOGICAL
CROSS-SECTIONS

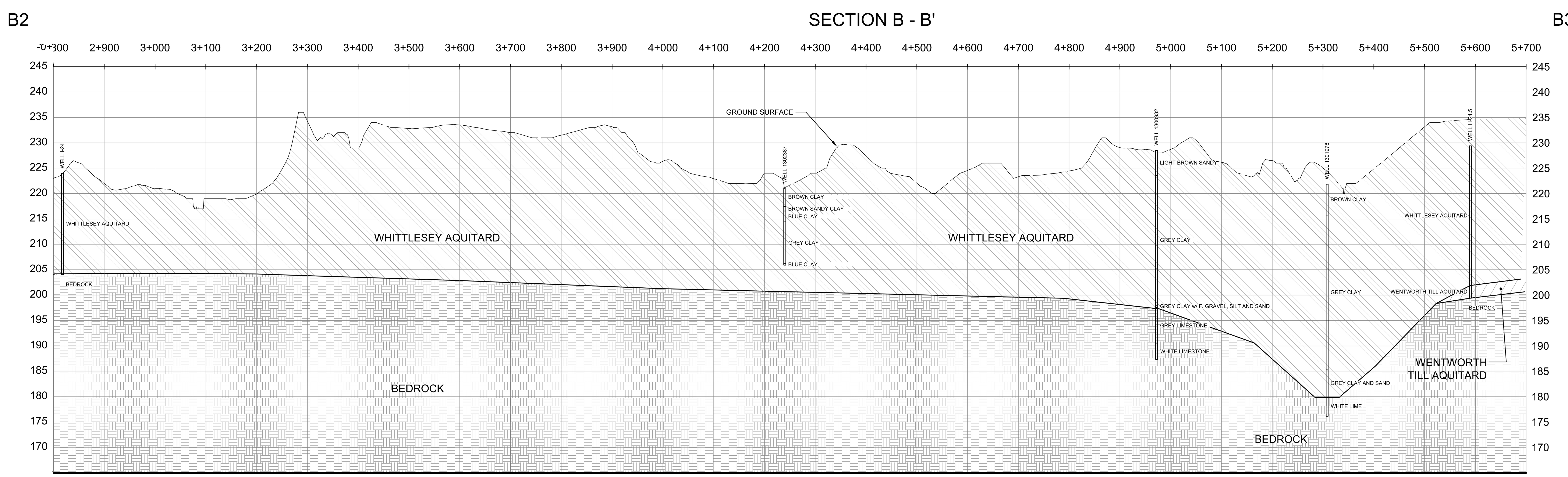
Figure No. 4

BluePlan
ENGINEERING

717003
NOVEMBER 2018
Scale: 1:5000 | NAD 1983 UTM Zone 17N

PROJECT: 717003
BRANTFORD
GROWTH
PLAN





HORIZONTAL
75 0 50 100 200
1:5000 (m)

VERTICAL
5 0 5 10 20
1:500 (m)

HYDROGEOLOGICAL
CROSS-SECTIONS

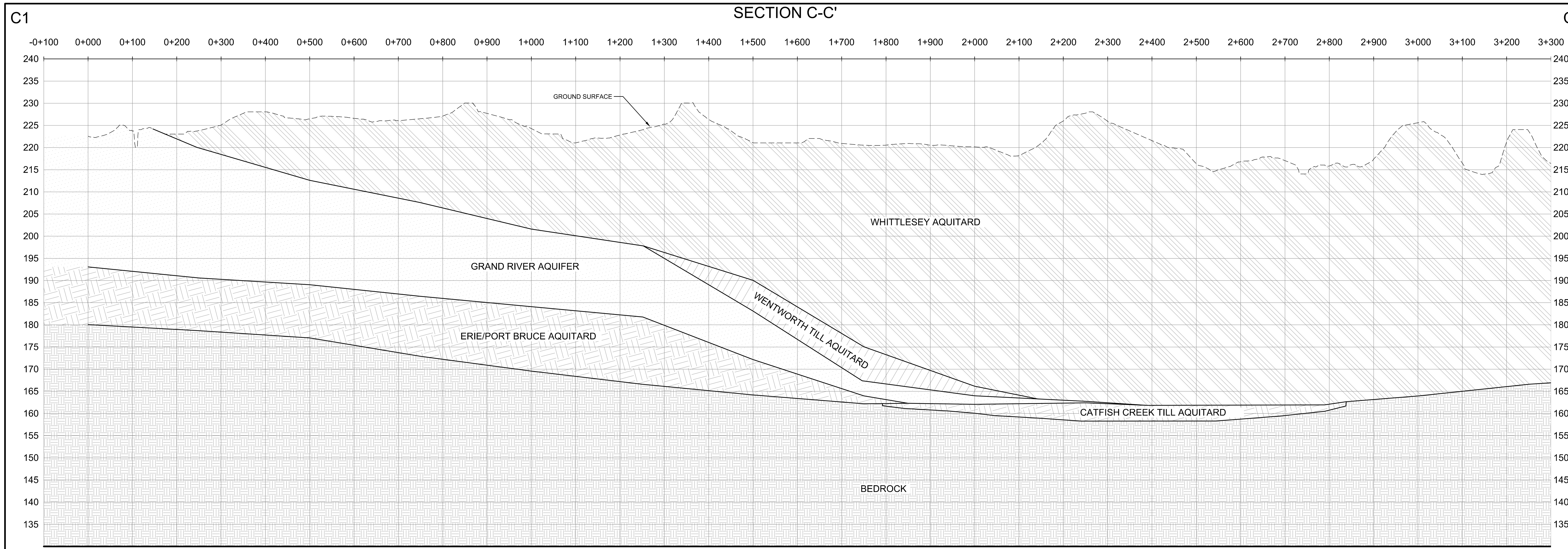
Figure No. 5

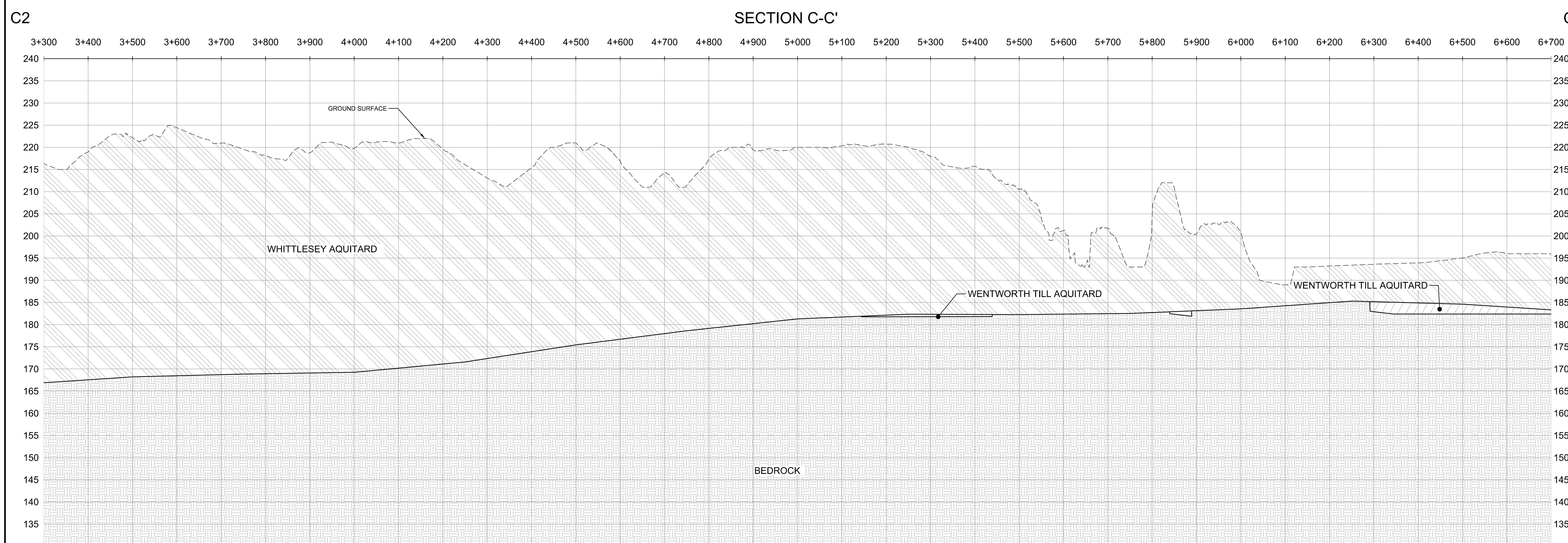
BluePlan
ENGINEERING

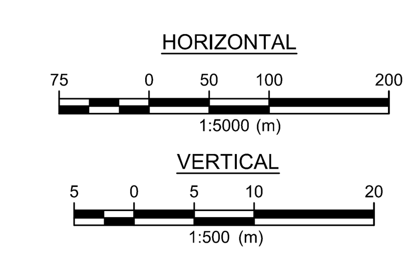
717003
NOVEMBER 2018
Scale: 1:5000 | NAD 1983 UTM Zone 17N

NOTE: WELLS J-23.5, I-24 & H-24.5 ARE FORMALLY REFERRED TO AS "VIRTUAL WELLS".
STRATIGRAPHY AT THIS LOCATION TAKEN FROM ONTARIO GEOLOGICAL SURVEY GROUNDWATER RESOURCES STUDY 10:
THREE-DIMENSIONAL MAPPING OF SURFICIAL DEPOSITS IN THE BRANTFORD-WOODSTOCK AREA, SOUTHWESTERN ONTARIO

PROJECT: 717003
BRANTFORD
GROWTH
PLAN





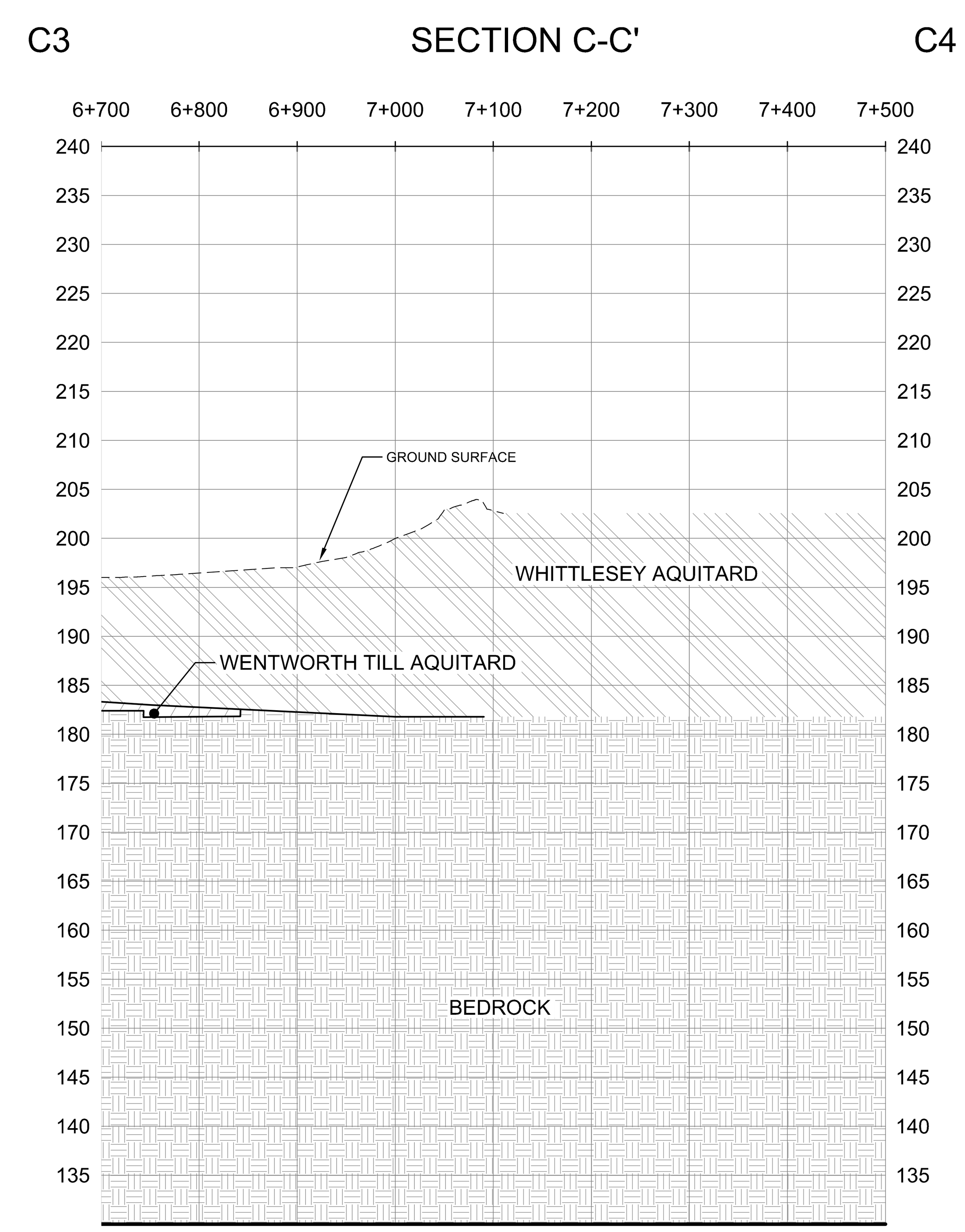


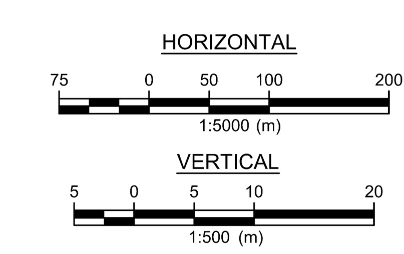
HYDROGEOLOGICAL
CROSS-SECTIONS

Figure No. 6

717003
NOVEMBER 2018
Scale: 1:5000 | NAD 1983 UTM Zone 17N

PROJECT: 717003
BRANTFORD
GROWTH
PLAN





HYDROGEOLOGICAL
CROSS-SECTIONS

Figure No. 7

717003
NOVEMBER 2018
Scale: 1:5000 | NAD 1983 UTM Zone 17N

APPENDIX F:
TECH MEMO 1: STORMWATER MODEL DEVELOPMENT

Date:	November 13, 2020	File:	717003
To:	City of Brantford		
From:	Julien Bell		
Project:	City of Brantford Urban Boundary Expansion		
Subject:	Expansion Lands Stormwater Model Development		

TECHNICAL MEMORANDUM

1. INTRODUCTION

The City of Brantford retained GM BluePlan to update their Master Servicing Plan, which covers water, wastewater, and stormwater infrastructure. Concurrently, SGL Planning & Design retained GM BluePlan to contribute to a Master Plan update for the City related to an urban boundary expansion into new growth areas recently acquired from County of Brant. The Urban Boundary Expansion Lands (Expansion Lands) are shown in Figure 1. The Master Plan update project includes a Subwatershed Study of the Expansion Lands and stormwater-servicing-related recommendations. As a component of both projects, the City's "all-pipe" stormwater system hydraulic model was updated. The purpose of this Memo is to summarize the methods and results of the model update and validation, with a specific focus on the Expansion Lands. This Memo includes:

- Overview of existing stormwater system
- Model data sources and assumptions
- Model development methodology
- Summary of model validation process and results
- Recommendations for model use and future improvements

1.1 Model Objectives

The objectives of the model were as follows:

- Improve accuracy of using up-to-date information and monitoring data, to:
    - Provide high level assessment of the existing minor and major system performances under existing conditions
    - Identify key issues and areas of concern
- Create base model of growth areas which can be used to generate approximate existing and future flow rates at key locations to allow for order-of-magnitude infrastructure sizing and costing
- Identify key data gaps and information to be collected for future model updates to refine the above analyses

1.2 Model Scope

The scope of the model comprises the following:

- Minor system: Ditches, watercourses and culverts
- Includes only the Expansion Lands
- Hydrologic (rainfall/runoff) and hydraulic modelling using the EPASWMM engine

The model does not represent the major system (overland flow). The model also does not incorporate private infrastructure such as on-site sewers or stormwater controls unless representation was required for network connectivity.

2. EXISTING SYSTEM

The Expansion Lands are comprised of 27 km^2 of land that was transferred from the County of Brant in 2017. These lands are located to the North and East of the former City of Brantford municipal boundary. These Expansion lands are mostly rural and are not serviced by storm sewers.

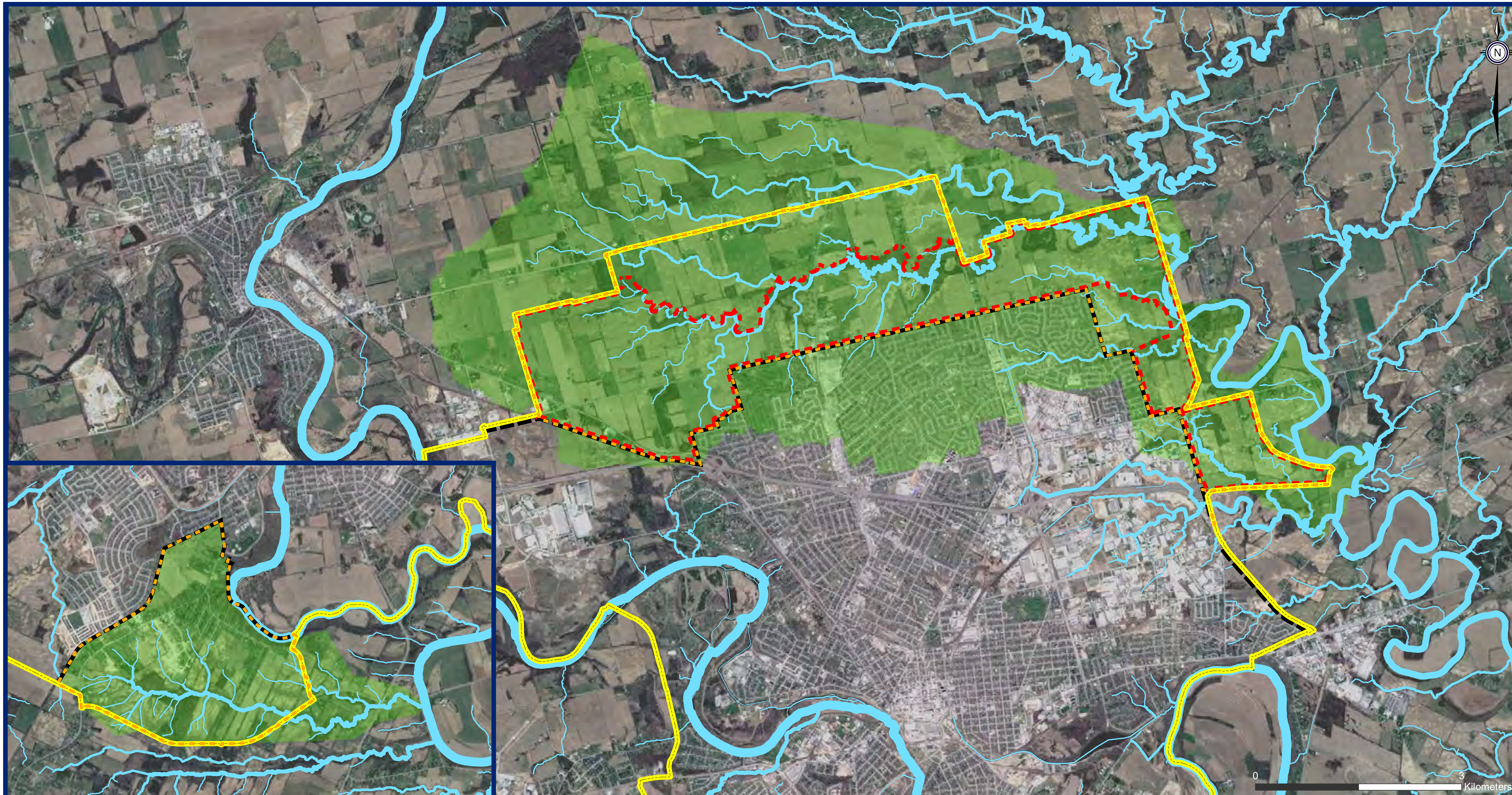
The existing stormwater system for the Expansion Lands is presented in Figure 1. More information regarding the existing system is presented in the following sections.

2.1 Ditches, Watercourses and Culverts

Since the Expansion Lands do not have an existing storm sewer network acting as the minor drainage system, open ditches, watercourses and culverts play a larger role in the minor and major drainage system, particularly:

- Where major roadways were designed with rural cross-sections (drained using roadside ditches)
- Where open watercourses were retained in the landscape (whether in a natural or altered state) and receive drainage from storm sewer outlets, conveying the stormwater from within the municipal boundary
- In undeveloped areas including new growth areas

Watercourse and ditch layers were obtained from the Grand River Conservation Authority (GRCA) and the County of Brant, which are shown in Figure 1. These layers do not include any elevation or cross-section information. Cross section dimensions were provided by Ecosystem Recovery Incorporated (ERI) from a field walk they completed in August 2018. Culvert information was available from the City.



THE CORPORATION OF THE CITY OF BRANTFORD

City of Brantford
Urban Boundary Expansion

Legend

- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Previous Municipal Boundary
- New Municipal Boundary
- Watercourse

Figure 1
Expansion Lands Stormwater Model Study Areas

GM BluePlan ENGINEERING

April 2019
717003-G-004
NAD 1983 UTM Zone 17N

3. DATA SOURCES

3.1 Existing System Information

The following data sources were used to support the model:

- GIS data from the City of Brantford and the GRCA, including:
    - Existing storm infrastructure: gravity main pipes, inlets, manholes, discharge points, culverts, detention ponds, ditches, watercourses, roads, buildings, land use, etc.
    - Aerial imagery
    - Topographical information, contours
    - Modelled stream groundwater discharge per length (GRCA)
- Field data collected by Ecosystem Recovery Inc. as part of the Master Plan update and Subwatershed Study
- Field data collected by GMBP staff as part of a separate Ditch Survey project

3.2 Stream Gauging Data and Other Monitoring Data

The following monitoring data sources were used to support the model:

- Rain data from the City Tourism Centre rain gauge
- Flow and level data from GRCA Jones Creek stream flow monitors, 2016-2018

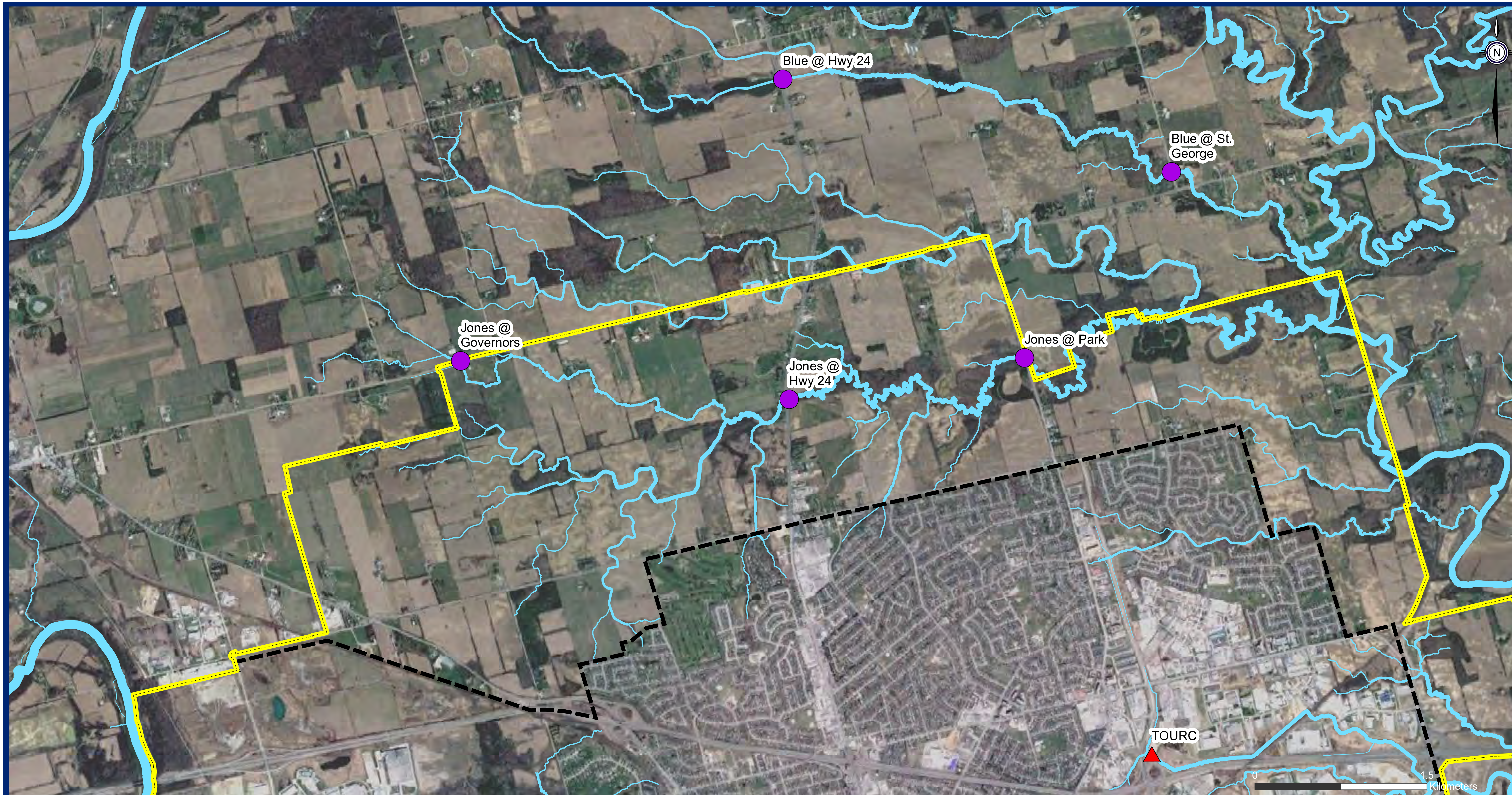
During this program, data was collected at three stream gauge locations on Jones Creek and one rain gauge locations shown in

Figure 2. Stream data taken from Blue Creek was outside of the study area and not used for model validation. The stream gauge locations are summarized in Table 1, including commentary on data quality or other issues.

