Premier Gateway

Scoped Subwatershed Study

Phase 1: Study Area Characterization (Draft)

Town of Halton Hills

Prepared for:

Town of Halton Hills

Prepared by:

Amec Foster Wheeler Environment & Infrastructure

3215 North Service Road

Burlington, ON L7N 3G2

(905) 335-2353

February 2016

Project No. TP115042

Premier Gateway
Scoped Subwatershed Study
Phase 1: Study Area Characterization (Draft)

Town of Halton Hills

Submitted to:

Town of Halton Hills

Submitted by:

Amec Foster Wheeler Environment & Infrastructure
3215 North Service Road
Burlington, ON L7N 3G2

Tel: (905) 335-2353
Fax: (905) 335-1414

February 2016

TP115042

TABLE OF CONTENTS

PAGE

LIST OF APPENDICES

1.0 INTRODUCTION

The Premier Gateway Lands lie at the southern limit of the Town of Halton Hills, and are generally bounded by Highway 401 to the south and agricultural lands to the north, between Eighth Line to the east and Sixth Line to the west. The study area lies within the Sixteen Mile Creek Watershed which generally flows southeast from the headwaters near Highway 7 to its outlet at Lake Ontario. The watershed contains three drainage basins (i.e. West branch, Middle and East Branches; and downstream reaches below the confluence of the two (2) upper drainage basins (Gore & Storrie. 1996), encompassing nine (9) subwatersheds.

1.1 Study Overview and Team

In 2015, the Town of Halton Hills initiated the Premier Gateway Phase 1B Employment Area Integrated Planning Project. This Project represents an integrated planning project that involves both secondary planning and subwatershed planning.

The Scoped Subwatershed Study fulfills the subwatershed planning component of the overall Project, and comprises the following:

i) Study Area Characterization
ii) Impact Assessment
iii) Preliminary Recommendations of Preferred Management Measures and Requirements for Future Studies

The Scoped Subwatershed Study is being completed under the guidance of a Technical Advisory Committee (SWTAC), which includes representatives from the Town, the Region, and Conservation Halton. The SWTAC has provided background information for use and reference in this study (ref. Appendix A), as well as technical review and input to the study findings.

The following individuals represent the principal authors and discipline leads for this study:

Ron Scheckenberger (Amec Foster Wheeler): Project Manager
Aaron Farrell (Amec Foster Wheeler): Hydrology / Hydraulics and Water Quality
Katharina Richter (Natural Resources Solutions Inc.): Terrestrial and Aquatic Ecology
Bill Blackport (Blackport and Associates): Groundwater
Tatiana Hrytsak (Parish Aquatic Services): Fluvial Geomorphology

1.2 Environmental Assessment Act Requirements

The Scoped Subwatershed Study component of the Integrated Planning Project incorporates the fundamental principles of the Municipal Engineers Association (MEA) Class Environmental Assessment process. The information developed through the subwatershed planning process satisfies Phases 1 and 2 of the MEA Class Environmental Assessment process. The Work Plan for the Scoped Subwatershed Study includes consultation with regulators, area land owners, and the general public. Consideration of other technical disciplines (i.e. area servicing, transportation, etc.) is fully integrated with the overall land use planning study.

1.3 Report Overview

This report summarizes the methodologies and results of the Study Area Characterization component of the Scoped Subwatershed Study. The information presented in Section 2 of this report provides the detailed methodologies and findings, and has been organized and presented according to the following core study disciplines:

- Terrestrial Ecology
- Aquatic Ecology
- Hydrogeology
- Hydrology/Hydraulics
- Stream Morphology
- Water Quality

Section 3 of this report provides an overview of the study integration, primarily with respect to the Study Area Characterization, as well as the general process to be applied in establishing the preliminary management plan. Section 4 summarizes the requirements to complete the Study Area Characterization, and proceed into the land use planning and impact assessment.

2.0 BASELINE INVENTORY

2.1 Natural Environment Existing Conditions

2.1.1 Scope Overview

Natural Resource Solutions Inc. (NRSI) has conducted the biological surveys and characterization of the natural heritage features within the study area. The Secondary Plan area, which represents the subject area, consists of rural residential areas along the major roads, industrial and commercial lands, agricultural fields, the Hornby Glen Golf Course, and natural areas (ref. Drawing E1). The natural features consist of woodlands, wetlands, watercourses, and areas designated as Regional Natural Heritage System. The provincial Greenbelt borders the southwest portion of the subject area (Drawing E1). The largest woodland within the study area is a Regional Forest, known as the Coulson Tract. The Region of Halton owns and manages its forests as recreational and natural spaces (Halton 2015).

This section of the report documents the characterization of the existing natural heritage features within the Secondary Plan area and its environs (i.e. the study area) based on the results of the background review and original field surveys including breeding birds, mammals, herpetofauna, insects, vascular flora, aquatic habitat, fish community, and benthic invertebrates. This section also identifies natural feature constraints in association with land use policy designations in order to inform the Secondary Plan and land use planning strategy. The subject area is located within Ecoregion 7E.

For the purposes of this report, the term “subject area” refers to the lands identified and described above and shown on Drawing E1. These are the lands contained within the Secondary Plan. The term “study area” refers to the subject area plus the surrounding area (at least 120 m) for which additional information was collected and reviewed (as could be gathered without direct access to these areas). Legacy data collected from agencies and wildlife atlases encompassed an area of approximately 1 km around the property to ensure that all surrounding natural features were considered.

2.1.2 Background Information Review

For the purposes of the natural environment characterization for Premier Gateway, information on the natural heritage features within the study area was collected and assessed for significance. To help inform suitable land-use concepts and identify areas to be protected, these features have been evaluated against the following relevant policies, legislation, and planning studies (reference Table 2.1.1).