Table 1: List of Stream Gauges

Stream Gauge Name	Conduit ID	Record Dates	Comment
Jones @ Governor's	Brant-8020	July 4, 2016 – May 24, 2018	GRCA stream gauge. No relationship between Level and Flow ever developed – moved to Park Rd.
Jones @ Hwy 24	Brant-8831	June 29, 2016 - Ongoing	GRCA stream gauge. Rating curve relating Level and Flow developed for flow up to 505 L/s; likely not valid at higher flows. Apparent changes to baseflow over time may be due to backwater effects – general data accuracy question.
Jones @ Park	1-Box-48	May 24, 2018 - Ongoing	Relocated GRCA stream gauge. Rating curve relating Level and Flow developed for flow up to 238 L/s; likely not valid at higher flows.

Note: Conduit ID indicates the model conduit where "total inflow" was compared to flow monitor observed flow.



THE CORPORATION OF THE CITY OF BRANTFORD

City of Brantford
Urban Boundary Expansion

Legend

- GRCA Stream Gauges
- Rain Gauge
- Previous Municipal Boundary
- New Municipal Boundary
- Watercourse

Figure 2
GRCA Monitoring Locations

GM BluePlan ENGINEERING

April 2019
717003-G-004
NAD 1983 UTM Zone 17N

4. MODEL DEVELOPMENT

4.1 Network Expansion

The following data sources were used to create the stormwater model:

- Ditches and watercourses were added, removed or spatially adjusted based on updated GIS data.
- Conduit lengths were assigned automatically based on GIS object length values.
- Shape, diameter and invert elevation information was updated when available in GIS data.
- Junction rim elevations (i.e. ground surface) were updated based on DEM, which was created from City contour information.
- Where necessary, additional conduits, junctions, and outfalls were added based on inferred connectivity/infrastructure to connect orphaned network components, or such components were deleted if suspected to be erroneous or irrelevant to model objectives.
- Where data was not available or where gross error was suspected based on audit, conduit inverts were assumed to be 2m below surface, then inverts were adjusted to ensure positive drainage and connection between upstream points and outfall. Default conduit shape (circular) and size (1m diameter) were assumed.

As noted above, junctions and conduits representing open ditches and watercourses have the least amount of information available. Arbitrary default stream cross-sections were initially applied and these were adjusted as described in Section 5; however, better information in this regard should be collected as a priority for any future flooding investigation, major system assessment and/or floodplain studies.

4.2 Facility Update

The following updates were made to representations of stormwater facilities (i.e. storage objects, outlets), using best available information:

- Junctions, conduits, outlet/orifice/weir objects were added or deleted
- Invert elevations of storage objects and outlets were updated
- Outlet/orifice/weir object characteristics were assigned (e.g. orifice diameter)
- Depth/storage curves were created and assigned to each storage
    - Bathymetric survey CAD files were used to generate curves where available
    - Calculations using areas, volumes, and depths from drawings, reports, ECA's, etc.
    - If no dimensional information was available, area from City GIS object was assumed.

4.3 Subcatchment Delineation

As part of the model creation, subcatchments were created based on the up-to-date GIS data according to the following procedure:

- DEM surface was created from contour information and modified in the following ways:
    - Buildings were raised based on City GIS layer to create barriers to flow
    - Inlet objects (ditches/watercourses and catchbasins) were dropped
- A catchment delineation algorithm was run on the created surface, which created polygons for areas likely to drain to each inlet object.
- Inlet objects were automatically assigned to model junctions based on proximity and connectivity using lateral line and gravity main layers. Results were manually checked.

- Inlet object catchment polygons were assigned to their respective model junctions and combined where necessary.
- A polygon smoothing algorithm was run to reduce number of vertices and remove "multiple" polygon objects (found to be mishandled by PCSWMM program).
- Polygons were manually edited where gross error was suspected based on visual review of contours, aerial imagery, Google Street View, etc., particularly for the largest 10% of subcatchments.

The following default parameters were assigned to each subcatchment:

- Area – per GIS shapefile
- Imperviousness – estimated for each subcatchment based on GIS algorithm which incorporated aerial imagery analysis and building and roadway layers
- Subcatchment width – estimated based on subcatchment area to give a default L:W ratio of 4:1, with a maximum length of 300m (exception for Fairchild Creek upstream catchment)
- Horton infiltration parameters – area weighted parameters assigned based on surficial geology

5. MODEL VALIDATION

5.1 Stream Gauging Data and Events

For the purposes of validating the Jones Creek area of the model, rainfall and stream gauge data were analyzed, and potential model validation events were identified and assessed according to the following criteria:

- Reasonable consistency between three rain gauges in City's rain gauge network
- Sufficiently large rainfall depth and intensity to generate measurable response at flow monitors
- Acceptable data recorded for event at flow monitor (accounting for data gaps/drops, data quality issues, GRCA stream rating curve limits, etc.)

Using these criteria, only one event was selected for validation of the Jones Creek catchments in the new growth area, which occurred on July 22, 2018. This event was chosen because its manually measured depths matched well with the recorded stream depths from the data logger.

Table 2 – Rain Events Used to Validate Model

Event ID	Date	Depth (mm)			Peak 1-hr (mm)			FM with Data	Comments
		WTP RMF	WWTP BB	TOUR C	WTP RMF	WWTP BB	TOUR C		
S	Jul 22, 2018			15			12	Jones @ 24, Jones @ Park	Selected for Jones Creek validation

During model validation, subcatchments were assigned rain gauges based on spatial proximity.

5.2 Model Adjustment Procedure

5.2.1 Expansion Lands Adjustment (Jones Creek Monitoring)

An early sensitivity analysis was used to narrow the list of target parameters for validation efforts of the model. It was found that the most important determinants of peak flow and volume at the monitored creek locations were not subcatchment properties, but properties of the upstream junctions and conduits: baseline flow at junctions, culvert diameters, creek cross-sections, and creek roughness coefficients. Unfortunately, as noted above, this information was not consistently available. In addition, concerns about flow data quality limited confidence in the validation exercise. Therefore, the approach was as follows:

- Apply baseline flow values based on manual GRCA flow measurements and modelled GRCA stream discharge shapefile.
- Where available, update culvert diameters based on recent inspection data by GMBP conducted for a separate assignment. Where not available, make reasonable estimate based on photos.
- Update creek cross-sections based on recent inspection data by Ecosystem Recovery, Inc. (ERI) conducted for the ongoing Subwatershed Study, and recent inspection data by GMBP conducted for a separate assignment. As not all watercourses were inspected, representative cross-sections were selected and assigned to similar reaches.
- Update creek roughness coefficients based on textbook values.

Further investigation is required to provide more confidence the model for the new growth areas.

5.3 Validation Results

The results for Event S is summarized in Table 3 below. The stream gauge at Jones Creek and Governor's Road was removed prior to the July 22, 2018 event and was not used in the analysis. Detailed results including all event hydrographs are included in Appendix A.

Table 3 – Summary of Flow Validation Results

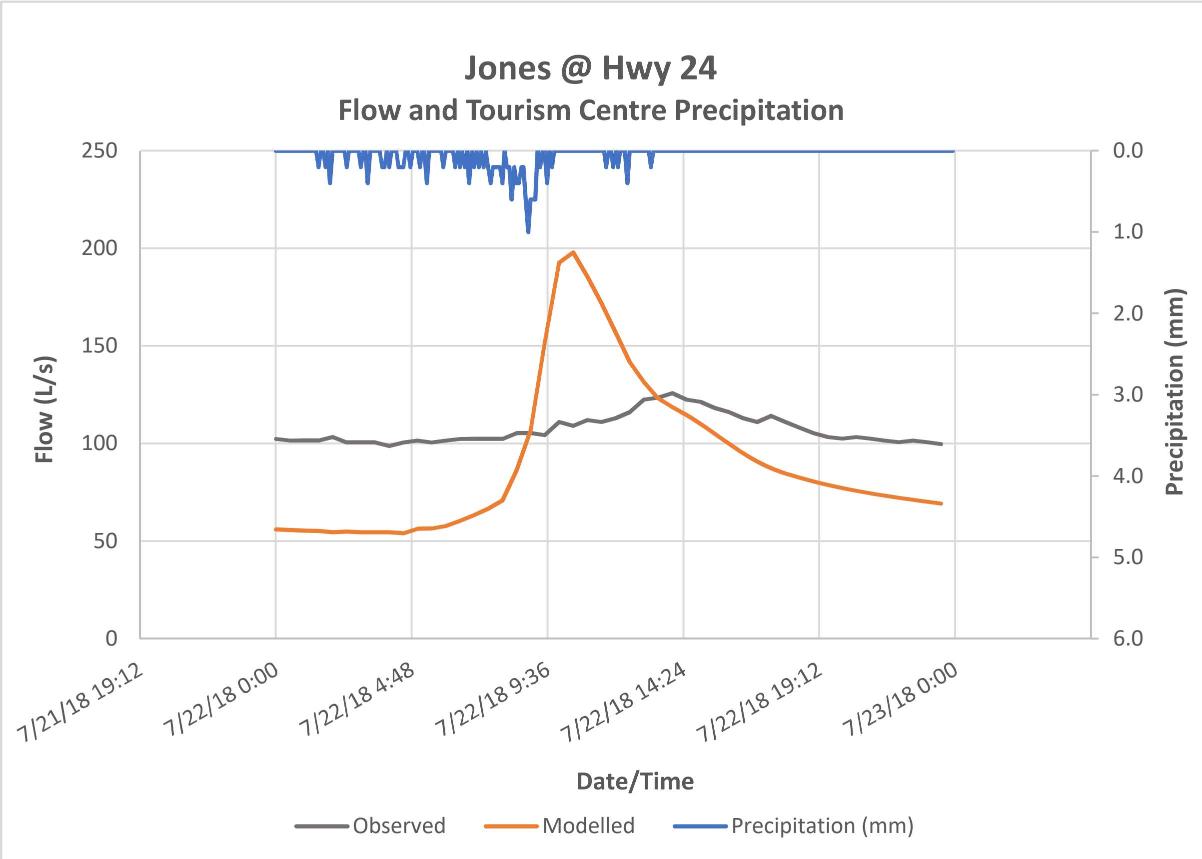
		Critical Event S (July 22, 2018)		
Stream Gauge	**Measurement**	**Observed**	**Model**	**Difference**
Jones @ Governor's	Peak Flow (L/s)	N/A	N/A	N/A
Jones @ Hwy 24	Peak Flow (L/s)	125.78	197.90	**57.34**
Jones @ Park	Peak Flow (L/s)	243.76	225.92	**-7.32**

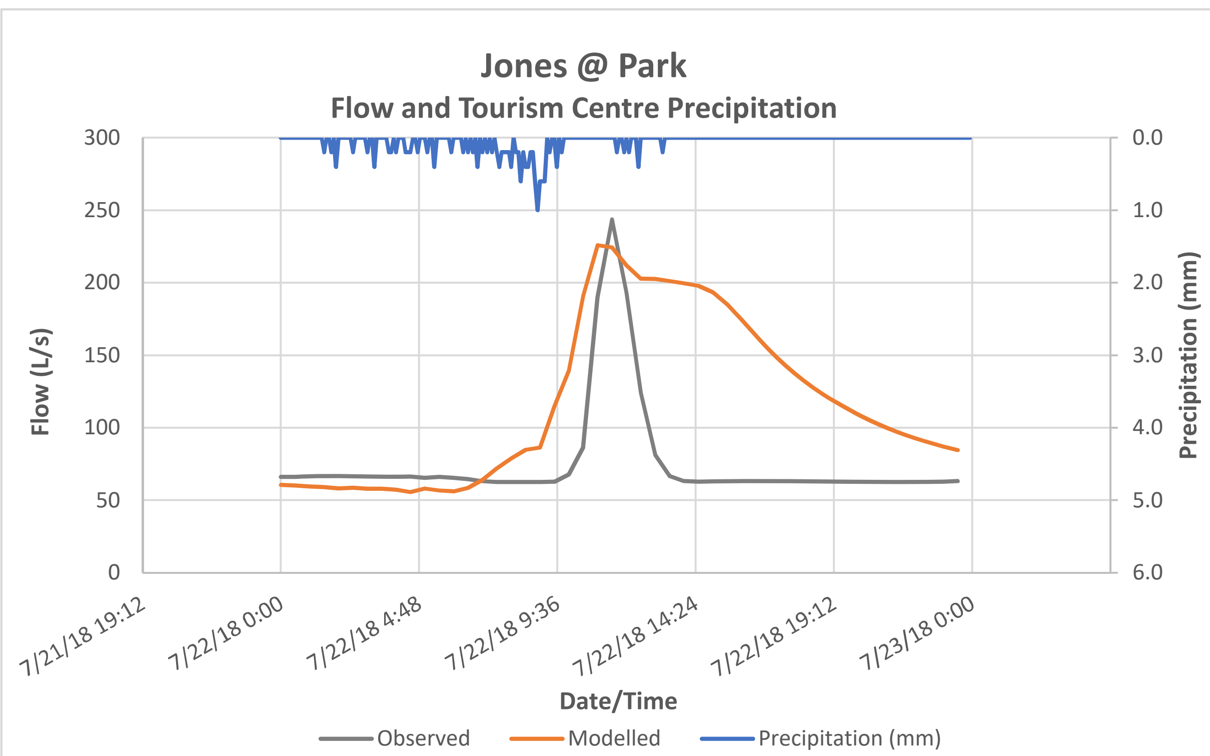
6. RECOMMENDATIONS

The existing City of Brantford stormwater model was updated to inform two ongoing projects. The following recommendations are provided with respect to the stormwater model:

- The model can be used as a base for future studies, with additional information collected to improve the model depending on the future study focus.
- The City's GIS data should continue to be updated and maintained. Specific recommended projects to improve the data include:
    - Improvements to ditch and watercourse GIS layers to include invert elevations and basic dimensional information
- Additional stream gauging should be undertaken to validate and/or refine the existing network model.

APPENDIX A MODEL VALIDATION RESULTS


Jones @ Hwy 24
Flow and Tourism Centre Precipitation
Flow (L/s)
Precipitation (mm)
250
200
150
100
50
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7/21/18 19:12
7/22/18 0:00
7/22/18 4:48
7/22/18 9:36
7/22/18 14:24
7/22/18 19:12
7/23/18 0:00
Date/Time
Observed
Modelled
Precipitation (mm)


Jones @ Park
Flow and Tourism Centre Precipitation
Flow (L/s)
Precipitation (mm)
300
250
200
150
100
50
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7/21/18 19:12
7/22/18 0:00
7/22/18 4:48
7/22/18 9:36
7/22/18 14:24
7/22/18 19:12
7/23/18 0:00
Date/Time
Observed
Modelled
Precipitation (mm)

C

City of Brantford

APPENDIX C

EVALUATION TABLES

Appendix C Table 1: Grand River – Homedale Subcatchment Alternative Evaluation

Category	Criteria	Alternative 1 – St. Paul Avenue Diversion		Alternative 2 – Albion Street Upgrade	
Technical Impacts	Meets existing and future servicing needs		- Yes		- Yes
	Provides a reliable service		- Yes		- Yes
	Minimizes and manages construction risk		- Potential construction delays related crossing of railway		- Follows existing alignments
	Supports phased expansion of the system		- Supports additional local upgrades		- Supports local upgrades
	Operational Complexity		- Hydraulically efficient		- Hydraulically efficient
	Resiliency to climate change		- Increase system capacity		- Increase system capacity
Environmental Impacts	Protects environment features		- No known impacts to environmental Features		- No known impacts to environmental Features
	Protects wildlife and species at risk		- No impacts		- No impacts
	Minimizes climate change impacts		- No impacts		- No impacts
Social and Cultural Impacts	Protects resident quality of life		- Construction disruptions in developed areas and nearby hospital		- Construction disruptions in developed areas and nearby hospital
	Manages and minimizes construction impacts		- Storm sewer construction with railway crossing		- Storm sewer construction
	Protects cultural heritage and archeological features		- No known impacts to Cultural Heritage and Archeological		- No known impacts to Cultural Heritage and Archeological
Financial Impacts	Capital and life-cycle costs		$$		$
	Operation and maintenance costs		- Standard O&M costs		- Standard O&M costs
	Aligns with approval and permitting process		- Requires railway crossing		- Upgrade of existing pipes within Right-of-Way

Appendix C Table 2: Grand River – Eagle Place Subcatchment Alternative Evaluation

Category	Criteria	Alternative 1 – Seventh Avenue Diversion		Alternative 2 – Sixth Avenue/Sanderson Street Upgrade	
Technical Impacts	Meets existing and future servicing needs	● (green)	- Yes	● (green)	- Yes
	Provides a reliable service	● (green)	- Yes	● (green)	- Yes
	Minimizes and manages construction risk	● (green)	- No expected construction delays	● (green)	- No expected construction delays
	Supports phased expansion of the system	● (yellow)	- Potential impacts with other growth areas	● (green)	- Supports local upgrades
	Operational Complexity	● (green)	- Hydraulically efficient	● (green)	- Hydraulically efficient
	Resiliency to climate change	● (green)	- Similar capacity increase	● (green)	- Similar capacity increase
Environmental Impacts	Protects environment features	● (green)	- Reduced flows to existing ditch/creek	● (green)	- No known impacts to environmental Features
	Protects wildlife and species at risk	● (green)	- No impacts	● (green)	- No impacts
	Minimizes climate change impacts	● (green)	- No impacts	● (green)	- No impacts
Social and Cultural Impacts	Protects resident quality of life	● (green)	- Construction within residential area	● (green)	- Construction within residential area
	Manages and minimizes construction impacts	● (green)	- Storm sewer construction - Minimal traffic delays	● (green)	- Storm sewer construction - Minimal traffic delays
	Protects cultural heritage and archeological features	● (green)	- No known impacts to Cultural Heritage and Archeological	● (green)	- No known impacts to Cultural Heritage and Archeological
Financial Impacts	Capital and life-cycle costs	● (green)	$	● (yellow)	$$
	Operation and maintenance costs	● (green)	- Standard O&M costs	● (green)	- Standard O&M costs
	Aligns with approval and permitting process	● (green)	- Upgrade of existing pipes within Right-of-Way (minor diversion)	● (green)	- Upgrade of existing pipes within Right-of-Way

Appendix C Table 3: Fairchild Creek – Garden Subcatchment Alternative Evaluation

Category	Criteria	Alternative 1 – Fairview Drive Diversion	Alternative 2 – Highway 403 Upgrade	Alternative 3 – Morton Avenue Diversion
Technical Impacts	Meets existing and future servicing needs	- Yes	- Yes	- No
	Provides a reliable service	- Yes	- Yes	- Yes
	Minimizes and manages construction risk	- Construction within major road corridor	- Construction within highway corridor	- Construction within major road corridor
	Supports phased expansion of the system	- Supports additional local upgrades	- Complicated phasing due to 403 corridor	- Recent repaving/ revitalization of Morton Ave.
	Operational Complexity	- Hydraulically efficient, significant sewer depths	- Hydraulically efficient, large sewer sizes	- Hydraulically efficient
	Resiliency to climate change	- Increases system capacity	- Upsizing required to provide benefit	- Increases system capacity, but restrictions remain
Environmental Impacts	Protects environment features	- No known impacts to environmental Features	- No known impacts to environmental Features	- No known impacts to environmental Features
	Protects wildlife and species at risk	- No impacts	- No impacts	- No impacts
	Minimizes climate change impacts	- No climate change impact	- No climate change impact	- No climate change impact
Social and Cultural Impacts	Protects resident quality of life	- Residential and commercial disruptions	- Possible highway disruptions	- Residential and industrial disruptions
	Manages and minimizes construction impacts	- Storm sewer construction - Major traffic delays	- Storm sewer construction - Major traffic delays	- Storm sewer construction - Major traffic delays
	Protects cultural heritage and archeological features	- No known impacts to Cultural Heritage and Archeological	- No known impacts to Cultural Heritage and Archeological	- No known impacts to Cultural Heritage and Archeological
Financial Impacts	Capital and life-cycle costs	$$$$	$$$$$	$$$
	Operation and maintenance costs	- Standard O&M costs	- Complicated O&M due to highway corridor	- Standard O&M costs
	Aligns with approval and permitting process	- Within existing Right-of-Way	- Additional MTO permitting	- Within existing Right-of-Way

Appendix C Table 4: Grand River – Northwest Subcatchment Alternative Evaluation

Category	Criteria	Alternative 1 – Flow Split at Oak Park Road		Alternative 2 – Direct all Stormwater to Grand River	
Technical Impacts	Meets existing and future servicing needs		- Yes		- Yes
	Provides a reliable service		- Yes		- Yes
	Minimizes and manages construction risk		- Risk with construction beneath Highway 403		- Risk with adequate grading and sewer depths to Grand River outlet
	Supports phased expansion of the system		- Supports local development		- Supports local development
	Operational Complexity		- Complexities with maintaining crossing within Ministry of Transportation corridor		- Complexity with hydraulics from possible future land grades
	Resiliency to climate change		- N/A		- N/A
Environmental Impacts	Protects environment features		- Potential impacts to wetland downstream of Highway 403		- No known impacts to environmental Features
	Protects wildlife and species at risk		- Potential impacts to wetland downstream of Highway 403		- No impacts
	Minimizes climate change impacts		- No climate change impact		- No climate change impact
Social and Cultural Impacts	Protects resident quality of life		- Minimal impact to existing residents/occupants		- Minimal impact to existing residents/occupants
	Manages and minimizes construction impacts		- Construction within greenfield area		- Construction within greenfield area
	Protects cultural heritage and archeological features		- No known impacts to Cultural Heritage and Archeological		- No known impacts to Cultural Heritage and Archeological
Financial Impacts	Capital and life-cycle costs		$$$$		$$$
	Operation and maintenance costs		- Operational complexities within Ministry of Transportation corridor		- Standard O&M costs
	Aligns with approval and permitting process		- Additional MTO permitting		- Developer driven ponds and grading coordination between developers required