Table 2.1.1. Relevant Policies, Legislation and Planning Studies

Policy/Legislation	Description	Project Relevance
Provincial Policy Statement (OMMAH 2014).	▶ Issued under the authority of Section 3 of the Planning Act and came into effect on April 30, 2014, replacing the 2005 PPS (OMMAH 2005). ▶ Section 2.1 of the PPS – Natural Heritage establishes clear direction on the adoption of an ecosystem approach and the protection of resources that have been identified as 'significant'. ▶ The Natural Heritage Reference Manual (OMNR 2010) and the Significant Wildlife Habitat Technical Guide (OMNR 2000, OMNR 2012) were prepared by the MNRF to provide guidance on identifying natural features and in interpreting the Natural Heritage sections of the PPS.	▶ Several natural features are present within the subject area that have implications under the PPS: ▶ Wetlands ▶ Woodlands ▶ Fish Habitat ▶ Significant Wildlife Habitat ▶ Habitat for Endangered and Threatened species
Endangered Species Act	▶ The original ESA, written in 1971, underwent a year-long review which resulted in a number of changes which came into force in 2007. ▶ The ESA prohibits killing, harming, harassing or capturing SAR and protects their habitats from damage and destruction.	▶ Based on a SAR screening and preliminary analysis, SAR were identified as having the potential to occur within the study area based on habitat present. These include birds, amphibians, reptiles, mammals, insects and plants. Several SAR were observed within the subject area.
Canadian Fisheries Act	▶ Manages threats to the sustainability and productivity of Canada's commercial, recreational and Aboriginal fisheries. ▶ The Act prohibits "serious harm to fish" including destruction of habitat. ▶ DFO has developed an online, self-assessment tool, where proponents can determine whether their projects require DFO review based on the type of water body the work is occurring in and the nature of the proposed activity.	▶ Several tributaries to Sixteen Mile Creek are present within the subject area. ▶ The Secondary Plan will have to consider the form and function of these watercourses in its development and land use plan.

Table 2.1.1. Relevant Policies, Legislation and Planning Studies

Policy/Legislation	Description	Project Relevance
Halton Region Official Plan (2014)	▶ The Halton Region Official Plan (HROP) outlines current policies for the protection of natural features within the Region (Halton Region 2014). ▶ It provides a policy framework that protects environmental features, sets out requirements for an Ecological and Environmental Advisory Committee and guidance for preparing Environmental Impact Assessments (EIAs).	▶ Policies speak to the protection of natural features including unique landforms, significant tree-covered areas, woodlands and regionally owned forests, and fish.
Region of Halton Official Plan Amendment No. 38 (2015a)	▶ The Official Plan Amendment incorporates the results of the Sustainable Halton Report, a review of the Official Plan and directions coming from that review, as well as various other matters. ▶ The Regional Natural Heritage System is updated based on the Sustainable Halton Natural Heritage System Reports. Identifies the concept of landscape permanence (i.e. protection of sensitive natural environment, heritage and culture features permanently).	▶ Revisions made to the goal and objectives of the Regional Natural Heritage System ▶ Addition of Significant Woodlands and Significant Wildlife Habitat to the Regional NHS ▶ Addition of Endangered species and Threatened species not included within Regional NHS mapping to the Regional NHS
Sustainable Halton (NSEI 2007, 2009)	▶ Sustainable Halton is a 4 phase process that occurred between 2006 and 2009 and included extensive public and agency consultation. ▶ Phase 1: Building Blocks, included 22 technical background reports that identified principles and priorities to direct future growth ▶ Phase 2: Strategic Planning, identified 9 high level land use concepts, which were narrowed down to 5 refined land use concepts showing the most appropriate locations for new urban growth ▶ Phase 3: Decision Making, included the selection of a preferred growth plan by Halton Regional Council for the period 2021 and 2031. This	▶ Identification and refinement of Regional Natural Heritage System as well as details of policies to protect the Natural Heritage System ▶ Features included in the Natural Heritage System within the study area are: ▶ Core Areas – Woodlands, wetlands, and floodplains ▶ Core and Linkage Enhancement Areas and Buffers ▶ Greenlands A features within the study area: regulated floodplain

Table 2.1.1. Relevant Policies, Legislation and Planning Studies

Policy/Legislation	Description	Project Relevance
Sustainable Halton (NSEI 2007, 2009) continued	included 13 technical background reports, including an evaluation framework to compare and contrast the strengths and weaknesses of the five refined land use concepts, in much greater detail than those in Phase 1 ▶ Phase 4: OPA 38 included the preparation of the Official Plan Amendment to implement the June 2009 Council directions on both the preferred land use plan and the Official Plan Review Directions.	▶ Greenlands B features within the study area: Halton Regional Forests
Regional Municipality of Halton By-Law No. 31-10 – Forest By-law	▶ This By-law outlines permitted and prohibited activities within Halton Regional Forest Tracts ▶ Permitted activities include non-motorized recreational activities ▶ Prohibited activities include bow and shotgun hunting within the Coulson Tract, camping, wood collection, open flames	▶ Coulson Tract, a Regional Forest, is located within the subject area.
Town of Halton Hills Official Plan (2008)	▶ The Town of Halton Hills Official Plan (2008) outlines current policies for the protection of the Town's natural heritage resources. ▶ Detailed policies for the identification and protection of natural features are laid out including significant natural features, the Greenlands System, and Environmentally Sensitive Areas. ▶ The environmental management policies speak to the protection of watercourses, areas susceptible to flooding, hazard lands, trees and woodlands, and habitat for Endangered and Threatened species.	▶ A detailed framework of policies is identified for management of the environmental features within the Town and the interconnection of features on a watershed / ecosystem scale. ▶ Within the subject area this applies to the Natural Heritage System, watercourses, floodplains, hazard lands, woodlands and treed areas, and habitat for Endangered and Threatened species.