D

City of Brantford

APPENDIX D

IMPLEMENTATION PLAN DETAILED STUDY OVERVIEW SHEETS

<table>
<tr><th colspan="4">Project #1: LiDAR City Right-of-Way</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of an Aerial LiDAR of the City owned road right-of-way for all streets within the City of Brantford</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Included in Project SW-SD-001 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">The scope of the study will include the following:
• Complete fieldwork required to acquire raw aerial LiDAR data
• Conduct data cleanup and validation in GIS or equivalent database software
• Support future studies requiring clear understanding of major overland flow pathways</td></tr>
<tr><td>Objectives</td><td colspan="3">Under existing conditions, the City of Brantford does not have a clear perspective of their major system flow path (emergency overland flow path). LiDAR of all City owned right-of-way (RoW) will provide the background information required to determine inadequate areas which may experience flooding during major storm events. With aerial LiDAR of the City's RoW, better classification of flooding issues within the City is possible. This allows differentiation between areas without major system outlets and areas where the capacity of the major system is not sufficient to convey stormwater to the outlet. Aerial LiDAR of the City RoW will also assist the City in better determining both the cause and liability of any future flooding within both private and public owned spaces.</td></tr>
<tr><td>Projected Completion Timeline</td><td>2026 (0 – 5 years)</td><td>Duration of Fieldwork or Studies</td><td>3 months</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">• N/A</td></tr>
<tr><td>Dependent Fieldwork or Studies</td><td colspan="3">• Stormwater Model Update
• GIS Inventory Update
• City-Wide Asset Inventory
• Dike System Outlet Program
• Subwatershed Studies Update
• Stormwater Master Servicing Plan Update</td></tr>
<tr><td>Cost Estimate</td><td colspan="3">$ 75,000</td></tr>
</table>

<table>
<tr><th colspan="4">Project #2: Rural Ditch Survey</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of a survey of all rural ditching interacting with the major and minor systems within the City of Brantford</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Included in Project SW-SD-001 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">The scope of the study will include the following:
• Complete fieldwork required to acquire raw survey data
• Conduct data cleanup and validation in GIS or equivalent database software
• Support future studies requiring clear understanding of major overland flow pathways or minor system interactions with rural ditching</td></tr>
<tr><td>Objectives</td><td colspan="3">Recently, the rural ditch surveys were completed within the City of Brantford. This was completed to provide the City with a clear understanding of the ways in which rural ditching within the City interacts with both the major or minor stormwater systems. A survey of rural ditching is required to quantify the capacity of the minor and/or major stormwater systems, as well as determine the interconnections between linear infrastructure, City right-of-way, and watercourse features. Without adequate rural ditching data, misunderstandings of the cause of flooding and problem areas within the City, as well as misallocation of municipal funds to solve flooding and problems within the drainage system is inevitable.</td></tr>
<tr><td>Projected Completion Timeline</td><td>Recently Completed (2018)</td><td>Duration of Fieldwork or Studies</td><td>3 months</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">• N/A</td></tr>
<tr><td>Dependent Fieldwork or Studies</td><td colspan="3">• Stormwater Model Update
• GIS Inventory Update
• City-Wide Asset Inventory
• Dike System Outlet Program
• Subwatershed Studies Update
• Stormwater Master Servicing Plan Update
• Existing Infrastructure Survey & Condition Assessment</td></tr>
<tr><td>Cost Estimate</td><td colspan="3">$ 0</td></tr>
</table>

<table>
<tr><th colspan="4">Project #3: Existing Infrastructure Survey & Condition Assessment</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of the fieldwork required to survey the existing infrastructure and perform a condition assessment for all linear infrastructure within the City of Brantford</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Included in Project SW-SD-001 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">The scope of the study will include the following:
• Complete fieldwork required to survey linear underground infrastructure and determine condition (CCTV, etc.)
• Complete Pond Condition Assessment and Stormwater Pond Bathymetric survey
• Conduct data cleanup and validation in GIS or equivalent database software
• Analyze data to create working database and maps of problem issues, including reporting of data analysis for future studies
• Support future studies requiring clear understanding of linear asset details (invert, obvert, slope, size, material, etc.) and existing condition of linear assets</td></tr>
<tr><td>Objectives</td><td colspan="3">The City of Brantford is surveying and determining the condition of existing infrastructure on an ongoing basis in order to determine regular maintenance schedules for linear infrastructure. The surveyed results are required in order to confirm the assumptions made throughout City stormwater models and support the general Asset Management initiatives. Proper planning by confirming as-constructed drawings via infrastructure surveys will ensure accurate forecasting of upgrades required due to flooding or inadequate sizing in the stormwater models. Additionally, the condition assessment is required to determine linear infrastructure with the greatest need of repair or replacement, thus positioning the City to encounter fewer unexpected infrastructure failures and assist in budget forecasting.</td></tr>
<tr><td>Projected Completion Timeline</td><td>Ongoing (2020)</td><td>Duration of Fieldwork or Studies</td><td>Ongoing works through City initiatives</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">• Rural Ditch Survey (condition assessment)</td></tr>
</table>

Project #3: Existing Infrastructure Survey & Condition Assessment	
Dependent Fieldwork or Studies	• Stormwater Model Update • GIS Inventory Update • City-Wide Asset Inventory • Dike System Outlet Program • Subwatershed Studies Update • Stormwater Master Servicing Plan Update
Cost Estimate	$ 0 (Included under existing operational costs)

<table>
<tr><th colspan="4">Project #4: GIS Inventory Update</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of an update to the City of Brantford's GIS inventory for all stormwater assets</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Included in Project SW-SD-001 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">The scope of the study will include the following:
• Input (update) all assets in the GIS database
• Conduct data cleanup and validation in GIS or equivalent database software
• Analyze data to create working database and maps of problem issues, including reporting of data analysis for future studies
• Support future studies requiring any details on City owned stormwater assets</td></tr>
<tr><td>Objectives</td><td colspan="3">A GIS database of all city stormwater infrastructure is essential to analyzing the system in its entirety. Each individual component of the stormwater system will be combined to create a master database of all City owned assets for use in future studies and for asset management purposes. The GIS inventory should cross reference City drawings and internal City databases to act as a first stop for all asset related queries. Throughout the inventory update, it is essential that the quality of input data is flagged to determine future fieldwork and asset planning for assets with a low confidence or level of informational quality. Without a unified GIS inventory as an asset database, unnecessary time and finances may be allocated to projects and infrastructure without a linked, full-system understanding.</td></tr>
<tr><td>Projected Completion Timeline</td><td>2026 (0 – 5 years)</td><td>Duration of Fieldwork or Studies</td><td>12 months</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">• LiDAR City Right-of-Way
• Rural Ditch Survey
• Existing Infrastructure Survey & Condition Assessment
• Dike System Outlet Program</td></tr>
<tr><td>Dependent Fieldwork or Studies</td><td colspan="3">• Stormwater Model Update
• City-Wide Asset Inventory
• Subwatershed Studies Update
• Stormwater Master Servicing Plan Update</td></tr>
<tr><td>Cost Estimate</td><td colspan="3">$ 100,000</td></tr>
</table>

Project #5: City-Wide Asset Inventory			
Overview	Project consists of an update to the City of Brantford's City-wide asset inventory for all stormwater assets		
Relevant Capital Project	Project **SW-SD-001** Capital Program Sheet		
Scope of Fieldwork or Study	The scope of the study will include the following: • Input (update) all assets into an asset management database • Analyze data to create working database with asset classes, conditions, value, life expectancy, etc. • Maintain linear stormwater assets within State of Good Repair (SoGR) • Support future studies requiring clear understanding of asset classes or conditions • Fulfill Ontario Regulation 588/17 requirements with asset management plan		
Objectives	An asset inventory is essential for both maintaining a State of Good Repair (SoGR) and meeting Ontario Regulation 588/17. All precedent fieldwork and studies will be entered into the asset inventory, in joint with the GIS inventory. An important factor of the asset inventory is the asset management plan, which will provide the City with a clear understanding of which assets require repair, replacement, or are critical to the reliable operation of major sections of the stormwater management and conveyance system. Without an asset inventory and asset management plan, there may be gaps within the replacement and upgrade programs and finances that the City is projecting to 2041. Through the precedent fieldwork and studies, the asset inventory and asset management plan ensure informed decision making.		
Projected Completion Timeline	2026 (0 – 5 years)	**Duration of Fieldwork or Studies**	18 months
Precedent Fieldwork or Studies	• LiDAR Right-of-Way (Aerial) • Rural Ditch Survey • GIS Inventory Update • Existing Infrastructure Survey & Condition Assessment		
Dependent Fieldwork or Studies	• Stormwater Model Update • Subwatershed Studies Update • Stormwater Master Servicing Plan Update		
Cost Estimate	$ 322,000 (including precedent fieldwork and studies)		

<table>
<tr><th colspan="4">Project #6: Continuous Water Quality & Flow Monitoring and Reporting</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of continuous water quality and flow monitoring at strategic locations within the City’s stormwater management system</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Project SW-SD-002 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">The scope of the study will include the following:
• Determination of strategic locations to monitor stormwater flows and water quality
• Monitor stormwater flows and water quality within the conveyance system (including natural streams)
• Analyze data to determine wet weather storm events for future modelling purposes and calibration
• Respond to residential and operations input on flooding to continually update flow monitoring locations through lifespan of project</td></tr>
<tr><td>Objectives</td><td colspan="3">The basis of the recommendations within the stormwater section of the Master Servicing Plan are flagged and determined through hydraulic and hydrologic modelling within the City of Brantford. Flow Monitoring is required to calibrate/validate the model in various locations to provide the most accurate information possible. The absence of continuous flow monitoring within the minor system reduces the accuracy of the modelling tools available and increases the frequency of decisions based on assumptions. As such, potentially significant financial decisions may be determined by inaccurate assumptions instead of through the best tools available. Ultimately, flow monitoring can provide clarity in problem areas, thus saving the City financially from unnecessary upgrades.</td></tr>
<tr><td>Projected Completion Timeline</td><td>Ongoing (20 years)</td><td>Duration of Fieldwork or Studies</td><td>Annual</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">• GIS Inventory Update
• Existing Infrastructure Survey & Condition Assessment</td></tr>
<tr><td>Dependent Fieldwork or Studies</td><td colspan="3">• Stormwater Model Update
• Subwatershed Studies Update
• Climate Change Action Plan and Best Practices Review
• Stormwater Master Servicing Plan Update</td></tr>
<tr><td>Cost Estimate</td><td colspan="3">$ 5,910,000 (20 year cost)</td></tr>
</table>

<table>
<tr><th colspan="4">Project #7: Stormwater Model Update</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of updating the City of Brantford's stormwater model build and calibration with new development information and additional existing infrastructure information</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Project SW-SD-003 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">The scope of the study will include the following:
• Utilizing data collected in precedent studies and fieldwork to increase the accuracy of the City's stormwater model
• Implement major overland flow path modelling info into existing minor system model
• Adjust model calibration/validation to align with new flow monitoring and storm events</td></tr>
<tr><td>Objectives</td><td colspan="3">As the City of Brantford is constantly changing, so is the stormwater management and conveyance system. This is due to both new developments, as well as infrastructure replacements and upgrades. The City's stormwater model will require an update to account for newly acquired information from the precedent fieldwork and studies to account for new infrastructure. The basis of the recommendations within the stormwater section of the Master Servicing Plan are flagged and determined through hydraulic and hydrologic modelling within the City of Brantford. As such, potentially significant financial decisions may be determined by inaccurate assumptions instead of through the best tools available. Ultimately, the stormwater model update will ensure that the City has a complete understanding of their infrastructure prior to future financial decisions.</td></tr>
<tr><td>Projected Completion Timeline</td><td>2026 (0 – 5 years)</td><td>Duration of Fieldwork or Studies</td><td>12 months</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">• LiDAR Right-of-Way (Aerial)
• Rural Ditch Survey
• GIS Inventory Update
• Continuous Water Quality & Flow Monitoring and Reporting
• Existing Infrastructure Survey & Condition Assessment
• Dike System Outlet Program
• Climate Change Action Plan and Best Practices Review</td></tr>
<tr><td>Dependent Fieldwork or Studies</td><td colspan="3">• Subwatershed Studies Update
• Stormwater Master Servicing Plan Update</td></tr>
<tr><td>Cost Estimate</td><td colspan="3">$ 371,000</td></tr>
</table>

<table>
<tr><th colspan="4">Project #8: Dike System Outlet Program</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of conducting a Schedule B EA to determine best strategy for managing dike outlet controls and stormwater within the City of Brantford as it relates to the dike system</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Project SW-SD-004 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">The scope of the study will include the following:
• Utilizing data collected in precedent studies and fieldwork to determine potential impacts of dike system on major overland flow pathway
• Determine effects of open/closed minor system outlet valves for dike system outlets
• Prepare Schedule B EA to determine mitigation strategy for major and minor systems with respect to dike outlets</td></tr>
<tr><td>Objectives</td><td colspan="3">The City of Brantford currently operates a dike system, which protects low elevation developments within the City from high Grand River flows. There are currently multiple minor system outlets along the dike system which require manual operation (opening and closing valves) depending on the water level of the Grand River. When the valves are closed due to the high Grand River water levels, the minor system no longer has an outlet and surcharges. Additionally, the dike system prevents major overland flows from reaching an adequate outlet, causing flooding in the lower elevation areas. The Schedule B EA will explore multiple scenarios in dealing with both the minor system and major system flooding caused by the dike system, as well as explore the possibility of an automated system for operation of the outlet valves. Ultimately, there are significant financial risks in a manually operated system.</td></tr>
<tr><td>Projected Completion Timeline</td><td>2026 (0 – 5 years)</td><td>Duration of Fieldwork or Studies</td><td>18 months</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">• LiDAR Right-of-Way (Aerial)
• Rural Ditch Survey
• Existing Infrastructure Survey & Condition Assessment</td></tr>
<tr><td>Dependent Fieldwork or Studies</td><td colspan="3">• Stormwater Model Update
• GIS Inventory Update
• Stormwater Master Servicing Plan Update
• Subwatershed Studies Update</td></tr>
<tr><td>Cost Estimate</td><td colspan="3">$ 439,000</td></tr>
</table>

<table>
<tr><th colspan="4">Project #9: Update Subwatershed Studies</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of updating the City of Brantford’s subwatershed studies to account for new data uncovered through precedent studies</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Project SW-SD-005 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">An overview of the scope of the study will include the following:
• Complete required field work and investigation
• Determine any environmental impacts of future proposed development on the existing surface water and groundwater system
• Identify natural heritage features within the City of Brantford limits
• Determine the impacts of an updated stormwater model on the existing watercourses
A comprehensive scope is included in the Subwatershed Phase 1 Report</td></tr>
<tr><td>Objectives</td><td colspan="3">The subwatershed study is the culmination of all of the technical data that has been collected and analyzed in the precedent studies, from an environmental perspective. Ultimately, the subwatershed study update will determine whether the additional data collected has any affect on the natural systems which interact with the City of Brantford’s minor and major stormwater systems. Future greenfield, infill, and expansion area development must comply with the environmental recommendations of a subwatershed study update. As such, it is crucial to perform an update to the subwatershed study as lands develop through 2041. Prevention of environmental impacts through the subwatershed study update will help prevent unnecessary or costly remediation during future build-out.</td></tr>
<tr><td>Projected Completion Timeline</td><td>2026 (0 – 5 years)</td><td>Duration of Fieldwork or Studies</td><td>18 months</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">• LiDAR Right-of-Way (Aerial)
• Rural Ditch Survey
• Existing Infrastructure Survey & Condition Assessment
• GIS Inventory Update
• City-Wide Asset Inventory
• Continuous Water Quality & Flow Monitoring and Reporting
• Stormwater Model Update
• Dike System Outlet Program</td></tr>
<tr><td>Dependent Fieldwork or Studies</td><td colspan="3">• Stormwater Master Servicing Plan Update</td></tr>
<tr><td>Cost Estimate</td><td colspan="3">$ 1,170,000</td></tr>
</table>

Project #10: Climate Change Action Plan and Best Practices Review			
Overview	Project consists of a review of current best practices for adaption and mitigation of the effects of climate change on municipal stormwater system		
Relevant Capital Project	Project **SW-SD-006** Capital Program Sheet		
Scope of Fieldwork or Study	The scope of the study will include the following: • Review current best practices within Ontario/Canada related to the impacts of climate change on stormwater infrastructure • Determine the impacts of climate change on intensity, duration, and frequency of storm events • Prepare a plan for adaption to climate change and mitigation of impacts within the minor and major stormwater systems		
Objectives	The scientific community currently agrees that the climate is changing and there may be impacts on the intensity, duration, and frequency of storm events compared existing conditions. Municipalities across Ontario are planning for the impacts of climate change on stormwater infrastructure; however, the impacts of climate change on rainfall and storm events are projected to be variable based on microclimates. As such, a best practices review is required to determine the best methodology for the City of Brantford to utilize in planning for the impacts of climate change on their infrastructure. Like asset management planning based on condition assessments, it will be important to analyze the stormwater conveyance and management system based on future projected storm events. A lack of proper planning for potential increases in intensity, duration, or frequency of storm events could lead to sudden extreme flooding and a sudden increased financial burden.		
Projected Completion Timeline	2026 (0 – 5 years)	**Duration of Fieldwork or Studies**	9 months
Precedent Fieldwork or Studies	• Continuous Water Quality & Flow Monitoring and Reporting		
Dependent Fieldwork or Studies	• Stormwater Model Update • Stormwater Master Servicing Plan Update		
Cost Estimate	$ 117,000		

<table>
<tr><th colspan="4">Project #11: Stormwater Master Servicing Plan Update</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of an update to the Stormwater Master Servicing Plan for planning of the stormwater management and conveyance system into a future planning horizon</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Project SW-SD-007 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">The scope of the study will include the following:
Update the Stormwater Master Servicing Plan to account for future growth projections within the City of Brantford
Determine problem areas or areas of concern following the Class EA process
Produce financial projections for infrastructure upgrades and projects</td></tr>
<tr><td>Objectives</td><td colspan="3">The Stormwater Master Servicing Plan update is the culmination of all fieldwork and studies from a technical perspective. Per the capital plan and implementation plan, the City of Brantford currently requires multiple studies and associated fieldwork preceding the next Master Servicing Plan update. With the new information acquired through the precedent studies, a more clear understanding of the interconnected nature of the City’s stormwater system will be achieved. The Class EA process with the new information from fieldwork and studies will ensure that logical and cost-efficient projects are proposed, while also ensuring that there are not false flags or financial inefficiencies.</td></tr>
<tr><td>Projected Completion Timeline</td><td>2026 (0 – 5 years)</td><td>Duration of Fieldwork or Studies</td><td>18 months</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">LiDAR Right-of-Way (Aerial)
Rural Ditch Survey
Existing Infrastructure Survey & Condition Assessment
GIS Inventory Update
City-Wide Asset Inventory
Continuous Water Quality & Flow Monitoring and Reporting
Stormwater Model Update
Dike System Outlet Program
Subwatershed Studies Update
Climate Change Action Plan and Best Practices Review
Stormwater Rate Review</td></tr>
<tr><td>Dependent Fieldwork or Studies</td><td colspan="3">N/A</td></tr>
<tr><td>Cost Estimate</td><td colspan="3">$ 293,000</td></tr>
</table>

<table>
<tr><th colspan="4">Project #12: Stormwater Rate Review</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of a review of past and future proposed stormwater costs to the City of Brantford to determine the practicality of a stormwater user rate</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Project SW-SD-008 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">The scope of the study will include the following:
• Determine the total and itemized costs for the operation and maintenance of stormwater infrastructure within the City of Brantford
• Quantify the annual cost of stormwater within the City on a per-capita basis
• Determine the applicability of a potential stormwater charge to either residents, industrial, commercial, or new developments proposed
• Determine rebates for private Low Impact Development or mitigation measures
• Prepare strategy and details for stormwater charge implementation</td></tr>
<tr><td>Objectives</td><td colspan="3">Both water and wastewater utilities charge the end user a fee to maintain and operate the systems; however, stormwater is more difficult to quantify and has historically not been funded directly by end users. A study is recommended to determine the mechanism for recovering finances related to regular stormwater infrastructure operations, maintenance, and developer driven upgrades. Each property within the City of Brantford is currently either contributing to the municipal stormwater system or is controlling stormwater entirely privately. As climate change continues and infrastructure ages, it will be necessary for the City to determine an adequate and fair funding source and mechanism to fund the required improvements.</td></tr>
<tr><td>Projected Completion Timeline</td><td>2026 (0 – 5 years)</td><td>Duration of Fieldwork or Studies</td><td>9 months</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">• N/A</td></tr>
<tr><td>Dependent Fieldwork or Studies</td><td colspan="3">• Stormwater Master Servicing Plan Update</td></tr>
<tr><td>Cost Estimate</td><td colspan="3">$ 293,000</td></tr>
</table>

Project #13: Stormwater Policy Review and Update			
Overview	Project consists of a review of existing stormwater policies and update based on results of MSP and various external studies being completed on behalf of the City.		
Relevant Capital Project	Project **SW-SD-009** Capital Program Sheet		
Scope of Fieldwork or Study	The scope of the study will include the following: • Review recommendations of MSP and precedent fieldwork or studies to determine deficiencies within existing stormwater policy • Review Grand River Conservation Authority and Brant County stormwater policies • Coordinate with external stakeholders • Prepare update to City stormwater policies to prepare for future City growth and conditions and mitigate stormwater concerns		
Objectives	Based on the outcome of the recommended studies from the stormwater MSP, the City's stormwater policy will need to be updated to incorporate the recommendations. The recommended studies may have impacts on the dike system and outlets, growth lands and subwatersheds within the City, climate change adaption, and potential stormwater user rates. It is important to keep the City's stormwater policy up to date with all available knowledge to ensure an efficient system. As new information becomes available, the City's stormwater policy should be adjusted to reflect the new information.		
Projected Completion Timeline	2026 (0 – 5 years)	**Duration of Fieldwork or Studies**	12 months
Precedent Fieldwork or Studies	• Dike System Outlet Program • Subwatershed Studies Update • Climate Change Action Plan and Best Practices Review • Stormwater Rate Review		
Dependent Fieldwork or Studies	• Stormwater Master Servicing Plan Update		
Cost Estimate	$ 140,000		

Project #14: Grand River – Homedale Feasibility Study			
Overview	Project consists of a study to determine the feasibility of the proposed trunk sewer and local sewer upgrades within the Grand River – Homedale subcatchment		
Relevant Capital Project	Included in Project **SW-LI-001** Capital Program Sheet		
Scope of Fieldwork or Study	The scope of the study will include the following: • Confirm feasibility of proposed trunk sewer alignment and upgrades, currently proposed within Lawrence Street, Albion Street, and Waterloo Street • Coordinate with the City of Brantford to determine priority local upgrade areas based on existing observed private or public flooding • Conduct overland flow and outlet analysis for major storms within local areas, including impact and influence of dike system on drainage • Determine impacts of street/utility crossings on proposed trunk sewer upgrades • Confirm timing, capital budget, and design details of proposed trunk sewer and local upgrades		
Objectives	The Stormwater Master Servicing Plan has determined the required upgrades to the trunk sewer within Albion Street, as well as local sewer upgrades in areas with street flooding under the 2-year storm event from a high level; however, data gaps such as the major system flows and their interaction with the Grand River dike system are still unknown. A detailed Feasibility Study specific to the Grand River – Homedale subcatchment will expand on and confirm the details of both the trunk sewer and local upgrades. This will ensure that capital program finances account for all potential variables, such as the dike system, as well as a methodology to fund the upgrades exists, via the Stormwater Rate Review. Conducting the study will ensure City finances are not misallocated due to the high-level nature of the MSP.		
Projected Completion Timeline	2026 (0 – 5 years)	**Duration of Fieldwork or Studies**	18 months
Precedent Fieldwork or Studies	• LiDAR Right-of-Way (Aerial) • Rural Ditch Survey • Existing Infrastructure Survey & Condition Assessment • Dike System Outlet Program • Stormwater Rate Review		

Project #14: Grand River – Homedale Feasibility Study	
Dependent Fieldwork or Studies	• GIS Inventory Update • City-Wide Asset Inventory • Stormwater Master Servicing Plan Update
Cost Estimate	$ 300,000

<table>
<tr><th colspan="4">Project #15: Grand River – Eagle Place Feasibility Study</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of a study to determine the feasibility of the proposed trunk sewer diversion and local sewer upgrades within the Grand River – Eagle Place subcatchment</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Included in Project SW-LI-002 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">The scope of the study will include the following:
• Confirm feasibility of proposed trunk sewer alignment and upgrades/diversion, currently proposed within Division Street, Seventh Avenue, and Whitehead Street
• Coordinate with the City of Brantford to determine priority local upgrade areas based on existing observed private or public flooding
• Conduct overland flow and outlet analysis for major storms within local areas, including impact and influence of dike system on drainage
• Determine impacts of street/utility crossings on proposed trunk sewer upgrades/diversion
• Confirm timing, capital budget, and design details of proposed trunk sewer and local upgrades</td></tr>
<tr><td>Objectives</td><td colspan="3">The Stormwater Master Servicing Plan has determined the required diversion to the trunk sewer within Seventh Avenue, as well as local sewer upgrades in areas with street flooding under the 2-year storm event from a high level; however, data gaps such as the major system flows and their interaction with the Grand River dike system are still unknown. A detailed Feasibility Study specific to the Grand River – Eagle Place subcatchment will expand on and confirm the details of both the trunk sewer and local upgrades. This will ensure that capital program finances account for all potential variables, such as the dike system, as well as a methodology to fund the upgrades exists, via the Stormwater Rate Review. Conducting the study will ensure City finances are not misallocated due to the high-level nature of the MSP.</td></tr>
<tr><td>Projected Completion Timeline</td><td>2026 (0 – 5 years)</td><td>Duration of Fieldwork or Studies</td><td>12 months</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">• LiDAR Right-of-Way (Aerial)
• Rural Ditch Survey
• Existing Infrastructure Survey & Condition Assessment
• Dike System Outlet Program
• Stormwater Rate Review</td></tr>
</table>

Project #15: Grand River – Eagle Place Feasibility Study	
Dependent Fieldwork or Studies	• GIS Inventory Update • City-Wide Asset Inventory • Stormwater Master Servicing Plan Update
Cost Estimate	$ 200,000

Project #16: Fairchild Creek – Garden Schedule B EA			
Overview	Project consists of a study to determine the feasibility of the proposed trunk sewer diversion within the Fairchild Creek – Garden subcatchment		
Relevant Capital Project	Included in Project **SW-LI-003** Capital Program Sheet		
Scope of Fieldwork or Study	The scope of the study will include the following: • Confirm feasibility of proposed trunk sewer alignment and diversion, currently proposed within Fairview Drive • Meet all requirements of a Schedule B EA project • Determine impacts of street/utility crossings on proposed trunk sewer diversion • Confirm timing, capital budget, and design details of proposed trunk sewer		
Objectives	The Stormwater Master Servicing Plan has determined the required diversion to a new trunk sewer within the Fairview Drive right-of-way to accommodate the 5-year storm event. The proposed project will involve significant deep sewer installation as well as new connections to the trunk sewer and impacts on the existing Highway 403 trunk sewer. The level of uncertainty due to the complexity and cost of the project requires a more in-depth investigation in the form of a Schedule B EA to confirm and determine additional details on the servicing strategy. The financial impact of the works will require a methodology to fund the upgrades, via the Stormwater Rate Review. Conducting the study will ensure City finances are not misallocated due to the high-level nature of the MSP. The Schedule B EA is to be done in conjunction with Fairchild Creek – Garden Feasibility Study.		
Projected Completion Timeline	2031 (0 – 10 years)	**Duration of Fieldwork or Studies**	24 months
Precedent Fieldwork or Studies	• LiDAR Right-of-Way (Aerial) • Rural Ditch Survey • Existing Infrastructure Survey & Condition Assessment • Stormwater Rate Review • Farichild Creek – Garden Feasibility Study		
Dependent Fieldwork or Studies	• GIS Inventory Update • City-Wide Asset Inventory • Stormwater Master Servicing Plan Update • Farichild Creek – Garden Feasibility Study		
Cost Estimate	$ 350,000		

<table>
<tr><th colspan="4">Project #17: Fairchild Creek – Garden Feasibility Study</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of a study to determine the feasibility of the proposed local sewer upgrades within the Fairchild Creek – Garden subcatchment</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Included in Project SW-LI-003 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">The scope of the study will include the following:
• Coordinate with the City of Brantford to determine priority local upgrade areas based on existing observed private or public flooding
• Conduct overland flow analysis for major storms within local areas
• Determine impacts of street/utility crossings on proposed trunk sewer upgrades/diversion
• Confirm timing, capital budget, and design details of proposed local upgrades</td></tr>
<tr><td>Objectives</td><td colspan="3">The Stormwater Master Servicing Plan has determined the required local sewer upgrades in areas with street flooding under the 5-year storm event from a high level; however, data gaps such as the major system flows, and the impact of the Fairview Drive trunk diversion design are still unknown. A detailed Feasibility Study specific to the Fairchild Creek – Garden subcatchment will expand on and confirm the details of the local upgrades. This will ensure that capital program finances account for all potential variables, such as the potential impact of the trunk diversion, as well as a methodology to fund the upgrades exists, via the Stormwater Rate Review. Conducting the study will ensure City finances are not misallocated due to the high-level nature of the MSP. The Feasibility Study is to be done in conjunction with Fairchild Creek – Garden Schedule B EA.</td></tr>
<tr><td>Projected Completion Timeline</td><td>2031 (0 – 10 years)</td><td>Duration of Fieldwork or Studies</td><td>12 months</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">• LiDAR Right-of-Way (Aerial)
• Rural Ditch Survey
• Existing Infrastructure Survey & Condition Assessment
• Stormwater Rate Review
• Fairchild Creek – Garden Schedule B EA</td></tr>
<tr><td>Dependent Fieldwork or Studies</td><td colspan="3">• GIS Inventory Update
• City-Wide Asset Inventory
• Stormwater Master Servicing Plan Update
• Fairchild Creek – Garden Schedule B EA</td></tr>
<tr><td>Cost Estimate</td><td colspan="3">$ 150,000</td></tr>
</table>

<table>
<tr><th colspan="4">Project #18: Grand River - Southwest Feasibility Study</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of a study to determine the feasibility of the proposed local sewer upgrades within the Grand River – Southwest subcatchment</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Included in Project SW-LI-004 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">The scope of the study will include the following:
• Coordinate with the City of Brantford to determine priority local upgrade areas based on existing observed private or public flooding
• Conduct overland flow and outlet analysis for major storms within local areas, including impact and influence of dike system on drainage
• Determine impacts of street/utility crossings on proposed trunk sewer upgrades/diversion
• Confirm timing, capital budget, and design details of proposed local upgrades</td></tr>
<tr><td>Objectives</td><td colspan="3">The Stormwater Master Servicing Plan has determined the required local sewer upgrades in areas with street flooding under the 2-year storm event from a high level; however, data gaps such as the major system flows are still unknown. A detailed Feasibility Study specific to the Grand River – Southwest subcatchment will expand on and confirm the details of the local upgrades. This will ensure that capital program finances account for all potential variables, as well as a methodology to fund the upgrades exists via the Stormwater Rate Review. Conducting the study will ensure City finances are not misallocated due to the high-level nature of the MSP.</td></tr>
<tr><td>Projected Completion Timeline</td><td>2031 (5-10 years)</td><td>Duration of Fieldwork or Studies</td><td>12 months</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">• LiDAR Right-of-Way (Aerial)
• Rural Ditch Survey
• Existing Infrastructure Survey & Condition Assessment
• Stormwater Rate Review</td></tr>
<tr><td>Dependent Fieldwork or Studies</td><td colspan="3">• GIS Inventory Update
• City-Wide Asset Inventory
• Stormwater Master Servicing Plan Update</td></tr>
<tr><td>Cost Estimate</td><td colspan="3">$ 200,000</td></tr>
</table>

<table>
<tr><th colspan="4">Project #19: Mohawk Lake Downtown Feasibility Study</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of a study to determine the feasibility of the proposed local sewer upgrades within the Mohawk Lake Downtown subcatchment</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Included in Project SW-LI-005 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">The scope of the study will include the following:
• Coordinate with the City of Brantford to determine priority local upgrade areas based on existing observed private or public flooding
• Conduct overland flow analysis for major storms within local areas
• Determine impacts of street/utility crossings on proposed trunk sewer upgrades/diversion
• Confirm timing, capital budget, and design details of proposed local upgrades</td></tr>
<tr><td>Objectives</td><td colspan="3">The Stormwater Master Servicing Plan has determined the required local sewer upgrades in areas with street flooding under the 2-year storm event from a high level; however, data gaps such as the major system flows are still unknown. A detailed Feasibility Study specific to the Mohawk Lake Downtown subcatchment will expand on and confirm the details of the local upgrades. This will ensure that capital program finances account for all potential variables, such as the potential for LID implementation within intensification areas, as well as a methodology to fund the upgrades exists, via the Stormwater Rate Review. Conducting the study will ensure City finances are not misallocated due to the high-level nature of the MSP.</td></tr>
<tr><td>Projected Completion Timeline</td><td>2031 (5 – 10 years)</td><td>Duration of Fieldwork or Studies</td><td>12 months</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">• LiDAR Right-of-Way (Aerial)
• Rural Ditch Survey
• Existing Infrastructure Survey & Condition Assessment
• Stormwater Rate Review</td></tr>
<tr><td>Dependent Fieldwork or Studies</td><td colspan="3">• GIS Inventory Update
• City-Wide Asset Inventory
• Stormwater Master Servicing Plan Update</td></tr>
<tr><td>Cost Estimate</td><td colspan="3">$ 200,000</td></tr>
</table>

Project #20: Fairchild Creek – South Feasibility Study			
Overview	Project consists of a study to determine the feasibility of the proposed local sewer upgrades within the Fairchild Creek South subcatchment		
Relevant Capital Project	Included in Project **SW-LI-008** Capital Program Sheet		
Scope of Fieldwork or Study	The scope of the study will include the following: • Coordinate with the City of Brantford to determine priority local upgrade areas based on existing observed private or public flooding • Conduct overland flow analysis for major storms within local areas • Determine impacts of street/utility crossings on proposed trunk sewer upgrades/diversion • Confirm timing, capital budget, and design details of proposed local upgrades		
Objectives	The Stormwater Master Servicing Plan has determined the required local sewer upgrades in areas with street flooding under the 5-year storm event from a high level; however, data gaps such as the major system flows are still unknown. A detailed Feasibility Study specific to the Fairchild Creek – South subcatchment will expand on and confirm the details of the local upgrades. This will ensure that capital program finances account for all potential variables, as well as a methodology to fund the upgrades exists via the Stormwater Rate Review. Conducting the study will ensure City finances are not misallocated due to the high-level nature of the MSP.		
Projected Completion Timeline	2031 (5 – 10 years)	**Duration of Fieldwork or Studies**	9 months
Precedent Fieldwork or Studies	• LiDAR Right-of-Way (Aerial) • Rural Ditch Survey • Existing Infrastructure Survey & Condition Assessment • Stormwater Rate Review		
Dependent Fieldwork or Studies	• GIS Inventory Update • City-Wide Asset Inventory • Stormwater Master Servicing Plan Update		
Cost Estimate	$ 75,000		

<table>
<tr><th colspan="4">Project #21: Fairchild Creek – Jones Feasibility Study</th></tr>
<tr><td>Overview</td><td colspan="3">Project consists of a study to determine the feasibility of the proposed local sewer upgrades within the Fairchild Creek – Jones subcatchment</td></tr>
<tr><td>Relevant Capital Project</td><td colspan="3">Included in Project SW-LI-009 Capital Program Sheet</td></tr>
<tr><td>Scope of Fieldwork or Study</td><td colspan="3">The scope of the study will include the following:
• Coordinate with the City of Brantford to determine priority local upgrade areas based on existing observed private or public flooding
• Conduct overland flow analysis for major storms within local areas
• Determine impacts of street/utility crossings on proposed trunk sewer upgrades/diversion
• Confirm timing, capital budget, and design details of proposed local upgrades</td></tr>
<tr><td>Objectives</td><td colspan="3">The Stormwater Master Servicing Plan has determined the required local sewer upgrades in areas with street flooding under the 5-year storm event from a high level; however, data gaps such as the major system flows are still unknown. A detailed Feasibility Study specific to the Fairchild Creek – Jones subcatchment will expand on and confirm the details of the local upgrades. This will ensure that capital program finances account for all potential variables, such as the potential for LID implementation within intensification areas, as well as a methodology to fund the upgrades exists, via the Stormwater Rate Review. Conducting the study will ensure City finances are not misallocated due to the high-level nature of the MSP.</td></tr>
<tr><td>Projected Completion Timeline</td><td>2031 (5 – 10 years)</td><td>Duration of Fieldwork or Studies</td><td>9 months</td></tr>
<tr><td>Precedent Fieldwork or Studies</td><td colspan="3">• LiDAR Right-of-Way (Aerial)
• Rural Ditch Survey
• Existing Infrastructure Survey & Condition Assessment
• Stormwater Rate Review</td></tr>
<tr><td>Dependent Fieldwork or Studies</td><td colspan="3">• GIS Inventory Update
• City-Wide Asset Inventory
• Stormwater Master Servicing Plan Update</td></tr>
<tr><td>Cost Estimate</td><td colspan="3">$ 75,000</td></tr>
</table>

E

City of Brantford

APPENDIX E

CAPITAL PROGRAM PROJECT SHEETS

Stormwater Capital Program

Capital Program ID	Name	Description	Stormwater Catchment	Class EA Schedule	Project Type	Size/Capacity	Length (m)	Class Estimate Type	Project Complexity	Accuracy Range	Area Condition	Total Estimated Cost (2020$)	Timeline	DC Benefit to Existing Class
SW-LI-001	Homedale Catchment Trunk & Local Upgrades	Upgrade trunk within Grand River - Homedale subcatchment and upgrade undersized local infrastructure	STORMWATER SUBCATCHMENT: Grand River - Homedale	A+	Linear Infrastructure	Varies	Varies	Class 4	Med	40%	Suburban	$ 9,129,000	0-5 years	E
SW-LI-002	Eagle Place Catchment Trunk & Local Upgrades	Upgrade trunk within Grand River - Eagle Place subcatchment and upgrade undersized local infrastructure	STORMWATER SUBCATCHMENT: Grand River - Eagle Place	A+	Linear Infrastructure	Varies	Varies	Class 4	Med	40%	Suburban	$ 6,336,000	0-5 years	E
SW-LI-003	Fairchild Garden Catchment Trunk & Local Upgrades	Upgrade trunk within Fairchild Creek - Garden subcatchment and upgrade undersized local infrastructure	STORMWATER SUBCATCHMENT: Fairchild Creek - Garden	B	Linear Infrastructure	Varies	Varies	Class 4	High	50%	Suburban	$ 49,156,000	0-10 years	E
SW-LI-004	Grand River Southwest Catchment Local Upgrades	Upgrade undersized local infrastructure	STORMWATER SUBCATCHMENT: Grand River - Southwest	A+	Linear Infrastructure	450 mm	1,400	Class 4	Low	30%	Suburban	$ 2,449,000	10-20 years	E
SW-LI-005	Mohawk Lake Local Catchment Upgrades	Upgrade undersized local infrastructure	STORMWATER SUBCATCHMENT: Mohawk Lake (+ Downtown)	A+	Linear Infrastructure	525 mm	10,100	Class 4	Low	30%	Suburban	$ 17,008,000	5-10 years	E
SW-LI-006	Mohawk Lake Catchment Upgrades	Upgrade local infrastructure	STORMWATER SUBCATCHMENT: Mohawk Lake (+ Downtown)	N/A	Linear Infrastructure	Varies	Varies	-	-	-	-	$ 7,180,000	0-5 years	E
SW-LI-007	Mohawk Lake Catchment Upgrades	Upgrade local infrastructure	STORMWATER SUBCATCHMENT: Mohawk Lake (+ Downtown)	N/A	Linear Infrastructure	Varies	Varies	-	-	-	-	$ 12,150,000	0-10 years	E
SW-LI-008	Fairchild Creek South Catchment Local Upgrades	Upgrade undersized local infrastructure	STORMWATER SUBCATCHMENT: Fairchild Creek - South	A+	Linear Infrastructure	450 mm	300	Class 4	Low	30%	Suburban	$ 557,000	10-20 years	F
SW-LI-009	Fairchild Creek Jones Catchment Local Upgrades	Upgrade undersized local infrastructure	STORMWATER SUBCATCHMENT: Fairchild Creek - Jones	A+	Linear Infrastructure	525 mm	1,900	Class 4	Low	30%	Suburban	$ 3,369,000	10-20 years	E
SW-LI-010	Grand River Northwest Catchment Local Upgrades	Upgrade undersized local infrastructure and determine stormwater management and outlet north of Highway 403	STORMWATER SUBCATCHMENT: Grand River - Northwest	B	Linear Infrastructure & Pond	Varies	Varies	Class 4	High	50%	Suburban	$ 11,011,000	0-5 years	A
SW-LI-011	Fairchild Creek North Catchment Local Upgrades	Local upgrades to mitigate flooding within Fairchild Creek - North catchment	STORMWATER SUBCATCHMENT: Fairchild Creek - North	N/A	Linear Infrastructure	Varies	Varies	-	-	-	-	$ 30,300,000	0-5 years	F
SW-PD-001	Northwest Employment Area (Pond #1)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Northwest Employment Area	B	Pond	94 ML	-	Class 4	Low	30%	Rural	$ 1,960,000	0-5 years	A
SW-PD-002	Southwest Employment Area (Pond #2)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Southwest Employment Area	B	Pond	62 ML	-	Class 4	Low	30%	Rural	$ 1,318,000	0-5 years	A
SW-PD-003	Golf Road North Employment Area (Pond #3)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Golf Road North Employment Area	B	Pond	25 ML	-	Class 4	Low	30%	Rural	$ 576,000	0-5 years	A
SW-PD-004	Golf-Powerline Employment Area (Pond #4)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Golf-Powerline Employment Area	B	Pond	40 ML	-	Class 4	Low	30%	Rural	$ 877,000	0-5 years	A
SW-PD-005	Balmoral-Powerline Northwest Area (Pond #5)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Balmoral-Powerline Northwest Area	B	Pond	25 ML	-	Class 4	Low	30%	Rural	$ 576,000	0-5 years	A
SW-PD-006	Balmoral-Powerline Southwest Area (Pond #6)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Balmoral-Powerline Southwest Area	B	Pond	19 ML	-	Class 4	Low	30%	Rural	$ 456,000	0-5 years	A
SW-PD-007	Northridge North Area (Pond #7)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Northridge North Area	B	Pond	14 ML	-	Class 4	Low	30%	Rural	$ 356,000	0-5 years	A
SW-PD-008	King George Corridor (Pond #8)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: King George Corridor	B	Pond	16 ML	-	Class 4	Low	30%	Rural	$ 396,000	0-10 years	A
SW-PD-009	King George Corridor (Pond #9)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: King George Corridor	B	Pond	10 ML	-	Class 4	Low	30%	Rural	$ 276,000	0-10 years	A
SW-PD-010	King George Corridor (Pond #10)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: King George Corridor	B	Pond	6 ML	-	Class 4	Low	30%	Rural	$ 195,000	10-20 years	A
SW-PD-011	Powerline-Park (Pond #11)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Powerline-Park	B	Pond	7 ML	-	Class 4	Low	30%	Rural	$ 216,000	10-20 years	A
SW-PD-012	Powerline-Park (Pond #12)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Powerline-Park	B	Pond	13 ML	-	Class 4	Low	30%	Rural	$ 335,000	10-20 years	A
SW-PD-013	Northeast Residential Area (Pond #13)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Northeast Residential	B	Pond	13 ML	-	Class 4	Low	30%	Rural	$ 335,000	0-5 years	A
SW-PD-014	Northeast Residential Area (Pond #14)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Northeast Residential	B	Pond	22 ML	-	Class 4	Low	30%	Rural	$ 516,000	0-5 years	A
SW-PD-015	Northeast Residential Area (Pond #15)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Northeast Residential	B	Pond	9 ML	-	Class 4	Low	30%	Rural	$ 256,000	0-5 years	A
SW-PD-016	Lynden-Garden Residential Area (Pond #16)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Lynden-Garden Residential	B	Pond	15 ML	-	Class 4	Low	30%	Rural	$ 376,000	0-5 years	A

City of Brantford
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SW-PD-017	Garden-403 Employment Area (Pond #17)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Garden-403 Employment	B	Pond	72 ML	-	Class 4	Low	30%	Rural	$ 1,519,000	0-10 years	A
SW-PD-018	Tutela Heights North Area (Pond #18)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Tutela Heights North	B	Pond	17 ML	-	Class 4	Low	30%	Rural	$ 417,000	0-5 years	A
SW-PD-019	Tutela Heights North Area (Pond #19)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Tutela Heights North	B	Pond	9 ML	-	Class 4	Low	30%	Rural	$ 256,000	0-5 years	A
SW-PD-020	Phelps Creek Area (Pond #20)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Phelps Creek	B	Pond	4 ML	-	Class 4	Low	30%	Rural	$ 156,000	10-20 years	A
SW-PD-021	Phelps Creek Area (Pond #21)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Phelps Creek	B	Pond	12 ML	-	Class 4	Low	30%	Rural	$ 316,000	10-20 years	A
SW-PD-022	Phelps Creek Area (Pond #22)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Phelps Creek	B	Pond	19 ML	-	Class 4	Low	30%	Rural	$ 456,000	10-20 years	A
SW-PD-023	Phelps Creek Area (Pond #23)	Developer driven stormwater management pond based on planning blocks	STORMWATER SUBCATCHMENT: Phelps Creek	B	Pond	6 ML	-	Class 4	Low	30%	Rural	$ 195,000	10-20 years	A
SW-SD-001	City-Wide Asset Inventory	Asset inventory for City owned stormwater assets	-	-	Study	-	-	-	-	-	-	$ 322,000	0-5 years	-
SW-SD-002	Continuous Water Quality & Flow Monitoring and Reporting	Continuous water quality & flow monitoring in existing system with strategic locations selected	-	-	Study	-	-	-	-	-	-	$ 5,910,000	0-5 years	-
SW-SD-003	Stormwater Model Update	Update stormwater infrastructure model to represent knew information	-	-	Study	-	-	-	-	-	-	$ 371,000	0-5 years	-
SW-SD-004	Dike System Outlet Program	Program to optimize use of dike system with existing stormwater system	-	-	Study	-	-	-	-	-	-	$ 439,000	0-5 years	-
SW-SD-005	Update Subwatershed Studies	Update Subwatershed Studies to account for new information collected through new developments and City collected data.	-	-	Study	-	-	-	-	-	-	$ 1,170,000	0-5 years	-
SW-SD-006	Climate Change Action Plan and Best Practices Review	Literature review of best practices for stormwater management, prediction, and mitigation as it applies to climate change.	-	-	Study	-	-	-	-	-	-	$ 117,000	0-5 years	-
SW-SD-007	Stormwater Master Servicing Plan Update	Update SW MSP based on recommendations of prior studies.	-	-	Study	-	-	-	-	-	-	$ 293,000	0-5 years	-
SW-SD-008	Stormwater Rate Review	Determine stormwater user charge	-	-	Study	-	-	-	-	-	-	$ 117,000	0-5 years	-
SW-SD-009	Stormwater Policy Review and Update	Review City stormwater policies and update per MSP and City study recommendations	-	-	Study	-	-	-	-	-	-	$ 140,000	0-5 years	-
Total												**$ 169,859,000**		

City of Brantford

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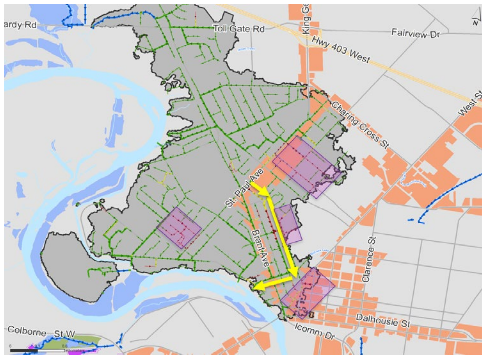
Stormwater Capital Program

PROJECT NO.:	**SW-LI-001**	**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Homedale Catchment Trunk & Local Upgrades**	**VERSION:**	
PROJECT OVERVIEW:	Upgrade trunk within Grand River - Homedale subcatchment and upgrade undersized local infrastructure	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Grand River - Homedale

PROJECT DESCRIPTION:

Upgrade trunk sewer from St. Paul Ave. to ultimate Grand River outlet to accommodate upstream flows.