Table 2.1.1. Relevant Policies, Legislation and Planning Studies

Policy/Legislation	Description	Project Relevance
Conservation Halton Regulation 162/06	▶ Regulation issued under *Conservation Authorities Act,* R.S.O. 1990. ▶ Through this regulation, the Halton Region Conservation Authority, generally known as Conservation Halton (CH), has the responsibility to regulate activities in natural and hazardous areas (i.e., areas in and near rivers, streams, floodplains, wetlands, and slopes). ▶ The Regulation outlines the requirements for permission to develop on the lands within or adjacent to the "Regulation Limit". Details regarding the application and approval process for development are also laid out in this document.	▶ CH regulates a large portion of the study area as the land is within its regulatory area, primarily associated with the presence of several tributaries to Sixteen Mile Creek and their associated floodplains and hazard lands. ▶ As such, CH is involved in the Subwatershed Study and Secondary Plan to provide input regarding their regulated areas, and appropriate buffers from these areas, where development may occur.
401 Corridor Integrated Planning Project Scoped Subwatershed Study (Dillon Consulting 2000)	▶ A Subwatershed Study encompassing several subwatersheds that include the current study area. ▶ Study includes existing conditions and recommendations for land management and natural areas protection.	▶ Recommendations for protection of natural heritage features and ecological function, including prohibition of incompatible development within and surrounding sensitive natural features, and the implementation of conditions on development within less sensitive areas.

The Terms of Reference for the Scoped Subwatershed Study issued by the Town provided a detailed outline of the study approach. Existing natural heritage information has been gathered and reviewed to identify key natural heritage features and species that are reported from the study area. Background information on the natural environmental features within the study area has been gathered from the Ministry of Natural Resources and Forestry (MNRF) Land Information Ontario (LIO) database, the MNRF Natural Heritage Information Centre (NHIC), Fisheries and Oceans Canada (DFO) Species at Risk (SAR) mapping, Halton Region (2014, 2015a) and Halton Hills (2008) Official Plan documents, and other files gathered from the Town and the Region, as well as Conservation Halton, and relevant taxa-specific databases, as listed below.

Initial wildlife species lists have been compiled to provide information on species reported from the study area and vicinity using various atlases including the Ontario Mammal Atlas (Dobbyn 1994), the Ontario Breeding Bird Atlas (BSC et al. 2006), the Ontario Reptile and Amphibian Atlas

(Ontario Nature 2015), the Ontario Butterfly Atlas (Jones et al. 2013), and the Ontario Odonata Atlas (NHIC 2005). As data from the atlases is based on 10 x 10 km survey squares, information on species from the square that overlaps the study area, was compiled. In the Bird Atlas (BSC et al. 2006), this is square 17NJ92.

Based on these initial species lists, records of SAR and species of Conservation Concern (SCC) have been identified within the vicinity of study area. For the purposes of this report, SAR are defined as species listed as Threatened or Endangered provincially which are afforded protection under the Endangered Species Act. Species of Conservation Concern refer to:

- species designated provincially or nationally as Special Concern,
- species that have been assigned a conservation status (S-Rank) of S1 to S3 or SH by the Natural Heritage Information Centre, and
- species that are designated federally as Threatened or Endangered by the Committee for the Status of Endangered Wildlife in Canada (COSEWIC) but not provincially by the Committee on the Status of Species at Risk in Ontario (COSSARO). These species are protected by the federal Species at Risk Act but not by the provincial Endangered Species Act.

A preliminary screening exercise has been conducted to determine whether there are suitable habitats within the study area for these species, as well as to ensure that the potential presence of all SAR and SCC within the study area was adequately considered and identified. This involved cross-referencing the preferred habitat for reported SAR and SCC (OMNR 2000) against habitats known to occur in the study area. Full results of the SAR and SCC screening are provided in Appendix B. SCC are discussed within the context of Significant Wildlife Habitat (SWH).

A preliminary screening for the presence of SWH has also been completed for the study area. The Significant Wildlife Habitat Technical Guide (SWHTG) is a guidance document that outlines the types of habitats that the MNRF considers significant in Ontario as well as criteria to identify these habitats (OMNR 2000, 2012, MNRF 2015). The SWHTG groups SWH into four broad categories: seasonal concentration areas, rare vegetation communities and specialized wildlife habitat, habitats of species of Conservation Concern, and animal movement corridors. Full results of the SWH screening are provided in Appendix B.

2.1.3 Terrestrial Field Survey Methods

Terrestrial field surveys have been undertaken within the subject area where property access was granted, in order to characterize natural features and identify significant and sensitive natural heritage features and species that have potential to be adversely affected by future development. A variety of field surveys, described in detail in the following sections, have been undertaken in accordance with provincial and local guidance documents as indicated below. All field surveys have been conducted in 2015 as part of the field monitoring program. Monitoring station locations are shown on Drawing E2. Table 2.1.2 outlines the numerous field surveys which have been conducted during 2015. Field data sheets are attached in Appendix B. The map contained in

Appendix B shows the properties where property access was granted, by date when permission was given.

2.1.3.1 Vegetation Surveys

Vegetation community delineation has been completed using aerial photography and thorough investigations in the field on May 4, 2015 with refinements on subsequent field visits as required. The standard Ecological Land Classification (ELC) System for southern Ontario has been applied (Lee et al. 1998). Details of vegetation communities have been recorded including species composition, dominance, uncommon species or features, and evidence of human impact. A three-season detailed botanical survey also has been undertaken with all observed species of vascular flora recorded during field surveys on May 4, 2015, June 29, 2015, and September 1, 2015.