Upgrade all local sewers that are flooding (surcharging to street level) within the Homedale subcatchment under the 2-year storm event level of service.

NOTE: For costing purposes, the average local pipe upgrade size was selected for one (1) standard pipe size.

Legend

- Model HGL below pipe obvert for storm event
- Model HGL above pipe obvert for storm event
- Model HGL at surface for storm event
- Open channels
- Approximate areas for recommended local upgrades

REQUIRED STUDIES:	**Feasibility Study**
STUDY SCOPE:	The feasibility study will confirm detailed sizing and location of trunk and local sewer upgrades.
OBJECTIVES:	Determine detailed sizing for the trunk sewer and local sewer upgrades and trunk sewer alignment. Determine the trunk upgrade schedule, overland flow analysis, and timing of local upgrades. Determine impacts of crossings or external factors on local upgrades. Determine impacts of dike system on pipe capacity as it affects local upgrades.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Med	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	40%	
Area Condition:	Suburban	Area Condition uplifts unit cost and restoration

TRUNK UPGRADES

AVERAGE DIAMETER:		975 mm	
ESTIMATED LENGTH:		1200 m	
	Tunneled	0 m	0%
	Open Cut	1200 m	100%

CLASS EA REQUIREMENTS:	A+
CONSTRUCTION ASSUMPTION:	Sewer 5m

LOCAL UPGRADES

AVERAGE DIAMETER:		450 mm	
ESTIMATED LENGTH:		1900 m	
	Tunneled	0 m	0%
	Open Cut	1900 m	100%

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Homedale Feasibility Study			0 - 5 yrs	$300,000	$300,000	
Sub-Total Study Costs						**$300,000**	
High-Level Planning Cost							
Trunk Upgrade Construction - Open Cut			m	1200 m	$1,968	$2,361,400	Existing road ROW
Trunk Upgrade Construction - Tunneling			m	0 m	$10,200	$0	
Local Upgrade Construction - Open Cut			m	1900 m	$760	$1,443,897	
Local Upgrade Construction - Tunneling			m	0 m	$6,400	$0	
Crossings Allowance	15%					$570,795	Allowance for crossings of creeks, roads, railways, and utilities
Pipe Construction Uplift (Based on Area Conditions)	10%					$437,609	
Additional Construction Costs	15%		ea.			$722,055	Includes Mod/Demob,connections, inspection, hydrants, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$481,370	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$6,017,000**	
Geotechnical / Hydrogeological / Materials	1.0%					$60,200	
Geotechnical Sub-Total Cost						**$60,200**	
Property Requirements	1.5%					$ 90,300	
Property Requirements Sub-Total						**$90,300**	
Consultant Engineering/Design	15%					$ 902,600	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$902,600**	
In House Labour/Engineering/Wages/CA	8%					$ 481,400	
In-house Labour/Wages Sub-Total						**$481,400**	
Project Contingency	15%					$1,133,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$1,133,000**	
Non-Refundable HST	1.76%					$144,400	
Non-Refundable HST Sub-Total						**$144,400**	
Total (2020 Dollars)						**$9,129,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$9,129,000**	**2020 Estimate**

City of Brantford
Water, Wastewater, and Stormwater Master Servicing Plan Update - 2051 Amendment
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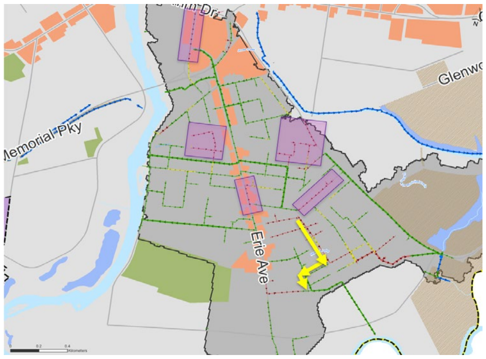
PROJECT NO.:	**SW-LI-002**	**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Eagle Place Catchment Trunk & Local Upgrades**	**VERSION:**	
PROJECT OVERVIEW:	Upgrade trunk within Grand River - Eagle Place subcatchment and upgrade undersized local infrastructure	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Grand River - Eagle Place

PROJECT DESCRIPTION:

Divert trunk sewer nearby Erie Ave. to ultimate Grand River outlet to accommodate upstream flows.

Upgrade all local sewers that are flooding (surcharging to street level) within the Eagle Place subcatchment under the 2-year storm event level of service.

NOTE: For costing purposes, the average local pipe upgrade size was selected for one (1) standard pipe size.

Legend

- Model HGL below pipe obvert for storm event
- Model HGL above pipe obvert for storm event
- Model HGL at surface for storm event
- Open channels
- Approximate areas for recommended local upgrades

REQUIRED STUDIES:	**Feasibility Study**
STUDY SCOPE:	The feasibility study will confirm detailed sizing and location of trunk and local sewer upgrades.
OBJECTIVES:	Determine detailed sizing for the trunk sewer and local sewer upgrades and trunk sewer alignment. Determine the trunk upgrade schedule, overland flow analysis, and timing of local upgrades. Determine impacts of crossings or external factors on local upgrades. Determine impacts of dike system on pipe capacity as it affects local upgrades.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Med	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	40%	
Area Condition:	Suburban	Area Condition uplifts unit cost and restoration

TRUNK UPGRADES

AVERAGE DIAMETER:	900 mm	
ESTIMATED LENGTH:	700 m	
Tunneled	0 m	0%
Open Cut	700 m	100%

CLASS EA REQUIREMENTS:	A+
CONSTRUCTION ASSUMPTION:	Sewer 5m

LOCAL UPGRADES

AVERAGE DIAMETER:	450 mm	
ESTIMATED LENGTH:	1800 m	
Tunneled	0 m	0%
Open Cut	1800 m	100%

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Eagle Place Feasibility Study			0 - 5 yrs	$200,000	$200,000	
Sub-Total Study Costs						**$200,000**	
High-Level Planning Cost							
Trunk Upgrade Construction - Open Cut			m	700 m	$1,824	$1,277,100	Existing road ROW
Trunk Upgrade Construction - Tunneling			m	0 m	$10,000	$0	
Local Upgrade Construction - Open Cut			m	1800 m	$760	$1,367,903	
Local Upgrade Construction - Tunneling			m	0 m	$6,400	$0	
Crossings Allowance	15%					$396,750	Allowance for crossings of creeks, roads, railways, and utilities
Pipe Construction Uplift (Based on Area Conditions)	10%					$304,175	
Additional Construction Costs	15%		ea.			$501,889	Includes Mod/Demob,connections, inspection, hydrants, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$334,593	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$4,182,000**	
Geotechnical / Hydrogeological / Materials	1.0%					$41,800	
Geotechnical Sub-Total Cost						**$41,800**	
Property Requirements	1.5%					$ 62,700	
Property Requirements Sub-Total						**$62,700**	
Consultant Engineering/Design	15%					$ 627,300	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$627,300**	
In House Labour/Engineering/Wages/CA	8%					$ 334,600	
In-house Labour/Wages Sub-Total						**$334,600**	
Project Contingency	15%					$787,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$787,000**	
Non-Refundable HST	1.76%					$100,300	
Non-Refundable HST Sub-Total						**$100,300**	
Total (2020 Dollars)						**$6,336,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$6,336,000**	**2020 Estimate**

City of Brantford
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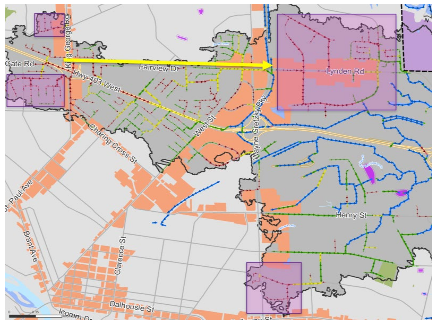
PROJECT NO.:	**SW-LI-003**	**CAPITAL BUDGET YEAR:**	**0-10 Years**
PROJECT NAME:	**Fairchild Garden Catchment Trunk & Local Upgrades**	**VERSION:**	
PROJECT OVERVIEW:	Upgrade trunk within Fairchild Creek - Garden subcatchment and upgrade undersized local infrastructure	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Fairchild Creek - Garden

PROJECT DESCRIPTION:

Divert portions of stormwater north of Highway 403 from the Highway 403 trunk to a new trunk within Fairview Drive, discharging to the Wayne Gretzky Parkway ditch, freeing capacity within the Highway 403 trunk sewer. Significant portions may require deep sewers (> 10 m)

Upgrade all local sewers that are flooding (surcharging to street level) within the Fairchild Creek - Garden subcatchment under the 5-year storm event level of service.

NOTE: For costing purposes, the average local pipe upgrade size was selected for one (1) standard pipe size.

Legend

- Model HGL below pipe obvert for storm event
- Model HGL above pipe obvert for storm event
- Model HGL at surface for storm event
- Open channels
- Approximate areas for recommended local upgrades

REQUIRED STUDIES:	**Feasibility Study**
STUDY SCOPE:	The feasibility study will confirm detailed sizing and location of local sewer upgrades.
OBJECTIVES:	Determine detailed sizing for the local sewer upgrades. Determine the upgrade schedule, overland flow analysis, and timing of local upgrades. Determine impacts of crossings or external factors on local upgrades.
REQUIRED STUDIES:	**Municipal Class Environmental Assessment (EA)**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the best alignment and detailed sizing for the trunk sewer upgrades. Determine trunk upgrade schedule. Determine impacts of crossings or external factors on pipe upgrades.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	High	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	50%	
Area Condition:	Suburban	Area Condition uplifts unit cost and restoration

TRUNK UPGRADES

AVERAGE DIAMETER:		1050 mm	
ESTIMATED LENGTH:		810 m	
	Tunnelled	0 m	0%
	Open Cut	810 m	100%
AVERAGE DIAMETER:		1350 mm	
ESTIMATED LENGTH:		1410 m	
	Tunnelled	0 m	0%
	Open Cut	1410 m	100%

CLASS EA REQUIREMENTS:	B
CONSTRUCTION ASSUMPTION:	Sewer 5m
CLASS EA REQUIREMENTS:	B
CONSTRUCTION ASSUMPTION:	Sewer 10m

LOCAL UPGRADES

AVERAGE DIAMETER:		600 mm	
ESTIMATED LENGTH:		9000 m	
	Tunnelled	0 m	0%
	Open Cut	9000 m	100%

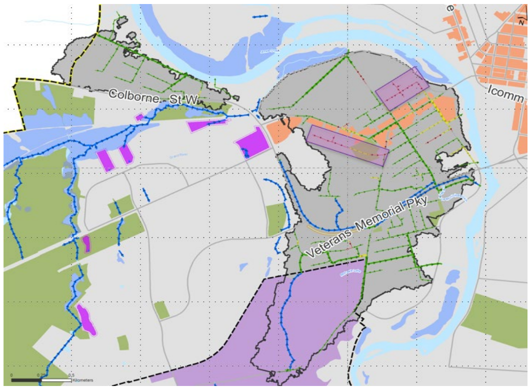
GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Fairchild Creek - Garden Local Upgrade Feasibility Study			0 - 10 yrs	$350,000	$350,000	
Study	Municipal Class EA			0 - 10 yrs	$150,000	$150,000	
Sub-Total Study Costs						**$500,000**	
High-Level Planning Cost							
Trunk Upgrade Construction - Open Cut (Sewer < 5m)			m	810 m	$2,181	$1,766,269	Existing road ROW
Trunk Upgrade Construction - Tunneling (Sewer < 5m)			m	0 m	$10,400	$0	
Trunk Upgrade Construction - Open Cut (Sewer 10m)			m	1410 m	$5,566	$7,847,743	
Trunk Upgrade Construction - Tunneling (Sewer 10m)			m	0 m	$11,500	$0	
Local Upgrade Construction - Open Cut			m	9000 m	$1,052	$9,464,575	
Local Upgrade Construction - Tunneling			m	0 m	$8,000	$0	
Crossings Allowance	15%					$2,861,788	Allowance for crossings of creeks, roads, railways, and utilities
Pipe Construction Uplift (Based on Area Conditions)	10%					$2,194,037	
Additional Construction Costs	20%		ea.			$4,826,882	Includes Mod/Demob,connections, inspection, hydrants, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$2,413,441	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$31,375,000**	
Geotechnical / Hydrogeological / Materials	2.0%					$627,500	
Geotechnical Sub-Total Cost						**$627,500**	
Property Requirements	2.0%					$ 627,500	
Property Requirements Sub-Total						**$627,500**	
Consultant Engineering/Design	12%					$ 3,765,000	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$3,765,000**	
In House Labour/Engineering/Wages/CA	6%					$ 1,882,500	
In-house Labour/Wages Sub-Total						**$1,882,500**	
Project Contingency	25%					$9,569,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$9,569,000**	
Non-Refundable HST	1.76%					$809,000	
Non-Refundable HST Sub-Total						**$809,000**	
Total (2020 Dollars)						**$49,156,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$49,156,000**	**2020 Estimate**

City of Brantford
Water, Wastewater, and Stormwater Master Servicing Plan Update - 2051 Amendment
Stormwater Capital Program

PROJECT NO.:	**SW-LI-004**	**CAPITAL BUDGET YEAR:**	**10-20 Years**
PROJECT NAME:	**Grand River Southwest Catchment Local Upgrades**	**VERSION:**	
PROJECT OVERVIEW:	Upgrade undersized local infrastructure	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Grand River - Southwest

PROJECT DESCRIPTION:

Upgrade all local sewers that are flooding (surcharging to street level) within the Grand River - Southwest subcatchment under the 2-year storm event level of service.

NOTE: For costing purposes, the average pipe upgrade size was selected for one (1) standard pipe size.

Legend
- Model HGL below pipe obvert for storm event
- Model HGL above pipe obvert for storm event
- Model HGL at surface for storm event
- Open channels
- Approximate areas for recommended local upgrades

REQUIRED STUDIES: **Feasibility Study**

STUDY SCOPE: The feasibility study will confirm detailed sizing and location of local sewer upgrades.

OBJECTIVES: Determine detailed sizing for the local sewer upgrades. Determine the upgrade schedule, overland flow analysis, and timing of local upgrades. Determine impacts of crossings or external factors on local upgrades. Determine impacts of dike system on pipe capacity as it affects local upgrades.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Suburban	Area Condition uplifts unit cost and restoration

AVERAGE DIAMETER:	450 mm		
ESTIMATED LENGTH:	1400 m		
Tunnelled	0 m	0%	
Open Cut	1400 m	100%	

CLASS EA REQUIREMENTS:	A+
CONSTRUCTION ASSUMPTION:	Sewer 5m

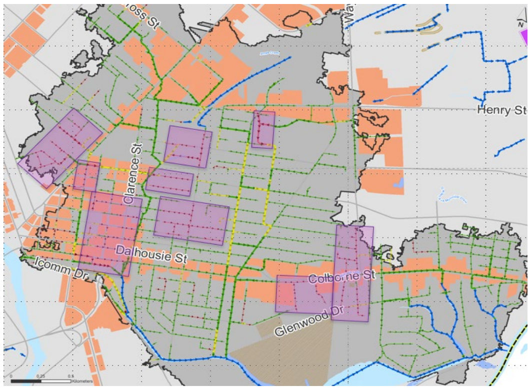
GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Feasibility Study			10 - 20 yrs	$200,000	$200,000	
Sub-Total Study Costs						**$200,000**	
High-Level Planning Cost							
Pipe Construction - Open Cut			m	1400 m	$760	$1,063,924	Existing road ROW
Pipe Construction - Tunneling			m	0 m	$6,400	$0	
Crossings Allowance	15%					$159,589	Allowance for crossings of creeks, roads, railways, and utilities
Pipe Construction Uplift (Based on Area Conditions)	10%					$122,351	
Additional Construction Costs	10%		ea.			$134,586	Includes Mod/Demob,connections, inspection, hydrants, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$134,586	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$1,615,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$8,100	
Geotechnical Sub-Total Cost						**$8,100**	
Property Requirements	1.0%					$ 16,200	
Property Requirements Sub-Total						**$16,200**	
Consultant Engineering/Design	15%					$ 242,300	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$242,300**	
In House Labour/Engineering/Wages/CA	8%					$ 129,200	
In-house Labour/Wages Sub-Total						**$129,200**	
Project Contingency	10%					$201,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$201,000**	
Non-Refundable HST	1.76%					$36,700	
Non-Refundable HST Sub-Total						**$36,700**	
Total (2020 Dollars)						**$2,449,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$2,449,000**	**2020 Estimate**

City of Brantford
Water, Wastewater, and Stormwater Master Servicing Plan Update - 2051 Amendment
Stormwater Capital Program

PROJECT NO.:	**SW-LI-005**	**CAPITAL BUDGET YEAR:**	**5-10 Years**
PROJECT NAME:	**Mohawk Lake Local Catchment Upgrades**	**VERSION:**	
PROJECT OVERVIEW:	Upgrade undersized local infrastructure	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Mohawk Lake (+ Downtown)

PROJECT DESCRIPTION:

Upgrade all local sewers that are flooding (surcharging to street level) within the Mohawk Lake (+ Downtown) subcatchment under the 2-year storm event level of service.

NOTE: For costing purposes, the average pipe upgrade size was selected for one (1) standard pipe size.

Legend

- Model HGL below pipe obvert for storm event
- Model HGL above pipe obvert for storm event
- Model HGL at surface for storm event
- Open channels
- Approximate areas for recommended local upgrades

REQUIRED STUDIES: **Feasibility Study**

STUDY SCOPE: The feasibility study will confirm detailed sizing and location of local sewer upgrades.

OBJECTIVES: Determine detailed sizing for the local sewer upgrades. Determine the upgrade schedule, overland flow analysis, and timing of local upgrades. Determine impacts of crossings or external factors on local upgrades.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Suburban	Area Condition uplifts unit cost and restoration

AVERAGE DIAMETER:	525 mm		
ESTIMATED LENGTH:	10100 m		
	Tunnelled	0 m	0%
	Open Cut	10100 m	100%

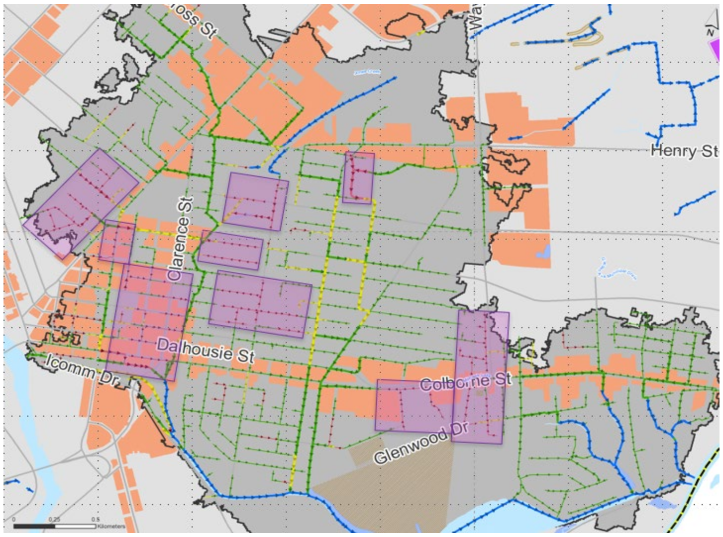
CLASS EA REQUIREMENTS:	A+
CONSTRUCTION ASSUMPTION:	Sewer 5m

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Feasibility Study			10 - 20 yrs	$200,000	$200,000	
Sub-Total Study Costs						**$200,000**	
High-Level Planning Cost							
Pipe Construction - Open Cut			m	10100 m	$820	$8,283,631	Existing road ROW
Pipe Construction - Tunneling			m	0 m	$6,500	$0	
Crossings Allowance	15%					$1,242,545	Allowance for crossings of creeks, roads, railways, and utilities
Pipe Construction Uplift (Based on Area Conditions)	10%					$952,618	
Additional Construction Costs	10%		ea.			$1,047,879	Includes Mod/Demob,connections, inspection, hydrants, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$1,047,879	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$12,575,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$62,900	
Geotechnical Sub-Total Cost						**$62,900**	
Property Requirements	1.0%					$ 125,800	
Property Requirements Sub-Total						**$125,800**	
Consultant Engineering/Design	12%					$ 1,509,000	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$1,509,000**	
In House Labour/Engineering/Wages/CA	6%					$ 754,500	
In-house Labour/Wages Sub-Total						**$754,500**	
Project Contingency	10%					$1,503,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$1,503,000**	
Non-Refundable HST	1.76%					$277,700	
Non-Refundable HST Sub-Total						**$277,700**	
Total (2020 Dollars)						**$17,008,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$17,008,000**	**2020 Estimate**

PROJECT NO.:	**SW-LI-006**	**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Mohawk Lake Catchment Upgrades** Upgrade	**VERSION:**	
PROJECT OVERVIEW:	local infrastructure	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Mohawk Lake (+ Downtown)

PROJECT DESCRIPTION:

Upgrades to the Mohawk Lake subcatchment, including Mohawk Lake and Canal per the Mohawk Lake and Mohawk Canal Functional Master Drainage and Restoration Study (2020). Projects and studies included for capital budget year 2020/2021.

NOTE: The provided information is a summary of the Mohawk Lake and Mohawk Canal Functional Master Drainage and Restoration Study (2020); the original study document is to be consulted for final costs and details.

Legend

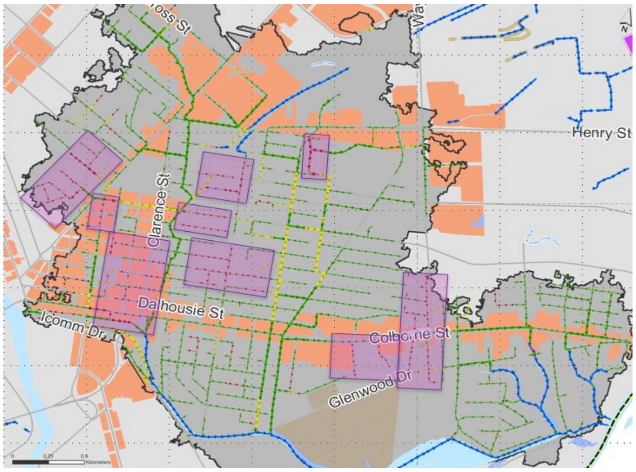
- Model HGL below pipe obvert for storm event
- Model HGL above pipe obvert for storm event
- Model HGL at surface for storm event
- Open channels
- Approximate areas for recommended local upgrades

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION	Class EA	COST PER UNIT	SUB-TOTAL	LOCATION
Component Cost					
Detailed Design	OGS Retrofits	A/A+		$465,000	3 highest priority locations
Detailed Design	SWMF Outfall Retrofits	B			Shallow Creek Park
Detailed Design	Watercourse Restoration and Retrofit	B			Mohawk West Canal restoration and retrofit (upstream)
Construction	OGS Retrofits	N/A		$900,000	3 highest priority locations
Construction	SWMF Outfall Retrofits	N/A		$4,500,000	Shallow Creek Park
Construction	Watercourse Restoration and Retrofit	N/A		TBD	Mohawk West Canal restoration and retrofit (upstream)
SWM Requirements for Developments	Development SWM Policy	N/A		$0	Subwatershed (or City-wide)
Assessment and Potential Remediation	Cross Connection Investigation	A/A+		$50,000	Rawdon Street and Bruce Street
Assessment and Potential Remediation		A/A+		$25,000	Various areas of subwatershed
Detailed Design	SWMF Outfall Retrofits	B		$150,000	Shallow Creek Trail (Rawdon Street)
Feasibility Review		N/A		$20,000	Glebe Lands
Feasibility Review		N/A		$20,000	Arrowdale Public Golf Course
Design and Construction	OGS Retrofits	A/A+		$300,000	1 of remaining high priority locations
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Elgin Street (CN overpass to Rawdon Street)
Design and Construction		A/A+		$150,000	Palace Street (Brant to Duke)
Design and Construction		A/A+		$150,000	Chatham Street (Stanley to Fourth)
Design and Construction		A/A+		$150,000	Drummond Street (Dead End to Park)
Design and Construction		A/A+		$150,000	Rawdon Street (Wellington to Grey)
Assessment/Preliminary Design	Strategic Sediment Removal and Lake Bed Recontouring	B		TBD	Mohawk Lake (and East Canal)
Study/Wildlife Management	Field Study into Carp Invasive Studies	B		TBD	Mohawk Lake
Sub-Total Study Costs				**$7,180,000**	
Total (2020 Dollars)				**$7,180,000**	Rounded to nearest $1,000
Other Estimate					
Chosen Estimate				**$7,180,000**	**2020 Estimate**

PROJECT NO.:	SW-LI-007	CAPITAL BUDGET YEAR:	0-10 Years
PROJECT NAME:	**Mohawk Lake Catchment Upgrades** Upgrade	VERSION:	
PROJECT OVERVIEW:	local infrastructure	DATE UPDATED:	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Mohawk Lake (+ Downtown)

PROJECT DESCRIPTION:

Upgrades to the Mohawk Lake subcatchment, including Mohawk Lake and Canal per the Mohawk Lake and Mohawk Canal Functional Master Drainage and Restoration Study (2020). Projects and studies included for capital budget year 2022 to 2029.