Table 2.1.2. Terrestrial Field Survey Summary

Survey Type	Protocol	Date (2015)	Start and End Time (24 hrs)	Air Temp. (°C)	Beaufort Wind Speed	Cloud Cover (%)	Precipitation	Observers
Vascular Flora Inventory (Spring) and Ecological Land Classification (ELC)	Lee et al. (1998), Systematic search by ELC polygon	May 4	0935-1438	21	4	40	None	A. Dean
								N. Miller
Vascular Flora Inventory (Summer) and ELC refinement		June 29	0600-0900	19	1	30	None	J. Bannon
								N. Miller
Vascular Flora Inventory (Fall) and ELC refinement		Sept 1	0755-1110	20-31	2	0	None	C. Moore
								N. Miller
Owl Survey	BSC (2014)	April 16	2029-2246	9	2-3	100	None	A. Ecclestone
								K. Walton
Calling Anuran Survey #1	BSC (2009)	April 16	2006-2208	9	2-3	100	None	A. Ecclestone
								K. Walton
Calling Anuran Survey #2		May 18	2108-2242	23	2	100	None	A. Cantwell
								C. Carter
Calling Anuran Survey #3		June 16	2139-2242	21	1	0	None	C. Carter
								V. Rawls

Table 2.1.2. Terrestrial Field Survey Summary

Survey Type	Protocol	Date (2015)	Start and End Time (24 hrs)	Air Temp. (°C)	Beaufort Wind Speed	Cloud Cover (%)	Precipitation	Observers
Breeding Bird Survey #1	10 minute point counts and area searches, breeding evidence as per OBBA (2001)	June 1	0600-0840	9	2	100	None	N. Clubine N. Miller
Breeding Bird Survey #2		June 29	0600-0850	19	1	30	None	J. Bannon N. Miller
Raptor Nest Searches	Thorough area searches in suitable habitat	Nov 18	0900-1200	7 - 8	3 - 5	100	None	A. Ecclestone S. Burgin
Herpetofauna and Insect Search	Systematic search by ELC polygon	May 4	0935-1438	21	4	40	None	A. Dean N. Miller
		June 1	0600-0840	9	2	100	None	N. Clubine N. Miller
		June 29	0615-0900	19	1	30	None	J. Bannon N. Miller
		Sept 1	0755-1110	20-31	2	0	None	C. Moore N. Miller

2.1.3.2 Bird Surveys

Breeding bird surveys have been completed on June 1 and 29, 2015, and data recorded using standard OBBA call codes (OBBA 2001). Surveys consisted of 10 minute point counts at 8 locations within the various habitat types (ELC community) present within the subject area. The surveys occurred between dawn and 1000 hrs. All visual and auditory observations of birds have been recorded, as well as the highest level of breeding evidence exhibited for each recorded species. Birds observed between point count locations have also have been recorded.

Owl surveys have been conducted on April 16, 2015 following the Ontario Nocturnal Owl Surveys protocol (BSC 2014), which involved 12 minute point counts at 4 monitoring stations using a combination of silent listening and playing an audio recording of owl calls (Northern Saw-whet Owl and Eastern Screech Owl).

The study area has been searched extensively for stick nests, which would indicate raptor nesting. Specific surveys have been undertaken on April 16, 2015 and November 18, 2015 when no leaves were on the trees.

Observations of birds during all field visits have been recorded.

2.1.3.3 Reptile Surveys

Snakes

Visual encounter surveys and active searches have been undertaken to identify snake species present within the subject area. Surveys have been conducted during each terrestrial site visit while walking throughout the subject area. The visual encounter surveys involved biologists approaching suitable basking areas (i.e. sunny, open grassy or rocky habitats) quietly and scanning the area with binoculars. Active searches involved turning over rocks, or other suitable covers. To ensure that no wildlife were harmed or crushed, when searching under rocks/logs, the cover feature was lifted straight up, rather than flipping to one side. Any moved items were carefully replaced to their original location to avoid disrupting the habitat.

Turtles

Visual encounter surveys have been similarly undertaken to search for turtle species present within the subject area. Surveys conducted in early spring were targeted at identifying turtle overwintering areas, while surveys conducted later in the season were focused on identifying general species presence. This involved biologists approaching suitable basking areas (i.e. wetlands, watercourses, ponds) quietly and scanning the area with binoculars. Visual surveys occurred on sunny, warm (>10ºC) days, although biologists were watching for turtles during all travel throughout the subject area. During each visual encounter survey detailed notes have been taken which described the habitat searched, level of effort, weather conditions, and species observed.

2.1.3.4 Anuran Call Surveys

Evening anuran (frog and toad) call surveys have been conducted on April 16, 2015, May 18, 2015, and June 16, 2015 using the Marsh Monitoring Program protocol (BSC 2009) at 8 stations. Monitoring focused on calling frogs and toads during 3 minute call counts, which included call intensity and an estimated number of individuals. Additional information, including survey time, air and water temperature, pH, wind speed, and cloud cover have been recorded at each survey station. The wetlands associated with the Hornby Tributary at Steeles Avenue and Trafalgar Road have not been surveyed as the habitat was deemed inappropriate to sustain anuran breeding; there were no open water pools. No calling anurans were heard during short drive-by stops.

2.1.3.5 Butterfly and Odonata Surveys

Visual encounter surveys have been conducted on May 4, 2015, June 1, 2015, June 29, 2015, and September 1, 2015, which involved thorough area searches in a variety of habitats. Surveys occurred between 0615 and 1106 hrs during suitable weather conditions (i.e. sunny, warm (>15ºC), low wind (<4 on Beaufort scale), and no precipitation). Species that could not be identified on the wing were captured using a butterfly net, identified if possible or described in detail, and released. Photographic records have been taken of individuals that could not be identified to species in the field for later confirmation in the lab. During each survey, detailed notes have been taken that described the habitat searched, level of effort, weather conditions, species observed, and number of individuals, as well as any habitat associations (e.g. nectaring or ovipositing on specific plants), larva, pupa, etc.

2.1.3.6 Mammal Surveys

Observations of all mammals have been documented on all field visits. This included direct observations of individuals, as well as signs of animal presence, such as tracks, scat, dens, etc. Searches for high quality cavity trees, suitable for bat maternity colony roosting were conducted together with other field work, primarily vegetation inventories.

2.1.4 Aquatic Field Survey Methods

Aquatic biologists from NRSI conducted 5 visits to the study area between May 28, 2015 and November 18, 2015. During these site visits a detailed characterization of aquatic habitats has been completed, as well as a fish community assessment and benthic invertebrate community assessment within the watercourses that flow through the study area, where property access was granted. These surveys are described in further detail in the following sections. Monitoring station locations are shown on Drawing E3. Table 2.1.3 outlines the numerous field surveys conducted during the 2015 field season. Field data sheets are provided in Appendix B. The map contained in Appendix B shows the properties where property access was granted, by date when permission was given.

2.1.4.1 Aquatic Habitat Assessment

Based on defined channel segments (i.e. reaches), a habitat assessment has been conducted to establish existing aquatic conditions and to identify and quantify key habitat areas within the study area. The channel segments assessed are shown on Drawing E3. The habitat assessment included an inventory of barriers to fish migration (using Stanfield et al. 2013), existing on-line ponds, sources of stream baseflow and groundwater discharge (e.g. seeps and springs), temperature measurements, and notation of aquatic vegetation. Additional habitat characterizations included basic channel morphology, channel substrates, bank stability, dissolved oxygen, instream habitat and cover, and general comments about the reaches.

Watercourses (permanent, intermittent, and ephemeral features) were classified based on the priority of habitat type and were assigned a cold, cold-cool, cool, cool-warm, or warm water designation, based on surveys and background information. The designation of thermal regime for each channel segment was based on a single temperature reading taken during aquatic habitat surveys (May 28, 2015) and fish community assessments (September 14 and 15, 2015). Although the timing and date of these readings are not consistent with sampling guidelines, thermal regime was inferred based on the temperature readings and the fish community present in each channel segment (Chu et al. 2009).

2.1.4.2 Fish Community Sampling

Electrofishing has been conducted by aquatic biologists to determine the fish community within aquatic habitats in the study area. Where possible, fish community sampling sites (EMS) coincided with benthic monitoring sites (BTH) (ref. Drawing E3). These surveys were undertaken by a two-person crew using a backpack electrofishing unit at locations shown on Drawing E3. The water conditions during electrofishing, the settings on the electrofishing unit, and the duration of sampling time are summarized in Table 2.1.4. All fish species were identified in the field and returned to the water.

In order to sample fish using electroshocking equipment, a License to Collect Fish for Scientific Purposes was applied for April 7, 2015 and obtained from the MNRF Aurora District Office on August 11, 2015 (License No. 1080976).

Table 2.1.3. Aquatic Field Survey Summary

Survey Type	Protocol	Date (2015)	Start and End Time (24 hrs)	Air Temp. (°C)	Beaufort Wind Speed	Cloud Cover (%)	Precipitation	Observers
Aquatic Habitat Assessment	Assessment on a reach by reach basis, guided by field form	May 28	0715-1545	15	1	0-25	None	A. Cantwell
								A. Ecclestone
Benthic Sampling	OBBN (2007)	May 28	0715-1545	15	1	0-25	None	A. Cantwell
								A. Ecclestone
Fish Survey	OSAP (Stanfield 2013)	Sept 14	0900-1600	17	1	0	None	A. Cantwell
								A. Ecclestone
Fish Survey	OSAP (Stanfield 2013)	Sept 15	0855-1630	21	0	0	None	A. Cantwell
								A. Ecclestone
Brook Trout Spawning Survey	TUC; Imhof 2010	Nov 18	0900-1200	7	3 - 5	100	None	A. Ecclestone
								S. Burgin

Table 2.1.4. Electrofishing Conditions, Settings, and Shocking Time

	Station EMS-001	Station EMS-001	Station EMS-003	Station EMS-004	Station EMS-005	Station EMS-006
Date	Sept 14	Sept 14	Sept 14	Sept 15	Sept 15	Sept 15
Sampling start time	0915 hrs	1215 hrs	1540 hrs	0900 hrs	1330 hrs	1500 hrs
Sampling end time	0950 hrs	1245 hrs	1610 hrs	1000 hrs	1400 hrs	1530 hrs
Air temperature (°C)	11	21	22	16	21	26
Water temperature (°C)	10.7	11	16.2	14.1	15.1	17.5
Time water temp. taken	0855 hrs	1050 hrs	1510 hrs	0910 hrs	1250 hrs	1445 hrs
Conductivity (µs/cm)	663	867	685	711	623	879
Dissolved Oxygen (ppm)	328	433	Not available	355	311	445
Electrofisher Type	Halltech backpack unit					
Number of Netters	1	1	1	1	1	1
Voltage (V)	100	100	150	150	150	150
Pulsating Frequency (Hz)	70	70	70	60	70	70
Shocking time (sec.)	689	1119	1133	978	732	1169

2.1.4.3 Brook Trout Spawning Surveys

A spawning survey for Brook Trout (Salvelinus fontinalis) has been conducted by aquatic biologists on November 18, 2015 to determine whether this species was spawning in a cold-water section of creek that flows through the Hornby Glen Golf Course (Golf001, ref. Drawing E3). This location was selected based on the presence of an adult Brook Trout captured within this reach during fish community sampling. Spawning surveys consisted of visual observations throughout the reach to identify the presence of actively spawning Brook Trout or redds (i.e. fish ‘nests’) that may have been used during the fall of 2015. Visual surveys were conducted by aquatic biologists wearing polarized sunglasses and walking the shoreline. If evidence of Brook Trout spawning was observed, the location, number of spawning fish, and habitat features have been recorded.