NOTE: The provided information is a summary of the Mohawk Lake and Mohawk Canal Functional Master Drainage and Restoration Study (2020); the original study document is to be consulted for final costs and details.

Legend

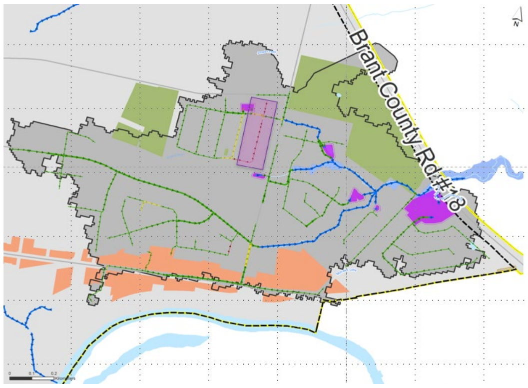
- Model HGL below pipe obvert for storm event
- Model HGL above pipe obvert for storm event
- Model HGL at surface for storm event
- Open channels
- Approximate areas for recommended local upgrades

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION	Class EA	COST PER UNIT	SUB-TOTAL	LOCATION
Component Cost					
Construction		N/A		$4,700,000	Shallow Creek Trail (Rawdon Street)
Detailed Design		B		$150,000	Arrowdale Public Golf Course
Detailed Design	SWM Outfall Retrofits	B		$200,000	Glebe Lands
Construction		N/A		TBC	Arrowdale Public Golf Course
Construction		N/A		TBC	Glebe Lands
Design and Construction	OGS Retrofits	A/A+		$2,400,000	Remaining high priority locations (1 per year - 8 total)
Annual Assessment	Cross-Connection Investigation	A/A+		$200,000	Various areas of subwatershed (annual review)
Street Sweeping - Policy and Capability Review		N/A		$0	Subwatershed (or City-wide)
Road Salt Management Plan	Studies	N/A		$50,000	Entire subwatershed (possibly City-wide)
Landfill Contamination Study		N/A		$100,000	Subwatershed (or City-wide)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Buffalo Street (Rushton to West)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Grey Street (Fourth to Wayne Gretzky)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Nelson Street (Stanley to Park)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Drummond Street (Dalhousie to Chatham)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Charlotte Street (Dalhousie to Colborne)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Clarence Street (Dalhousie to Colborne)
Design and Construction	SWM for Road Reconstruction	A/A+		$300,000	Colborne Street (Brant to Dalhousie)
Design and Construction	SWM for Road Reconstruction	A/A+		$300,000	Dalhousie Street (Brant to Colborne)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	King Street (Dalhousie to Colborne)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Queen Street (Dalhousie to Colborne)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Chatham Street (Park to Murray)
Design and Construction	SWM for Road Reconstruction	A/A+		$300,000	Clarence Street (Colborne to West)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Sheridan Street (Rawdon to Fourth)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Pearl Street (St. James to West)
Design and Construction	SWM for Road Reconstruction	A/A+		$300,000	Wayne Gretzky Parkway (Lynden to Colborne)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Alfred Street (Colborne to Dalhousie)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Aylmer Street (Darling to Chatham)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Brighton Avenue (Huron to Superior)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Darling Street (Queen to Market)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Dundas Street (St. Paul to West)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Stanley Street and Rawdon Street
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Usher Street (Main to Dead End)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	West Street (Dundas to Charing Cross)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Charing Cross (West to Henry)
Design and Construction	SWM for Road Reconstruction	A/A+		$150,000	Rawdon Street (Dalhousie to Wellington)
Detailed Design and Construction	Strategis Sediment Removal and Lake Bed Recontouring	B		TBD	Mohawk Lake (and East Canal)
Detailed Design and Construction of Carp Control Measures	Wildlife Management	B		TBD	Mohawk Lake
Study, Detailed Design and Construction of West Mohawk Canal Restoration	Strategic Sediment Removal, Channel Naturalization	B		TBD	West Canal (downstream portion)
Sub-Total Study Costs				**$12,150,000**	
Total (2020 Dollars)				**$12,150,000**	Rounded to nearest $1,000
Other Estimate					
Chosen Estimate				**$12,150,000**	**2020 Estimate**

PROJECT NO.:	**SW-LI-008**	**CAPITAL BUDGET YEAR:**	**10-20 Years**
PROJECT NAME:	**Fairchild Creek South Catchment Local Upgrades**	**VERSION:**	
PROJECT OVERVIEW:	Upgrade undersized local infrastructure	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Fairchild Creek - South

PROJECT DESCRIPTION:

Upgrade all local sewers that are flooding (surcharging to street level) within the Fairchild Creek - South subcatchment under the 5-year storm event level of service.

NOTE: For costing purposes, the average pipe upgrade size was selected for one (1) standard pipe size.

Legend

- Model HGL below pipe obvert for storm event
- Model HGL above pipe obvert for storm event
- Model HGL at surface for storm event
- Open channels
- Approximate areas for recommended local upgrades

REQUIRED STUDIES: **Feasibility Study**

STUDY SCOPE: The feasibility study will confirm detailed sizing and location of local sewer upgrades.

OBJECTIVES: Determine detailed sizing for the local sewer upgrades. Determine the upgrade schedule, overland flow analysis, and timing of local upgrades. Determine impacts of crossings or external factors on local upgrades.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Suburban	Area Condition uplifts unit cost and restoration

AVERAGE DIAMETER:		450 mm	
ESTIMATED LENGTH:		300 m	
	Tunnelled	0 m	0%
	Open Cut	300 m	100%

CLASS EA REQUIREMENTS:	A+
CONSTRUCTION ASSUMPTION:	Sewer 5m

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION		TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost						
Study	Feasibility Study		10 - 20 yrs	$75,000	$75,000	
Sub-Total Study Costs					**$75,000**	
High-Level Planning Cost						
Pipe Construction - Open Cut			m	300 m	$760	$227,984	Existing road ROW
Pipe Construction - Tunneling			m	0 m	$6,400	$0	
Crossings Allowance	15%					$34,198	Allowance for crossings of creeks, roads, railways, and utilities
Pipe Construction Uplift (Based on Area Conditions)	10%					$26,218	
Additional Construction Costs	10%		ea.			$28,840	Includes Mod/Demob,connections, inspection, hydrants, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$28,840	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$346,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$1,700	
Geotechnical Sub-Total Cost						**$1,700**	
Property Requirements	1.0%					$ 3,500	
Property Requirements Sub-Total						**$3,500**	
Consultant Engineering/Design	15%					$ 51,900	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$51,900**	
In House Labour/Engineering/Wages/CA	8%					$ 27,700	
In-house Labour/Wages Sub-Total						**$27,700**	
Project Contingency	10%					$43,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$43,000**	
Non-Refundable HST	1.76%					$7,900	
Non-Refundable HST Sub-Total						**$7,900**	
Total (2020 Dollars)						**$557,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$557,000**	**2020 Estimate**

City of Brantford
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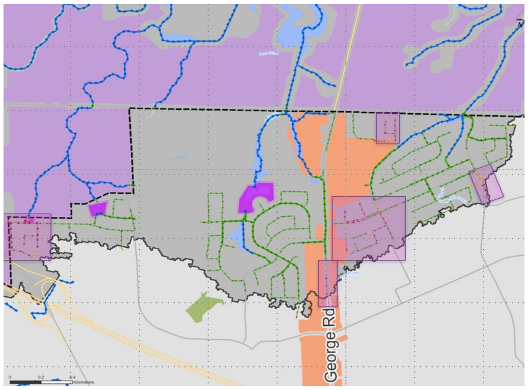
PROJECT NO.:	**SW-LI-009**	**CAPITAL BUDGET YEAR:**	**10-20 Years**
PROJECT NAME:	**Fairchild Creek Jones Catchment Local Upgrades**	**VERSION:**	
PROJECT OVERVIEW:	Upgrade undersized local infrastructure	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Fairchild Creek - Jones

PROJECT DESCRIPTION:

Upgrade all local sewers that are flooding (surcharging to street level) within the Fairchild Creek - Jones subcatchment under the 5-year storm event level of service.

NOTE: For costing purposes, the average pipe upgrade size was selected for one (1) standard pipe size.

Legend

- Model HGL below pipe obvert for storm event
- Model HGL above pipe obvert for storm event
- Model HGL at surface for storm event
- Open channels
- Approximate areas for recommended local upgrades

REQUIRED STUDIES: **Feasibility Study**

STUDY SCOPE: The feasibility study will confirm detailed sizing and location of local sewer upgrades.

OBJECTIVES: Determine detailed sizing for the local sewer upgrades. Determine the upgrade schedule, overland flow analysis, and timing of local upgrades. Determine impacts of crossings or external factors on local upgrades.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Suburban	Area Condition uplifts unit cost and restoration

AVERAGE DIAMETER:	525 mm	
ESTIMATED LENGTH:	1900 m	
Tunnelled	0 m	0%
Open Cut	1900 m	100%

CLASS EA REQUIREMENTS:	A+
CONSTRUCTION ASSUMPTION:	Sewer 5m

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Feasibility Study			5 - 10 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pipe Construction - Open Cut			m	1900 m	$820	$1,558,307	Existing road ROW
Pipe Construction - Tunneling			m	0 m	$6,500	$0	
Crossings Allowance	15%					$233,746	Allowance for crossings of creeks, roads, railways, and utilities
Pipe Construction Uplift (Based on Area Conditions)	10%					$179,205	
Additional Construction Costs	10%		ea.			$197,126	Includes Mod/Demob,connections, inspection, hydrants, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$197,126	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$2,366,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$11,800	
Geotechnical Sub-Total Cost						**$11,800**	
Property Requirements	1.0%					$ 23,700	
Property Requirements Sub-Total						**$23,700**	
Consultant Engineering/Design	15%					$ 354,900	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$354,900**	
In House Labour/Engineering/Wages/CA	8%					$ 189,300	
In-house Labour/Wages Sub-Total						**$189,300**	
Project Contingency	10%					$295,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$295,000**	
Non-Refundable HST	1.76%					$53,700	
Non-Refundable HST Sub-Total						**$53,700**	
Total (2020 Dollars)						**$3,369,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$3,369,000**	**2020 Estimate**

City of Brantford
Water, Wastewater, and Stormwater Master Servicing Plan Update - 2051 Amendment
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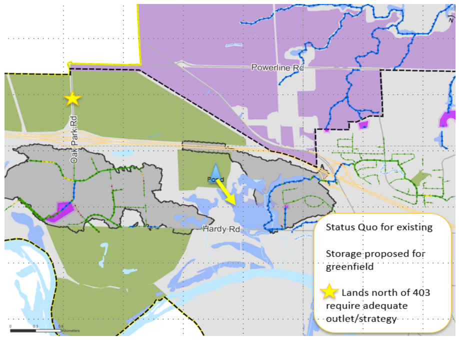
PROJECT NO.:	**SW-LI-010**	**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Grand River Northwest Catchment Local Upgrades**	**VERSION:**	
PROJECT OVERVIEW:	Upgrade undersized local infrastructure and determine stormwater management and outlet north of Highway 403	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Grand River - Northwest

PROJECT DESCRIPTION:

Upgrade all local sewers that are flooding (surcharging to street level) within the Grand River - Northwest subcatchment under the 5-year storm event level of service.

NOTE: For costing purposes, the average pipe upgrade size was selected for one (1) standard pipe size.

Legend
- Model HGL below pipe obvert for storm event
- Model HGL above pipe obvert for storm event
- Model HGL at surface for storm event
- Open channels
- Approximate areas for recommended local upgrades

REQUIRED STUDIES: **Stormwater Management Study EA**

STUDY SCOPE: The Stormwater Management EA will confirm detailed sizing and location of local sewer upgrades and the strategy/sizing of the pond north of Highway 403.

OBJECTIVES: Determine the detailed sizing for the local sewer upgrades and ponds. Determine the upgrade schedule, overland flow analysis, and timing of local upgrades. Determine impacts of crossings or external factors on local upgrades.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	High	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	50%	
Area Condition:	Suburban	Area Condition uplifts unit cost and restoration

HWY 403 SWM STRATEGY

ASSUMED HWY 403 CROSSING DIAMETER:		600 mm	
ESTIMATED LENGTH:		1800 m	
	Tunnelled	150 m	8%
	Open Cut	1650 m	92%
ESTIMATED ACTIVE STORAGE (M3):		90000 m3	
ESTIMATED AREA (HA):		9.0 ha	

CLASS EA REQUIREMENTS:	B
CONSTRUCTION ASSUMPTION:	Sewer 5m

LOCAL UPGRADES

AVERAGE DIAMETER:		525 mm	
ESTIMATED LENGTH:		300 m	
	Tunnelled	0 m	0%
	Open Cut	300 m	100%

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 5 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Hwy 403 Trunk Construction - Open Cut (Sewer < 5m)			m	1650 m	$1,052	$1,735,172	Existing road ROW
Hwy 403 Trunk Construction - Tunneling (Sewer < 5m)			m	150 m	$8,000	$1,200,000	
Pond Construction			ha	9.0 ha	$100,000	$900,000	
Maintenance Roads & Side Slopes	20%					$180,000	
Local Upgrade Construction - Open Cut			m	300 m	$820	$246,048	
Local Upgrade Construction - Tunneling			m	0 m	$6,500	$0	
Crossings Allowance	15%					$477,183.09	Allowance for crossing of Highway 403 & general local upgrade crossings
Pipe Construction Uplift (Based on Area Conditions)	10%					$473,840	
Additional Construction Costs	20%		ea.			$1,042,449	Includes Mod/Demob,connections, inspection, hydrants, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$521,224	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$6,776,000**	
Geotechnical / Hydrogeological / Materials	2.0%					$135,500	
Geotechnical Sub-Total Cost						**$135,500**	
Property Requirements	2.0%					$ 135,500	
Property Requirements Sub-Total						**$135,500**	
Consultant Engineering/Design	15%					$ 1,016,400	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$1,016,400**	
In House Labour/Engineering/Wages/CA	8%					$ 542,100	
In-house Labour/Wages Sub-Total						**$542,100**	
Project Contingency	25%					$2,151,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$2,151,000**	
Non-Refundable HST	1.76%					$179,800	
Non-Refundable HST Sub-Total						**$179,800**	
Total (2020 Dollars)						**$11,011,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$11,011,000**	**2020 Estimate**

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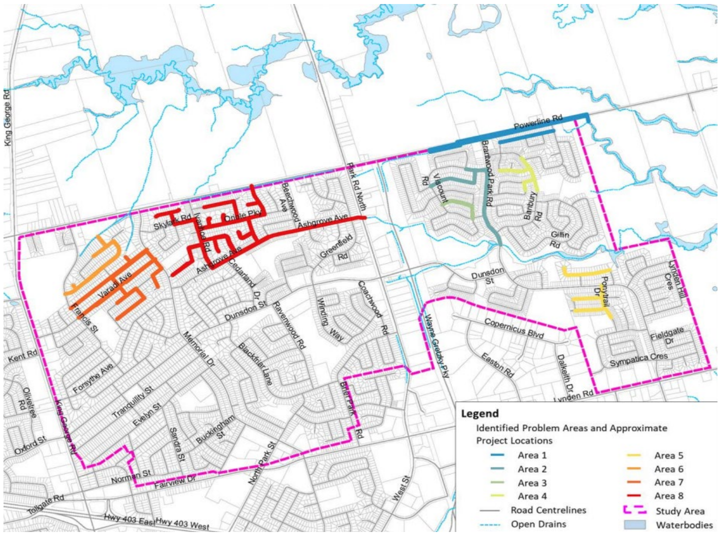
PROJECT NO.:	**SW-LI-011**	**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Fairchild Creek North Catchment Local Upgrades**	**VERSION:**	
PROJECT OVERVIEW:	Local upgrades to mitigate flooding within Fairchild Creek - North catchment	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Fairchild Creek - North

PROJECT DESCRIPTION:

Upgrade all local sewers that are flooding (surcharging to street level) within the Grand River - North subcatchment under the 5-year storm event level of service.

NOTE: For costing purposes, values directly transcribed from North-East Flood Remediation Study (Aquafor Beech, 2020)

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Construction Cost							
Area 1 - Powerline Road			ea.			$530,000	
Area 2 - Coxwell Crescent / Viscount Road			ea.			$2,800,000	
Area 3 - White Owl Crescent			ea.			$400,000	
Area 4 - Enfield Crescent / Banbury Road			ea.			$2,500,000	
Area 5 - Hackney Ridge			ea.			$1,200,000	
Area 6 - Royal Oak Drive			ea.			$1,800,000	
Area 7 - Kensington Avenue / Varadi Avenue			ea.			$4,200,000	
Area 8 - Ashgrove Avenue Area			ea.			$10,800,000	
Sub-Total Construction Base Costs						**$24,230,000**	
Consultant Engineering/Design	10%					$ 2,430,000	
Engineering/Design Sub-Total						**$2,430,000**	
Project Contingency	15%					$3,640,000	Contingency calculation does not include Consultant Engineering/Design in subtotal
Project Contingency Sub-Total						**$3,640,000**	
Total (2020 Dollars)						**$30,300,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$30,300,000**	**2020 Estimate**

City of Brantford
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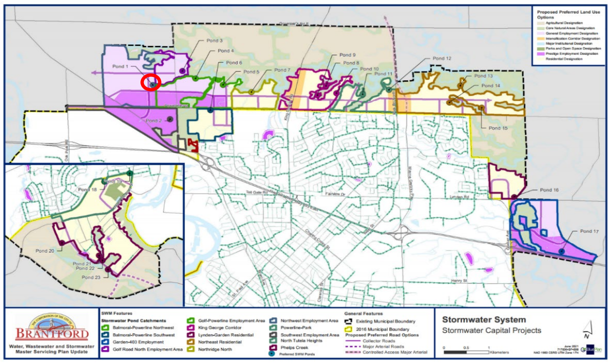
PROJECT NO.:	**SW-PD-001**		**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Northwest Employment Area (Pond #1)**		**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks		**DATE UPDATED:**	
			UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Northwest Employment Area

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Northwest Employment Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	94 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	9.4 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 5 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	9.4 ha	$100,000	$940,000	
Maintenance Roads & Side Slopes	20%					$188,000	
Additional Construction Costs	10%		ea.			$112,800	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$112,800	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$1,354,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$6,800	
Geotechnical Sub-Total Cost						**$6,800**	
Property Requirements	1.0%					$ 13,500	
Property Requirements Sub-Total						**$13,500**	
Consultant Engineering/Design	15%					$ 203,100	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$203,100**	
In House Labour/Engineering/Wages/CA	8%					$ 108,300	
In-house Labour/Wages Sub-Total						**$108,300**	
Project Contingency	10%					$169,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$169,000**	
Non-Refundable HST	1.76%					$30,700	
Non-Refundable HST Sub-Total						**$30,700**	
Total (2020 Dollars)						**$1,960,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$1,960,000**	**2020 Estimate**

City of Brantford
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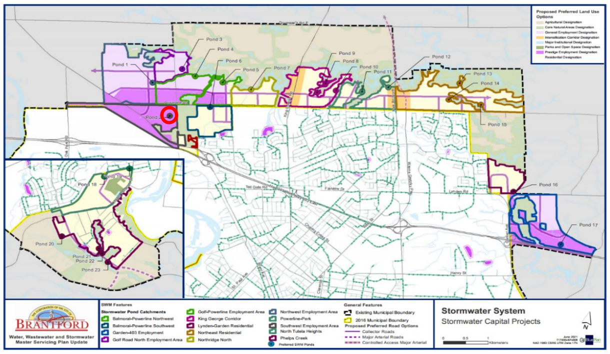
PROJECT NO.:	**SW-PD-002**	**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Southwest Employment Area (Pond #2)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Southwest Employment Area

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Southwest Employment Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	62 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	6.2 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 5 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	6.2 ha	$100,000	$620,000	
Maintenance Roads & Side Slopes	20%					$124,000	
Additional Construction Costs	10%		ea.			$74,400	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$74,400	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$893,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$4,500	
Geotechnical Sub-Total Cost						**$4,500**	
Property Requirements	1.0%					$ 8,900	
Property Requirements Sub-Total						**$8,900**	
Consultant Engineering/Design	15%					$ 134,000	Includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$134,000**	
In House Labour/Engineering/Wages/CA	8%					$ 71,400	
In-house Labour/Wages Sub-Total						**$71,400**	
Project Contingency	10%					$111,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$111,000**	
Non-Refundable HST	1.76%					$20,300	
Non-Refundable HST Sub-Total						**$20,300**	
Total (2020 Dollars)						**$1,318,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$1,318,000**	**2020 Estimate**

City of Brantford
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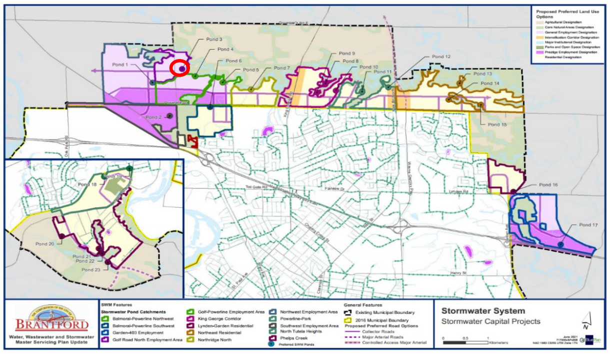
PROJECT NO.:	**SW-PD-003**	**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Golf Road North Employment Area (Pond #3)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Golf Road North Employment Area

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Golf Road North Employment Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	25 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	2.5 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 5 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	2.5 ha	$100,000	$250,000	
Maintenance Roads & Side Slopes	20%					$50,000	
Additional Construction Costs	10%		ea.			$30,000	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$30,000	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$360,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$1,800	
Geotechnical Sub-Total Cost						**$1,800**	
Property Requirements	1.0%					$ 3,600	
Property Requirements Sub-Total						**$3,600**	
Consultant Engineering/Design	15%					$ 54,000	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$54,000**	
In House Labour/Engineering/Wages/CA	8%					$ 28,800	
In-house Labour/Wages Sub-Total						**$28,800**	
Project Contingency	10%					$45,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$45,000**	
Non-Refundable HST	1.76%					$8,200	
Non-Refundable HST Sub-Total						**$8,200**	
Total (2020 Dollars)						**$576,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$576,000**	**2020 Estimate**

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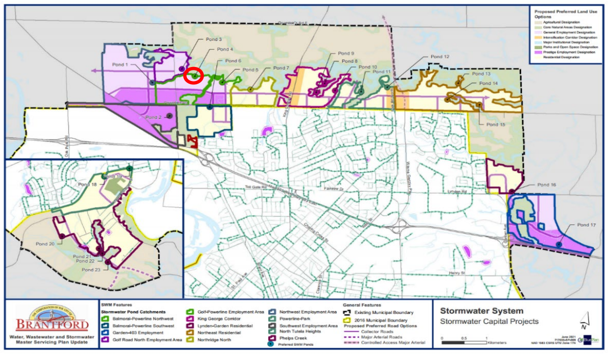
PROJECT NO.:	**SW-PD-004**	**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Golf-Powerline Employment Area (Pond #4)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Golf-Powerline Employment Area

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Golf-Powerline Employment Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	40 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	4.0 ha	**CONSTRUCTION ASSUMPTION:**	Other

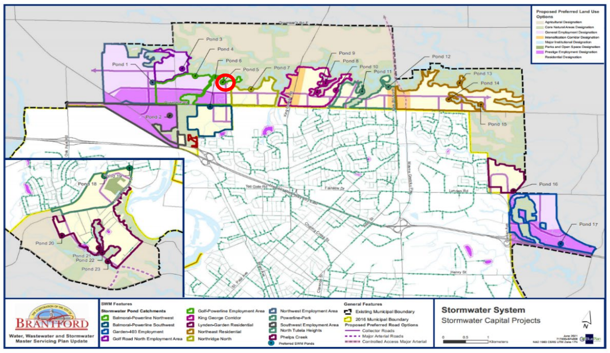
Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 5 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	4.0 ha	$100,000	$400,000	
Maintenance Roads & Side Slopes	20%					$80,000	
Additional Construction Costs	10%		ea.			$48,000	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$48,000	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$576,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$2,900	
Geotechnical Sub-Total Cost						**$2,900**	
Property Requirements	1.0%					$ 5,800	
Property Requirements Sub-Total						**$5,800**	
Consultant Engineering/Design	15%					$ 86,400	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$86,400**	
In House Labour/Engineering/Wages/CA	8%					$ 46,100	
In-house Labour/Wages Sub-Total						**$46,100**	
Project Contingency	10%					$72,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$72,000**	
Non-Refundable HST	1.76%					$13,100	
Non-Refundable HST Sub-Total						**$13,100**	
Total (2020 Dollars)						**$877,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$877,000**	**2020 Estimate**

PROJECT NO.:	**SW-PD-005**	**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Balmoral-Powerline Northwest Area (Pond #5)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Balmoral-Powerline Northwest Area

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Balmoral-Powerline Northwest Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	25 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	2.5 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 5 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	2.5 ha	$100,000	$250,000	
Maintenance Roads & Side Slopes	20%					$50,000	
Additional Construction Costs	10%		ea.			$30,000	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$30,000	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$360,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$1,800	
Geotechnical Sub-Total Cost						**$1,800**	
Property Requirements	1.0%					$ 3,600	
Property Requirements Sub-Total						**$3,600**	
Consultant Engineering/Design	15%					$ 54,000	Includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$54,000**	
In House Labour/Engineering/Wages/CA	8%					$ 28,800	
In-house Labour/Wages Sub-Total						**$28,800**	
Project Contingency	10%					$45,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$45,000**	
Non-Refundable HST	1.76%					$8,200	
Non-Refundable HST Sub-Total						**$8,200**	
Total (2020 Dollars)						**$576,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$576,000**	**2020 Estimate**

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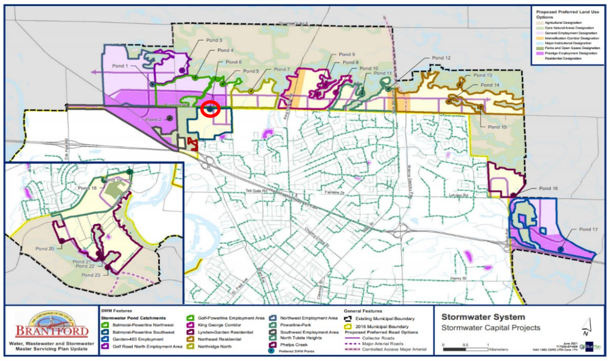
PROJECT NO.:	**SW-PD-006**	**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Balmoral-Powerline Southwest Area (Pond #6)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Balmoral-Powerline Southwest Area

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Balmoral-Powerline Southwest Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	19 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	1.9 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 5 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	1.9 ha	$100,000	$190,000	
Maintenance Roads & Side Slopes	20%					$38,000	
Additional Construction Costs	10%		ea.			$22,800	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$22,800	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$274,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$1,400	
Geotechnical Sub-Total Cost						**$1,400**	
Property Requirements	1.0%					$ 2,700	
Property Requirements Sub-Total						**$2,700**	
Consultant Engineering/Design	15%					$ 41,100	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$41,100**	
In House Labour/Engineering/Wages/CA	8%					$ 21,900	
In-house Labour/Wages Sub-Total						**$21,900**	
Project Contingency	10%					$34,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$34,000**	
Non-Refundable HST	1.76%					$6,200	
Non-Refundable HST Sub-Total						**$6,200**	
Total (2020 Dollars)						**$456,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$456,000**	**2020 Estimate**

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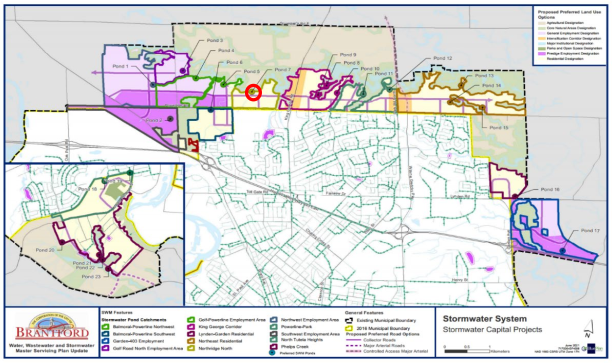
PROJECT NO.:	**SW-PD-007**		**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Northridge North Area (Pond #7)**		**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks		**DATE UPDATED:**	
			UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Northridge North Area

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Northridge North Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	14 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	1.4 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 5 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	1.4 ha	$100,000	$140,000	
Maintenance Roads & Side Slopes	20%					$28,000	
Additional Construction Costs	10%		ea.			$16,800	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$16,800	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$202,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$1,000	
Geotechnical Sub-Total Cost						**$1,000**	
Property Requirements	1.0%					$ 2,000	
Property Requirements Sub-Total						**$2,000**	
Consultant Engineering/Design	15%					$ 30,300	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$30,300**	
In House Labour/Engineering/Wages/CA	8%					$ 16,200	
In-house Labour/Wages Sub-Total						**$16,200**	
Project Contingency	10%					$25,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$25,000**	
Non-Refundable HST	1.76%					$4,600	
Non-Refundable HST Sub-Total						**$4,600**	
Total (2020 Dollars)						**$356,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$356,000**	**2020 Estimate**

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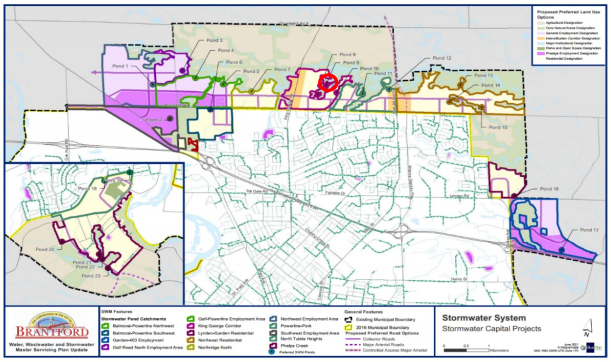
PROJECT NO.:	**SW-PD-008**	**CAPITAL BUDGET YEAR:**	**0-10 Years**
PROJECT NAME:	**King George Corridor (Pond #8)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: King George Corridor

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the King George Corridor of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	16 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	1.6 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 10 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	1.6 ha	$100,000	$160,000	
Maintenance Roads & Side Slopes	20%					$32,000	
Additional Construction Costs	10%		ea.			$19,200	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$19,200	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$230,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$1,200	
Geotechnical Sub-Total Cost						**$1,200**	
Property Requirements	1.0%					$ 2,300	
Property Requirements Sub-Total						**$2,300**	
Consultant Engineering/Design	15%					$ 34,500	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$34,500**	
In House Labour/Engineering/Wages/CA	8%					$ 18,400	
In-house Labour/Wages Sub-Total						**$18,400**	
Project Contingency	10%					$29,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$29,000**	
Non-Refundable HST	1.76%					$5,200	
Non-Refundable HST Sub-Total						**$5,200**	
Total (2020 Dollars)						**$396,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$396,000**	**2020 Estimate**

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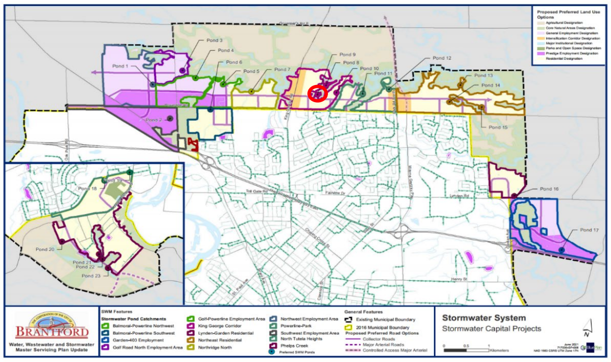
PROJECT NO.:	**SW-PD-009**		**CAPITAL BUDGET YEAR:**	**0-10 Years**
PROJECT NAME:	**King George Corridor (Pond #9)**		**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks		**DATE UPDATED:**	
			UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: King George Corridor

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the King George Corridor of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	10 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	1.0 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 10 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	1.0 ha	$100,000	$100,000	
Maintenance Roads & Side Slopes	20%					$20,000	
Additional Construction Costs	10%		ea.			$12,000	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$12,000	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$144,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$700	
Geotechnical Sub-Total Cost						**$700**	
Property Requirements	1.0%					$ 1,400	
Property Requirements Sub-Total						**$1,400**	
Consultant Engineering/Design	15%					$ 21,600	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$21,600**	
In House Labour/Engineering/Wages/CA	8%					$ 11,500	
In-house Labour/Wages Sub-Total						**$11,500**	
Project Contingency	10%					$18,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$18,000**	
Non-Refundable HST	1.76%					$3,300	
Non-Refundable HST Sub-Total						**$3,300**	
Total (2020 Dollars)						**$276,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$276,000**	**2020 Estimate**

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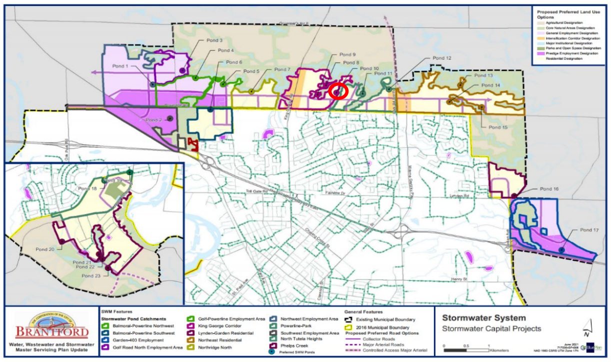
PROJECT NO.:	**SW-PD-010**		**CAPITAL BUDGET YEAR:**	**10-20 Years**
PROJECT NAME:	**King George Corridor (Pond #10)**		**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks		**DATE UPDATED:**	
			UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: King George Corridor

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the King George Corridor of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	6 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	0.6 ha	**CONSTRUCTION ASSUMPTION:**	Other

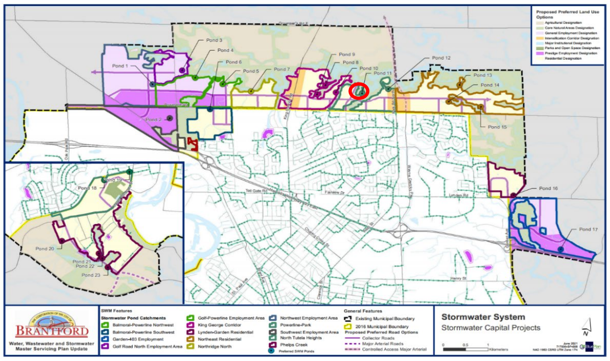
Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			10 - 20 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	0.6 ha	$100,000	$60,000	
Maintenance Roads & Side Slopes	20%					$12,000	
Additional Construction Costs	10%		ea.			$7,200	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$7,200	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$86,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$400	
Geotechnical Sub-Total Cost						**$400**	
Property Requirements	1.0%					$ 900	
Property Requirements Sub-Total						**$900**	
Consultant Engineering/Design	15%					$ 12,900	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$12,900**	
In House Labour/Engineering/Wages/CA	8%					$ 6,900	
In-house Labour/Wages Sub-Total						**$6,900**	
Project Contingency	10%					$11,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$11,000**	
Non-Refundable HST	1.76%					$2,000	
Non-Refundable HST Sub-Total						**$2,000**	
Total (2020 Dollars)						**$195,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$195,000**	**2020 Estimate**

PROJECT NO.:	SW-PD-011	CAPITAL BUDGET YEAR:	10-20 Years
PROJECT NAME:	Powerline-Park (Pond #11)	VERSION:	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	DATE UPDATED:	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Powerline-Park

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Powerline-Park area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	Stormwater Management Study EA
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	7 ML	CLASS EA REQUIREMENTS:	B
ESTIMATED AREA (HA):	0.7 ha	CONSTRUCTION ASSUMPTION:	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			10 - 20 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	0.7 ha	$100,000	$70,000	
Maintenance Roads & Side Slopes	20%					$14,000	
Additional Construction Costs	10%		ea.			$8,400	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$8,400	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$101,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$500	
Geotechnical Sub-Total Cost						**$500**	
Property Requirements	1.0%					$ 1,000	
Property Requirements Sub-Total						**$1,000**	
Consultant Engineering/Design	15%					$ 15,200	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$15,200**	
In House Labour/Engineering/Wages/CA	8%					$ 8,100	
In-house Labour/Wages Sub-Total						**$8,100**	
Project Contingency	10%					$13,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$13,000**	
Non-Refundable HST	1.76%					$2,300	
Non-Refundable HST Sub-Total						**$2,300**	
Total (2020 Dollars)						**$216,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$216,000**	**2020 Estimate**

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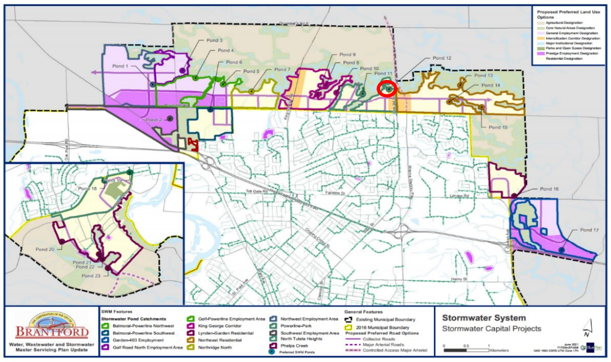
PROJECT NO.:	**SW-PD-012**	**CAPITAL BUDGET YEAR:**	**10-20 Years**
PROJECT NAME:	**Powerline-Park (Pond #12)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Powerline-Park

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Powerline-Park area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	13 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	1.3 ha	**CONSTRUCTION ASSUMPTION:**	Other

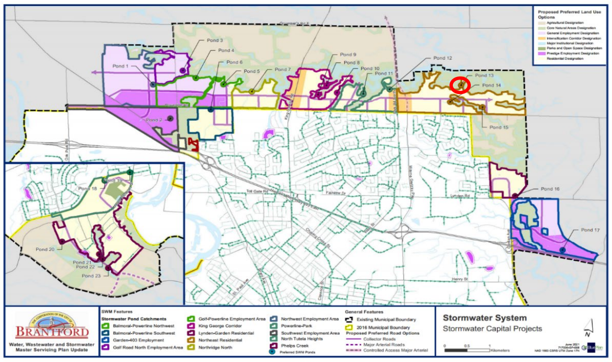
Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			10 - 20 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	1.3 ha	$100,000	$130,000	
Maintenance Roads & Side Slopes	20%					$26,000	
Additional Construction Costs	10%		ea.			$15,600	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$15,600	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$187,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$900	
Geotechnical Sub-Total Cost						**$900**	
Property Requirements	1.0%					$ 1,900	
Property Requirements Sub-Total						**$1,900**	
Consultant Engineering/Design	15%					$ 28,100	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$28,100**	
In House Labour/Engineering/Wages/CA	8%					$ 15,000	
In-house Labour/Wages Sub-Total						**$15,000**	
Project Contingency	10%					$23,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$23,000**	
Non-Refundable HST	1.76%					$4,200	
Non-Refundable HST Sub-Total						**$4,200**	
Total (2020 Dollars)						**$335,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$335,000**	**2020 Estimate**

PROJECT NO.:	**SW-PD-013**	**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Northeast Residential Area (Pond #13)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Northeast Residential

PROJECT DESCRIPTION:
Design and construct stormwater management pond to support development within the Northeast Residential Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	13 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	1.3 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 5 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	1.3 ha	$100,000	$130,000	
Maintenance Roads & Side Slopes	20%					$26,000	
Additional Construction Costs	10%		ea.			$15,600	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$15,600	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$187,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$900	
Geotechnical Sub-Total Cost						**$900**	
Property Requirements	1.0%					$ 1,900	
Property Requirements Sub-Total						**$1,900**	
Consultant Engineering/Design	15%					$ 28,100	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$28,100**	
In House Labour/Engineering/Wages/CA	8%					$ 15,000	
In-house Labour/Wages Sub-Total						**$15,000**	
Project Contingency	10%					$23,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$23,000**	
Non-Refundable HST	1.76%					$4,200	
Non-Refundable HST Sub-Total						**$4,200**	
Total (2020 Dollars)						**$335,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$335,000**	**2020 Estimate**

City of Brantford
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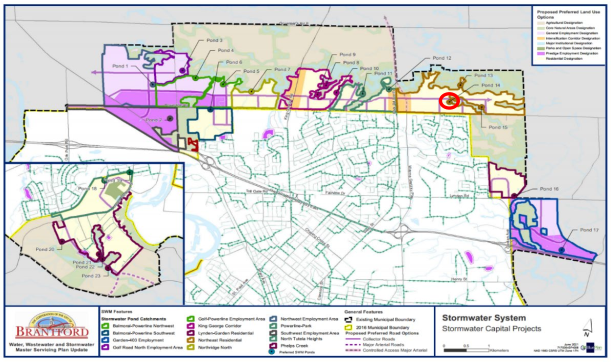
Stormwater Capital Program

PROJECT NO.:	**SW-PD-014**	**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Northeast Residential Area (Pond #14)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Northeast Residential

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Northeast Residential Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	22 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	2.2 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 5 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	2.2 ha	$100,000	$220,000	
Maintenance Roads & Side Slopes	20%					$44,000	
Additional Construction Costs	10%		ea.			$26,400	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$26,400	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$317,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$1,600	
Geotechnical Sub-Total Cost						**$1,600**	
Property Requirements	1.0%					$ 3,200	
Property Requirements Sub-Total						**$3,200**	
Consultant Engineering/Design	15%					$ 47,600	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$47,600**	
In House Labour/Engineering/Wages/CA	8%					$ 25,400	
In-house Labour/Wages Sub-Total						**$25,400**	
Project Contingency	10%					$39,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$39,000**	
Non-Refundable HST	1.76%					$7,200	
Non-Refundable HST Sub-Total						**$7,200**	
Total (2020 Dollars)						**$516,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$516,000**	**2020 Estimate**

City of Brantford
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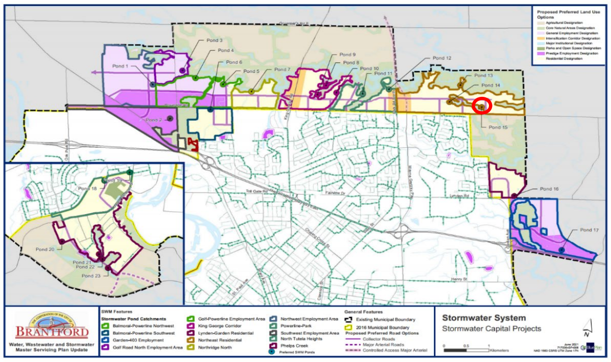
Stormwater Capital Program

PROJECT NO.:	**SW-PD-015**	**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Northeast Residential Area (Pond #15)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Northeast Residential

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Northeast Residential Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	9 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	0.9 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 5 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	0.9 ha	$100,000	$90,000	
Maintenance Roads & Side Slopes	20%					$18,000	
Additional Construction Costs	10%		ea.			$10,800	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$10,800	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$130,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$700	
Geotechnical Sub-Total Cost						**$700**	
Property Requirements	1.0%					$ 1,300	
Property Requirements Sub-Total						**$1,300**	
Consultant Engineering/Design	15%					$ 19,500	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$19,500**	
In House Labour/Engineering/Wages/CA	8%					$ 10,400	
In-house Labour/Wages Sub-Total						**$10,400**	
Project Contingency	10%					$16,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$16,000**	
Non-Refundable HST	1.76%					$2,900	
Non-Refundable HST Sub-Total						**$2,900**	
Total (2020 Dollars)						**$256,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$256,000**	**2020 Estimate**

City of Brantford
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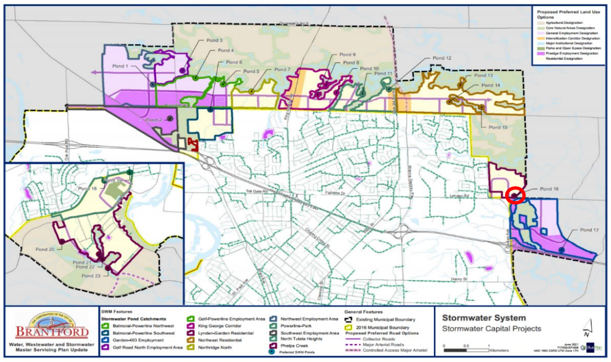
Stormwater Capital Program

PROJECT NO.:	**SW-PD-016**		**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Lynden-Garden Residential Area (Pond #16)**		**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks		**DATE UPDATED:**	
			UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Lynden-Garden Residential

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Lynden-Garden Residential Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	15 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	1.5 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

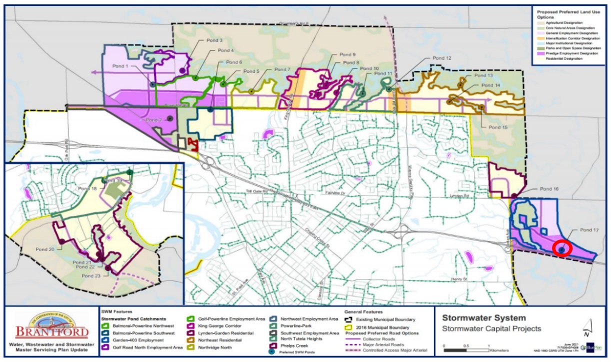
GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 5 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	1.5 ha	$100,000	$150,000	
Maintenance Roads & Side Slopes	20%					$30,000	
Additional Construction Costs	10%		ea.			$18,000	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$18,000	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$216,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$1,100	
Geotechnical Sub-Total Cost						**$1,100**	
Property Requirements	1.0%					$ 2,200	
Property Requirements Sub-Total						**$2,200**	
Consultant Engineering/Design	15%					$ 32,400	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$32,400**	
In House Labour/Engineering/Wages/CA	8%					$ 17,300	
In-house Labour/Wages Sub-Total						**$17,300**	
Project Contingency	10%					$27,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$27,000**	
Non-Refundable HST	1.76%					$4,900	
Non-Refundable HST Sub-Total						**$4,900**	
Total (2020 Dollars)						**$376,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$376,000**	**2020 Estimate**

City of Brantford
Water, Wastewater, and Stormwater Master Servicing Plan Update - 2051 Amendment
Stormwater Capital Program

PROJECT NO.:	SW-PD-017	CAPITAL BUDGET YEAR:	0-10 Years
PROJECT NAME:	Garden-403 Employment Area (Pond #17)	VERSION:	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	DATE UPDATED:	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Garden-403 Employment

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Garden-403 Employment Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	Stormwater Management Study EA
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	72 ML	CLASS EA REQUIREMENTS:	B
ESTIMATED AREA (HA):	7.2 ha	CONSTRUCTION ASSUMPTION:	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			5 - 10 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	7.2 ha	$100,000	$720,000	
Maintenance Roads & Side Slopes	20%					$144,000	
Additional Construction Costs	10%		ea.			$86,400	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$86,400	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$1,037,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$5,200	
Geotechnical Sub-Total Cost						**$5,200**	
Property Requirements	1.0%					$ 10,400	
Property Requirements Sub-Total						**$10,400**	
Consultant Engineering/Design	15%					$ 155,600	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$155,600**	
In House Labour/Engineering/Wages/CA	8%					$ 83,000	
In-house Labour/Wages Sub-Total						**$83,000**	
Project Contingency	10%					$129,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$129,000**	
Non-Refundable HST	1.76%					$23,500	
Non-Refundable HST Sub-Total						**$23,500**	
Total (2020 Dollars)						**$1,519,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$1,519,000**	**2020 Estimate**

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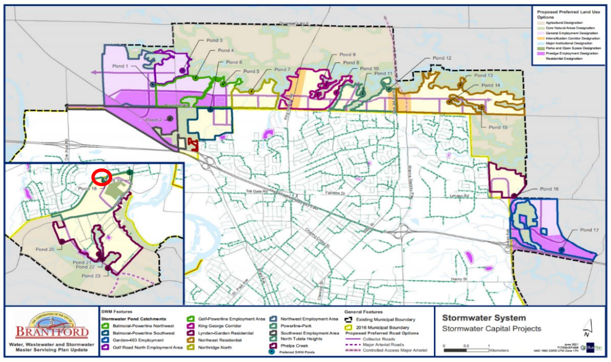
PROJECT NO.:	**SW-PD-018**	**CAPITAL BUDGET YEAR:**	**0-5 Years**
PROJECT NAME:	**Tutela Heights North Area (Pond #18)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Tutela Heights North

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Tutela Heights North Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES: **Stormwater Management Study EA**

STUDY SCOPE: The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.