2.1.4.4 Benthic Invertebrate Community Assessment

Benthic Invertebrate Sampling

Sampling for the benthic invertebrates has been conducted at 5 stations on May 28, 2015 using the Ontario Benthos Biomonitoring Network (OBBN) protocol (Jones et al. 2007) sampling methodology. Where possible, benthic monitoring sites (BTH) coincided with fish community sampling sites (EMS) (ref. Drawing E3)1. The OBBN data form was used to record habitat information at the benthic invertebrate sampling stations. The form includes both measured and visually estimated parameters, and will facilitate comparison with other years, provided the estimated parameters are treated as approximations.

According to the OBBN methods for streams, a total of 3 subsamples have been collected at each station in stream habitats: 2 from riffles and 1 from a pool. Where riffle and pool habitats are not clearly defined, pools and riffles can be functionally defined as slow/deep and fast/shallow sections, respectively. For wadable streams, the OBBN protocol employs a Travelling Transect Kick and Sweep method. For each subsample, a total of at least 10 linear metres of transect has been sampled in approximately 3 minutes. Beginning at one bank and moving across each transect, the substrate was disturbed to a depth of approximately 5cm by vigorously kicking the substrate. A 500-µm-mesh D-net was held downstream of and close to the disturbed area by the person sampling. The net was held on or close to the bottom of the channel, and was swept back and forth so that dislodged invertebrates would be carried into the net. In areas of slow current, the sweeping motion is important for collecting the invertebrates into the net. A stopwatch was used to time the sampling.

When sampling was complete, the net was rinsed and the sample was placed in a plastic jar. The sample was then preserved with a 75% concentration of ethyl alcohol and stored for later identification.

Benthic samples have been processed and identified in the NRSI laboratory. Samples have been subsampled using the weight-based subsampling procedure as described by Sebastien et al. (1988) to accurately represent the makeup of the benthic community. Sub-samples were sorted

[1] Benthic monitoring was not undertaken at EMS-006, as site access was not available at the time of the benthic survey.

using a dissection microscope to collect all invertebrate individuals within the sub-sample. Successive sub-samples were sorted to achieve a minimum of 100 organisms, as indicted by the OBBN protocol (Jones et al. 2007). Upon collection of the 100th organism, the remaining sub-sample was assessed until all remaining organisms in that sub-sample were collected. Thus, the level of subsampling and sorting was 100 organisms plus the remaining organisms in the last subsample. The samples were then identified to the lowest practical taxonomic level. The difference between the 2 measurements represents the portion sampled, which is recorded as a percentage of the total sample. While the OBBN protocol requires that a minimum of 100 organisms be collected, 200 organisms per subsample are collected to provide a robust sample for this program's use of the Percent Model Affinity analysis.

Benthic Invertebrate Analysis

A total of 14 metrics and indices have been calculated in order to assess the benthic invertebrate community in the exposure and reference areas. The metrics are listed and described as follows.

- Density – the number of individuals per unit area of sampled substrate, extrapolated from proportional subsampling as required.
- Taxa Richness – the number of taxa generally increases with habitat diversity and water quality (Jones et al. 2007).
- EPT Taxa Richness – the number of taxa from orders sensitive to pollution, specifically the orders Ephemeroptera, Plecoptera, and Tricoptera (Barbour et al. 1999; Weber 1973).
- Percent EPT – percent composition of a community by taxa from orders sensitive to pollution, specifically the orders Ephemeroptera, Plecoptera, and Tricoptera (Barbour et al. 1999; Weber 1973).
- Percent Oligochaetes – percent composition of a community of aquatic worms, a group tolerant to pollutants (Jones et al. 2007).
- Percent Diptera – percent composition of a community of fly larvae which provides a context for other analysis (Jones et al. 2007).
- Percent Chironomidae – percent composition of a community of larval midges, a highly tolerant family (Jones et al. 2007).
- Percent Gastropoda – percent composition of a community of snails and other gastropods which provides a context for other analysis (Jones et al. 2007).
- Percent Insecta – percent composition of a community of invertebrates (Jones et al. 2007).
- Shannon Wiener Index (H') – an index used to measure the diversity in categorical data, taking into account the number of species and evenness of the species. This metric is calculated as:

  $$H' = -\sum(p_i)(\ln p_i)$$

  Where "p_i" is the proportion of individuals in the i^{th} taxon (Environment Canada 2011).

- Simpson's Diversity Index (D) – a measure that takes into account the abundance patterns and taxonomic richness of the benthic community. The formula determines the proportion of individuals of each taxonomic group at a station that contribute to the total number of individuals at that station. This metric is calculated as:

$$D = 1 - \sum_{i=1}^{S} (p_i)^2$$

Where S = the total number of taxa at the station, and p_i is the proportion of the i^{th} taxon at the station.

- Hilsenhoff Biotic Index (BI) – a measure of water quality based on the species-level “tolerance values” and the number of individuals of each species and the total number of individuals within the sample. This metric is calculated as:

  $BI = \sum \frac{x_i t_i}{n}$

  Where “x_i” is the number of individuals within the i^{th} taxon, “t_i” is the tolerance value of the i^{th} taxon, and n is the total number of individuals within the sample (Hilsenhoff 1987).

- Dominant/Subdominant Taxa – highest and second highest number of taxa sampled.
- Percent Functional Feeding Groups – the percent composition of a community by Collector-filterers, Collector-gatherers, Predators, Scrapers, and Shredders. Feeding groups can provide an indication of habitat conditions (Merritt et al. 2008).

2.1.5 Characterization and Analysis

The existing conditions are characterized in the following sections.

2.1.5.1 Designated Natural Areas

Information on designated natural areas has been obtained from the MNRF LIO database, NHIC, Halton Region, Town of Halton Hills, and Conservation Halton. According to background information collected, there are no locally, provincially, or regionally significant wetlands, Areas of Natural and Scientific Interest (ANSI), or Environmentally Sensitive Areas (ESAs) within the subject area. Portions of the Regional Natural Heritage System (NHS) and a Regional Forest (Coulson Tract) are located within the subject area and are shown on Drawing E1. The provincial Greenbelt forms the southwestern boundary of the subject area.

2.1.5.2 Vegetation

Vegetation Communities

The subject lands consist of agricultural fields, meadows, woodlands, plantations, rural residential areas, and a golf course. A summary of ELC communities identified within the subject area is provided in Table 2.1.5. ELC communities are described below and shown on Drawings E4a and E4b. ELC data sheets are provided in Appendix B.

Mineral Cultural Meadow (CUM1)

This vegetation community exists in several locations within the study area, primarily associated with riparian corridors. Sparse coverage of woody species includes Hawthorn (Crataegus sp.), Manitoba Maple (Acer negundo), European Buckthorn (Rhamnus cathartica), Black Raspberry (Rubus occidentalis), and Red-osier Dogwood (Cornus stolonifera). The groundcover vegetation is comprised of Smooth Brome (Bromus inermis ssp. inermis), Lance-leaved Aster (Symphyotrichum lanceolatum), and Reed Canary Grass (Phalaris arundinacea).

Two distinct habitat inclusions exist within this vegetation community: Graminoid Mineral Meadow Marsh (MAM2), and Cattail Mineral Shallow Marsh (MAS2-1). The Mineral Meadow Marsh (MAM2) community is largely dominated by Reed-canary Grass, Lance-leaved Aster, and Purple Loosestrife (Lythrum salicaria). The Cattail Mineral Shallow Marsh (MAS2-1) is dominated by Narrow-leaved Cattail (Typha angustifolia), Reed Canary Grass, and European Common Reed (Phragmites australis ssp. australis).

Agriculture (AG)

The majority of the study area is dominated by agricultural land use, including row crops, hayfield, and pasture.

Open Water (OA)

Several areas of Open Water exist throughout the study area, and are of anthropogenic origin, mostly ponds on the golf course and one dug farm pond.

Table 2.1.5. Vegetation Communities Identified within the Study Area	
Cultural	
CUM1	Mineral Cultural Meadow
Ag	Agriculture
Plantation	
CUP1-3	Black Walnut Deciduous Plantation
CUP2	Mixed Plantation
CUP3	Coniferous Plantation
Deciduous Forest	
FOD3-1	Dry-Fresh Poplar Deciduous Forest
FOD5-8	Dry-Fresh Sugar Maple-White Ash Deciduous Forest
FOD7	Fresh-Moist Lowland Deciduous Forest
FOD7-3	Fresh-Moist Willow Lowland Deciduous Forest
Wetland	
MAM2	Graminoid Mineral Meadow Marsh
MAS2-1	Cattail Mineral Shallow Marsh
SWM1-1	White Cedar – Hardwood Mixed Swamp
Aquatic System	
OA	Open Water
Constructed	
Res	Residential
Ind/Com	Industrial and Commercial

Black Walnut Deciduous Plantation (CUP1-3)

This plantation type is found in several areas of Coulson Tract, the Regional Forest, central to the subject area. Several deciduous tree species comprise the plantation, including Black Walnut (Juglans nigra), Bur Oak (Quercus macrocarpa), White Ash (Fraxinus americana), and Eastern Cottonwood (Populus deltoides). The sub-canopy is regenerating with Black Walnut, White Ash, and European Buckthorn. The understorey vegetation is dominated by Choke Cherry (Prunus virginiana), Black Raspberry, and Tartarian Honeysuckle (Lonicera tatarica). Groundcover vascular flora is dominated by Wild Strawberry (Fragaria virginiana), Avens species (Geum sp.), and Heal-all (Prunella vulgaris ssp. lanceolata).

Two distinct habitat inclusions exist within this vegetation community: Coniferous Plantation (CUP3), and Dry-Fresh Poplar Deciduous Forest (FOD3-1). The Coniferous Plantation (CUP3) is dominated by White Pine (Pinus strobus) and Scot's Pine (Pinus sylvestris) and is naturalizing well. The Poplar Deciduous Forest (FOD3-1) is dominated by Large-toothed Aspen (Populus grandidentata) with White Ash, Trembling Aspen (Populus tremuloides), European Buckthorn, Canada Goldenrod (Solidago canadensis), Tall Goldenrod (Solidago altissima var. altissima), Wild Strawberry (Fragaria virginiana), Riverbank Grape (Vitis riparia), and Field Sow-thistle (Sonchus arvensis ssp. arvensis).

Mixed Plantation (CUP2)

This plantation type is located in several areas of Coulson Tract. Dominant plantation species include White Pine and White Ash. Woody species regeneration in the sub-canopy and understorey consist of White Ash, Alternate-leaved Dogwood (Cornus alternifolia), Scot's Pine, Tartarian Honeysuckle, Black Raspberry, and Choke Cherry. The groundcover vegetation is comprised of Avens species, Wild Strawberry, and Dame's Rocket (Herperis matronalis). This vegetation community was noted as having significant dieback of White Ash, resulting from a local infestation of Emerald Ash Borer (Agrilus planipennis).

Coniferous Plantation (CUP3)

This small community is located north of Trafalgar Road, adjacent to a riparian corridor. The plantation north of Trafalgar Road is used recreationally by local area residents, and was noted as having little to no groundcover vegetation. Plantation species consist solely of Norway Spruce (Picea abies), with common plantation associates such as Hawthorn, Tartarian Honeysuckle, Choke Cherry, and White Ash in the understorey. The sparsely vegetated groundcover is comprised of Wild Strawberry, Garlic Mustard (Alliaria petiolata), and Common Dandelion (Taraxacum officinale). Other small conifer plantations are located in the Coulson Tract, as discussed above, as inclusions to the Black Walnut plantation.