OBJECTIVES: Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	17 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	1.7 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 5 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	1.7 ha	$100,000	$170,000	
Maintenance Roads & Side Slopes	20%					$34,000	
Additional Construction Costs	10%		ea.			$20,400	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$20,400	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$245,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$1,200	
Geotechnical Sub-Total Cost						**$1,200**	
Property Requirements	1.0%					$ 2,500	
Property Requirements Sub-Total						**$2,500**	
Consultant Engineering/Design	15%					$ 36,800	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$36,800**	
In House Labour/Engineering/Wages/CA	8%					$ 19,600	
In-house Labour/Wages Sub-Total						**$19,600**	
Project Contingency	10%					$31,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$31,000**	
Non-Refundable HST	1.76%					$5,600	
Non-Refundable HST Sub-Total						**$5,600**	
Total (2020 Dollars)						**$417,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$417,000**	**2020 Estimate**

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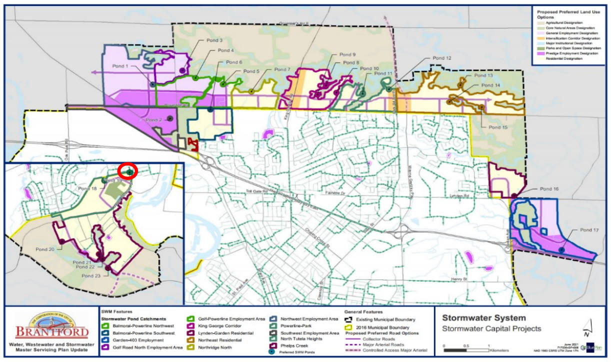
PROJECT NO.:	SW-PD-019	CAPITAL BUDGET YEAR:	0-5 Years
PROJECT NAME:	Tutela Heights North Area (Pond #19)	VERSION:	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	DATE UPDATED:	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Tutela Heights North

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Tutela Heights North Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	Stormwater Management Study EA
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	9 ML	CLASS EA REQUIREMENTS:	B
ESTIMATED AREA (HA):	0.9 ha	CONSTRUCTION ASSUMPTION:	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			0 - 5 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	0.9 ha	$100,000	$90,000	
Maintenance Roads & Side Slopes	20%					$18,000	
Additional Construction Costs	10%		ea.			$10,800	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$10,800	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$130,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$700	
Geotechnical Sub-Total Cost						**$700**	
Property Requirements	1.0%					$ 1,300	
Property Requirements Sub-Total						**$1,300**	
Consultant Engineering/Design	15%					$ 19,500	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$19,500**	
In House Labour/Engineering/Wages/CA	8%					$ 10,400	
In-house Labour/Wages Sub-Total						**$10,400**	
Project Contingency	10%					$16,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$16,000**	
Non-Refundable HST	1.76%					$2,900	
Non-Refundable HST Sub-Total						**$2,900**	
Total (2020 Dollars)						**$256,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$256,000**	**2020 Estimate**

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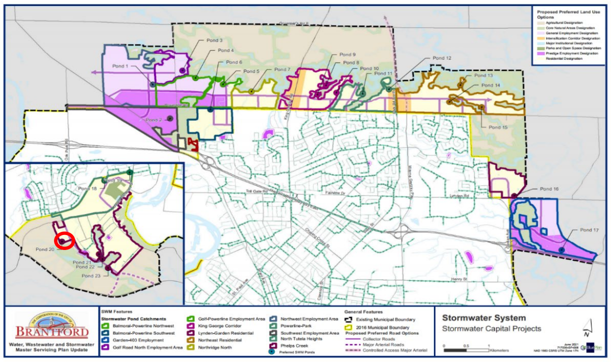
PROJECT NO.:	**SW-PD-020**	**CAPITAL BUDGET YEAR:**	**10-20 Years**
PROJECT NAME:	**Phelps Creek Area (Pond #20)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Phelps Creek

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Phelps Creek Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	4 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	0.4 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			10 - 20 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	0.4 ha	$100,000	$40,000	
Maintenance Roads & Side Slopes	20%					$8,000	
Additional Construction Costs	10%		ea.			$4,800	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$4,800	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$58,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$300	
Geotechnical Sub-Total Cost						**$300**	
Property Requirements	1.0%					$ 600	
Property Requirements Sub-Total						**$600**	
Consultant Engineering/Design	15%					$ 8,700	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$8,700**	
In House Labour/Engineering/Wages/CA	8%					$ 4,600	
In-house Labour/Wages Sub-Total						**$4,600**	
Project Contingency	10%					$7,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$7,000**	
Non-Refundable HST	1.76%					$1,300	
Non-Refundable HST Sub-Total						**$1,300**	
Total (2020 Dollars)						**$156,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$156,000**	**2020 Estimate**

City of Brantford
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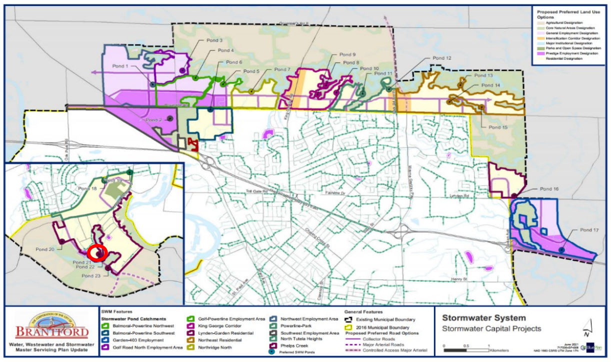
PROJECT NO.:	**SW-PD-021**	**CAPITAL BUDGET YEAR:**	**10-20 Years**
PROJECT NAME:	**Phelps Creek Area (Pond #21)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Phelps Creek

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Phelps Creek Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	12 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	1.2 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			10 - 20 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	1.2 ha	$100,000	$120,000	
Maintenance Roads & Side Slopes	20%					$24,000	
Additional Construction Costs	10%		ea.			$14,400	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$14,400	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$173,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$900	
Geotechnical Sub-Total Cost						**$900**	
Property Requirements	1.0%					$ 1,700	
Property Requirements Sub-Total						**$1,700**	
Consultant Engineering/Design	15%					$ 26,000	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$26,000**	
In House Labour/Engineering/Wages/CA	8%					$ 13,800	
In-house Labour/Wages Sub-Total						**$13,800**	
Project Contingency	10%					$22,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$22,000**	
Non-Refundable HST	1.76%					$3,900	
Non-Refundable HST Sub-Total						**$3,900**	
Total (2020 Dollars)						**$316,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$316,000**	**2020 Estimate**

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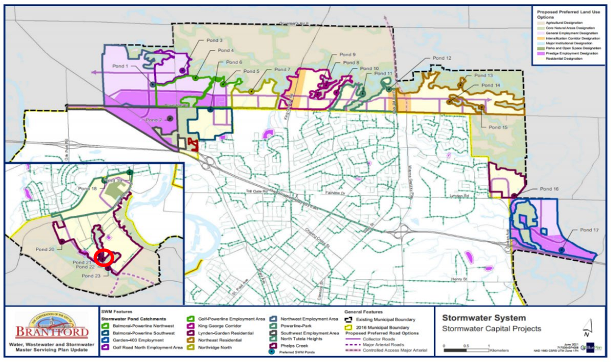
PROJECT NO.:	**SW-PD-022**	**CAPITAL BUDGET YEAR:**	**10-20 Years**
PROJECT NAME:	**Phelps Creek Area (Pond #22)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Phelps Creek

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Phelps Creek Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	19 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	1.9 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			10 - 20 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	1.9 ha	$100,000	$190,000	
Maintenance Roads & Side Slopes	20%					$38,000	
Additional Construction Costs	10%		ea.			$22,800	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$22,800	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$274,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$1,400	
Geotechnical Sub-Total Cost						**$1,400**	
Property Requirements	1.0%					$ 2,700	
Property Requirements Sub-Total						**$2,700**	
Consultant Engineering/Design	15%					$ 41,100	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$41,100**	
In House Labour/Engineering/Wages/CA	8%					$ 21,900	
In-house Labour/Wages Sub-Total						**$21,900**	
Project Contingency	10%					$34,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$34,000**	
Non-Refundable HST	1.76%					$6,200	
Non-Refundable HST Sub-Total						**$6,200**	
Total (2020 Dollars)						**$456,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$456,000**	**2020 Estimate**

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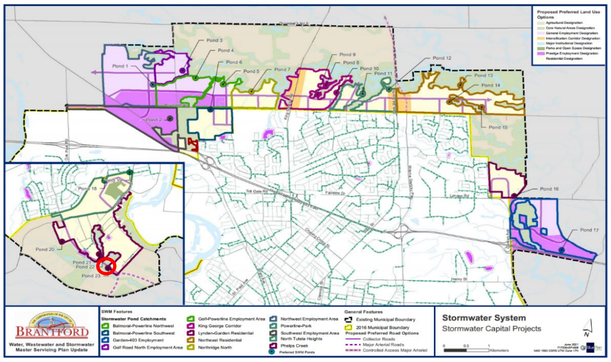
PROJECT NO.:	**SW-PD-023**	**CAPITAL BUDGET YEAR:**	**10-20 Years**
PROJECT NAME:	**Phelps Creek Area (Pond #23)**	**VERSION:**	
PROJECT OVERVIEW:	Developer driven stormwater management pond based on planning blocks	**DATE UPDATED:**	
		UPDATED BY:	

MAP



STORMWATER SUBCATCHMENT: Phelps Creek

PROJECT DESCRIPTION:

Design and construct stormwater management pond to support development within the Phelps Creek Area of the Expansion Lands.

NOTE: For costing purposes, the average pond depth was assumed to be one (1) meter deep.

REQUIRED STUDIES:	**Stormwater Management Study EA**
STUDY SCOPE:	The study will be a Schedule 'B' project in accordance with all requirements of the Municipal Class Environmental Assessment.
OBJECTIVES:	Determine the required pond size and contributing areas for the pond located north of Powerline Road.

CONSTRUCTION

Class Estimate Type:	Class 4	Class adjusts Construction Contingency and expected accuracy
Project Complexity	Low	Complexity adjusts Construction Contingency, and expected accuracy
Accuracy Range:	30%	
Area Condition:	Rural	Area Condition uplifts unit cost and restoration

ESTIMATED ACTIVE STORAGE (ML):	6 ML	**CLASS EA REQUIREMENTS:**	B
ESTIMATED AREA (HA):	0.6 ha	**CONSTRUCTION ASSUMPTION:**	Other

Note: Estimated area (ha) accounts for maintenance road area and contingencies

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Study Cost							
Study	Stormwater Management Study EA			10 - 20 yrs	$75,000	$75,000	
Sub-Total Study Costs						**$75,000**	
High-Level Planning Cost							
Pond Construction			ha	0.6 ha	$100,000	$60,000	
Maintenance Roads & Side Slopes	20%					$12,000	
Additional Construction Costs	10%		ea.			$7,200	Includes connections, inspection, signage, traffic management, bonding, insurance
Provisional & Allowance	10%		ea.			$7,200	Provisional Labour and Materials in addition to base construction cost
Sub-Total Construction Base Costs						**$86,000**	
Geotechnical / Hydrogeological / Materials	0.5%					$400	
Geotechnical Sub-Total Cost						**$400**	
Property Requirements	1.0%					$ 900	
Property Requirements Sub-Total						**$900**	
Consultant Engineering/Design	15%					$ 12,900	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Design Sub-Total						**$12,900**	
In House Labour/Engineering/Wages/CA	8%					$ 6,900	
In-house Labour/Wages Sub-Total						**$6,900**	
Project Contingency	10%					$11,000	Construction Contingency is dependent on Cost Estimate Class and Project Complexity
Project Contingency Sub-Total						**$11,000**	
Non-Refundable HST	1.76%					$2,000	
Non-Refundable HST Sub-Total						**$2,000**	
Total (2020 Dollars)						**$195,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$195,000**	**2020 Estimate**

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PROJECT NO.:	SW-SD-001	TIMELINE:	0-5 Years
PROJECT NAME:	City-Wide Asset Inventory	VERSION:	
PROJECT OVERVIEW:	Asset inventory for City owned stormwater assets	DATE UPDATED:	
		UPDATED BY:	
PROJECT DESCRIPTION:	Complete fieldwork required to quantify all stormwater assets within the City of Brantford. Includes data collection, data analysis (clean-up), and reporting to meet requirements of Ontario Regulation 588/17. See Implementation Plan for preceding studies/works required..		

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Fieldwork/Component Cost							
LiDAR City Right-of-Way (Aerial)				0 - 5 yrs	$75,000	$75,000	
Rural Ditch Survey				0 - 5 yrs	$0	$0	Recently Completed
GIS Inventory Update				0 - 5 yrs	$100,000	$100,000	
Existing Infrastructure Survey and Condition Assessment				0 - 5 yrs	$0	$0	Completed through other ongoing City initiatives
Sub-Total Fieldwork/Component Base Costs						**$175,000**	
Consultant Engineering/Reporting						$ 100,000	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Reporting-Total						**$100,000**	
Project Contingency	15%					$41,000	Construction Contingency is dependent on Project Complexity
Project Contingency Sub-Total						**$41,000**	
Non-Refundable HST	1.76%					$5,600	
Non-Refundable HST Sub-Total						**$5,600**	
Total (2020 Dollars)						**$322,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$322,000**	**2020 Estimate**

City of Brantford
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PROJECT NO.:	**SW-SD-002**	**TIMELINE:**	**0-5 Years**
PROJECT NAME:	**Continuous Water Quality & Flow Monitoring and Reporting**	**VERSION:**	
PROJECT OVERVIEW:	Continuous water quality & flow monitoring in existing system with strategic locations selected	**DATE UPDATED:**	
		UPDATED BY:	
PROJECT DESCRIPTION:	Continued planning of flow monitoring locations and fieldwork required for continuous WQ & flow monitoring. Includes consulting required to determine strategic locations. See Implementation Plan for preceding studies/works required.		

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Fieldwork/Component Cost							
Continuous WQ & Flow Monitoring				Annual (20 yrs)	$250,000	$5,000,000	Flow monitoring and water quality monitoring
Sub-Total Fieldwork/Component Base Costs						**$5,000,000**	
Consultant Engineering/Reporting						$ 50,000	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Reporting-Total						**$50,000**	
Project Contingency	15%					$758,000	Construction Contingency is dependent on Project Complexity
Project Contingency Sub-Total						**$758,000**	
Non-Refundable HST	1.76%					$102,200	
Non-Refundable HST Sub-Total						**$102,200**	
Total (2020 Dollars)						**$5,910,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$5,910,000**	**2020 Estimate**

City of Brantford
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PROJECT NO.:	**SW-SD-003**	**TIMELINE:**	**0-5 Years**
PROJECT NAME:	**Stormwater Model Update**	**VERSION:**	
PROJECT OVERVIEW:	Update stormwater infrastructure model to represent knew information	**DATE UPDATED:**	
		UPDATED BY:	
PROJECT DESCRIPTION:	Update the City stormwater model to include new information from flow monitoring programs, asset inventories, and new storm/Conservation Authority information. See Implementation Plan for preceding studies/works required..		

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Fieldwork/Component Cost							
Stormwater Model Build Update and Calibration				0 - 5 yrs	$267,000	$267,000	
Sub-Total Fieldwork/Component Base Costs						**$267,000**	
Consultant Engineering/Reporting						$ 50,000	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Reporting-Total						**$50,000**	
Project Contingency	15%					$48,000	Construction Contingency is dependent on Project Complexity
Project Contingency Sub-Total						**$48,000**	
Non-Refundable HST	1.76%					$6,400	
Non-Refundable HST Sub-Total						**$6,400**	
Total (2020 Dollars)						**$371,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$371,000**	**2020 Estimate**

City of Brantford

Water, Wastewater, and Stormwater Master Servicing Plan Update - 2051 Amendment

Stormwater Capital Program

PROJECT NO.:	**SW-SD-004**	**TIMELINE:**	**0-5 Years**
PROJECT NAME:	**Dike System Outlet Program**	**VERSION:**	
PROJECT OVERVIEW:	Program to optimize use of dike system with existing stormwater system	**DATE UPDATED:**	
		UPDATED BY:	
PROJECT DESCRIPTION:	Monitor Grand River dike outlets and perform risk and cost-benefit analysis to determine best solution for dike outlet controls. Will follow Municipal Class EA process. See Implementation Plan for preceding studies/works required..		

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Fieldwork/Component Cost							
Dike Outlet Municipal EA				0 - 5 yrs	$300,000	$300,000	
Sub-Total Fieldwork/Component Base Costs						**$300,000**	
Consultant Engineering/Reporting						$ 75,000	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Reporting-Total						**$75,000**	
Project Contingency	15%					$56,000	Construction Contingency is dependent on Project Complexity
Project Contingency Sub-Total						**$56,000**	
Non-Refundable HST	1.76%					$7,600	
Non-Refundable HST Sub-Total						**$7,600**	
Total (2020 Dollars)						**$439,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$439,000**	**2020 Estimate**

City of Brantford
Water, Wastewater, and Stormwater Master Servicing Plan Update - 2051 Amendment
Stormwater Capital Program

PROJECT NO.:	**SW-SD-005**	**TIMELINE:**	**0-5 Years**
PROJECT NAME:	**Update Subwatershed Studies**	**VERSION:**	
PROJECT OVERVIEW:	Update Subwatershed Studies to account for new information collected through new developments and City collected data.	**DATE UPDATED:**	
		UPDATED BY:	
PROJECT DESCRIPTION:	Scope will be Phase 2 of 2020 North Brantford and Tutela Heights Subwatershed Study. See Implementation Plan for preceding studies/works required.		

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Consultant Engineering/Reporting						$ 1,000,000	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Reporting-Total						**$1,000,000**	
Project Contingency	15%					$150,000	Construction Contingency is dependent on Project Complexity
Project Contingency Sub-Total						**$150,000**	
Non-Refundable HST	1.76%					$20,200	
Non-Refundable HST Sub-Total						**$20,200**	
Total (2020 Dollars)						**$1,170,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$1,170,000**	**2020 Estimate**

City of Brantford
Water, Wastewater, and Stormwater Master Servicing Plan Update - 2051 Amendment
Stormwater Capital Program

PROJECT NO.: SW-SD-006

PROJECT NAME: Climate Change Action Plan and Best Practices Review

PROJECT OVERVIEW: Literature review of best practices for stormwater management, prediction, and mitigation as it applies to climate change.

PROJECT DESCRIPTION: Literature review of best practices for stormwater management, prediction, and mitigation as it applies to climate change. See Implementation Plan for preceding studies/works required..

TIMELINE: 0-5 Years

VERSION:

DATE UPDATED:

UPDATED BY:

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Consultant Engineering/Reporting						$ 100,000	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Reporting-Total						**$100,000**	
Project Contingency	15%					$15,000	Construction Contingency is dependent on Project Complexity
Project Contingency Sub-Total						**$15,000**	
Non-Refundable HST	1.76%					$2,000	
Non-Refundable HST Sub-Total						**$2,000**	
Total (2020 Dollars)						**$117,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$117,000**	**2020 Estimate**

PROJECT NO.: SW-SD-007
PROJECT NAME: Stormwater Master Servicing Plan Update
PROJECT OVERVIEW: Update SW MSP based on recommendations of prior studies.
PROJECT DESCRIPTION: Update SW MSP based on recommendations of prior studies. See Implementation Plan for preceding studies/works required..

TIMELINE: 0-5 Years
VERSION:
DATE UPDATED:
UPDATED BY:

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Consultant Engineering/Reporting						$ 250,000	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Reporting-Total						**$250,000**	
Project Contingency	15%					$38,000	Construction Contingency is dependent on Project Complexity
Project Contingency Sub-Total						**$38,000**	
Non-Refundable HST	1.76%					$5,100	
Non-Refundable HST Sub-Total						**$5,100**	
Total (2020 Dollars)						**$293,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$293,000**	**2020 Estimate**

City of Brantford
Water, Wastewater, and Stormwater Master Servicing Plan Update - 2051 Amendment
Stormwater Capital Program

PROJECT NO.:	**SW-SD-008**	**TIMELINE:**	**0-5 Years**
PROJECT NAME:	**Stormwater Rate Review**	**VERSION:**	
PROJECT OVERVIEW:	Determine stormwater user charge	**DATE UPDATED:**	
		UPDATED BY:	
PROJECT DESCRIPTION:	Review funding sources and feasibility of stormwater user rate.		

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION		TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Consultant Engineering/Reporting					$ 100,000	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Reporting-Total					**$100,000**	
Project Contingency	15%				$15,000	Construction Contingency is dependent on Project Complexity
Project Contingency Sub-Total					**$15,000**	
Non-Refundable HST	1.76%				$2,000	
Non-Refundable HST Sub-Total					**$2,000**	
Total (2020 Dollars)					**$117,000**	Rounded to nearest $1,000
Other Estimate						
Chosen Estimate					**$117,000**	**2020 Estimate**

City of Brantford
Water, Wastewater, and Stormwater Master Servicing Plan Update - 2051 Amendment
Stormwater Capital Program

PROJECT NO.: **SW-SD-009**
TIMELINE: **0-5 Years**

PROJECT NAME: **Stormwater Policy Review and Update**
VERSION:

PROJECT OVERVIEW: Review City stormwater policies and update per MSP and City study recommendations
DATE UPDATED:

UPDATED BY:

PROJECT DESCRIPTION: The City's stormwater policies are to be updated to reflect the results of the Stormwater MSP as well as the results of various external studies being completed on behalf of the City.

GENERAL COST ESTIMATION SPREADSHEET

COMPONENT	PROJECT COMPONENT DESCRIPTION			TIMELINE	COST PER UNIT	SUB-TOTAL	COMMENTS
Consultant Engineering/Reporting						$ 120,000	includes planning, pre-design, detailed design, training, CA, commissioning
Engineering/Reporting-Total						**$120,000**	
Project Contingency	15%					$18,000	Construction Contingency is dependent on Project Complexity
Project Contingency Sub-Total						**$18,000**	
Non-Refundable HST	1.76%					$2,400	
Non-Refundable HST Sub-Total						**$2,400**	
Total (2020 Dollars)						**$140,000**	Rounded to nearest $1,000
Other Estimate							
Chosen Estimate						**$140,000**	**2020 Estimate**