Dry-Fresh Sugar Maple – White Ash Deciduous Forest (FOD5-8)

This vegetation community is located in the west corner of the subject area adjacent to 6th Line, and is the largest, natural woodland within the subject lands. The canopy and sub-canopy are comprised of Sugar Maple (Acer saccharum), American Beech (Fagus grandifolia), Red Oak (Quercus rubra), White Ash, and Hawthorn. Understorey vegetation is dominated by White Ash, Choke Cherry, and European Buckthorn. The groundcover layer has abundant Trout Lily (Erythronium americanum ssp. americanum), with lesser amounts of Garlic Mustard, and Running Strawberry-bush (Euonymus obovata).

There is evidence of past tree harvesting within this feature, which has resulted in a visibly different forest composition, when compared to relatively undisturbed portions. Sugar Maple and White Ash are regenerating well within these disturbed areas. Historically this forest was used as cattle pasture (Kowal pers. comm. 2015).

Fresh-Moist Lowland Deciduous Forest (FOD7)

This small vegetation community is located within Coulson Tract, associated with the plantation areas and a watercourse. It has formed as a result of naturalization of the riparian corridor, utilizing the seed source from the adjacent Black Walnut Deciduous Plantation (CUP1-3). The canopy and sub-canopy are comprised of Green Ash (Fraxinus pensylvanica), Black Walnut, and Manitoba Maple. Common understorey species include Red-osier Dogwood, European Buckthorn, and Tartarian Honeysuckle. The groundcover is dominated by opportunistic species such as Dame's Rocket, Avens, and Garlic Mustard.

Fresh-Moist Willow Lowland Deciduous Forest (FOD7-3)

This small vegetation community is located in the northeast portion of the golf course property, and is associated with a riparian corridor. The canopy is dominated by Weeping Willow (Salix alba var. vitellina), Black Walnut, Freeman's Maple, and Honey Locust (Gleditsia triacanthos var intermis). The sub-canopy and understorey are comprised of White Elm (Ulmus americana), Black Walnut, Bur Oak, and Black Raspberry. Groundcover vegetation includes Reed Canary Grass, Lance-leaved Aster, and Smooth Brome.

The origin of the Honey Locusts is unknown; some thorns were observed on some individuals, whereas some individuals remained thornless, suggesting these trees were planted and are of non-native origin, therefore not significant. As well, the Honey Locusts appeared to be evenly-aged, suggesting an anthropogenic origin.

White Cedar – Hardwood Mixed Swamp (SWM1-1)

This vegetation community is located within the golf course property, towards the south, and is associated with a low-lying area. The canopy and sub-canopy are comprised of White Cedar (Thuja occidentalis), Yellow Birch (Betula alleghaniensis), Green Ash, and White Elm. Understorey vegetation is dominated by Red-osier Dogwood, Manitoba Maple, and Narrow-leaved Cattail. The groundcover layer is comprised of Reed Canary Grass, Lance-leaved Aster, and Spotted Jewelweed (Impatiens capensis).

Vascular Flora

A total of 100 species of plants were recorded during detailed vegetation inventories within the study area. A complete list of these species in included in Appendix B. Of the total plant species observations, 36 were non-native. Edge effects and habitat fragmentation within the broader landscape has resulted in a predominance of opportunistic and adventive species within the study area, typical of habitats within the Greater Toronto Area.

Background information and SAR/SCC screening (Appendix B) indicates that 9 significant plant species are reported from the study area. Based on field work conducted, none of these species were confirmed within the study area. Three dead Butternut trees (Juglans cinerea), an Endangered species, were observed within the Halton Regional Forest in the Black Walnut Cultural Plantation (CUP1-3). Despite further searches and vegetation inventories, live Butternut trees were not identified.

A regionally significant species, Common Evening-primrose (Oenothera biennis), is identified as rare from Halton Region (Varga et al. 2000). Common Evening-primrose is usually found on dry often sandy roadsides, fields, clearings, and disturbed ground, as well as on stream banks and at borders of forests (Reznicek et al. 2011). This species was observed in the Mixed Plantation (CUP2) in the Regional Forest tract, occurring occasionally.

2.1.5.3 Birds

A total of 75 birds are reported from the study area based on the OBBA (BSC et al. 2008). During field surveys, 61 bird species were documented within the subject area of which 45 exhibited signs of breeding. Of the species observed from the subject area, 14 were not reported from the OBBA. A list of bird species found in the subject area and vicinity is provided in Appendix B. Three bird SAR were observed in the subject area: Barn Swallow (Hirundo rustica), Bobolink (Dolichonyx oryzivorus), and Eastern Meadowlark (Sturnella magna); as well as one bird species of Conservation Concern: Eastern Wood-Pewee (Contopus virens). Table 2.1.6 provides a summary of significant species observed in the study area, their current status ranks, and preferred habitats.

Barn Swallows were observed widely throughout the subject area during site visits on May 4, 2015, June 1, 2015, and June 29, 2015. Nesting was not confirmed within the subject area as biologists did not have access to barns or other agricultural structures. Barn Swallow were observed foraging primarily over golf course lands and agricultural fields. Nesting habitat for Barn Swallow is present within the broader study area in the form of barns, outbuildings, garages, houses, and culverts.

Bobolink and Eastern Meadowlark were both observed within grassy agricultural fields north of Trafalgar Road on May 4, 2015, with Bobolink also observed on the first breeding bird survey on June 1, 2015. Both of these species favour large contiguous grassland habitats which are not found abundantly in the subject area (OMNR 2000). Breeding was not confirmed for either species and it is unlikely that they are breeding within the subject area due to lack of suitable habitat.

A pair of Eastern Wood-Pewee was observed within the Mixed Plantation (CUP2) of the Halton Regional Forest on June 29, 2015 indicating that this species is likely breeding within the woodland. Eastern Wood-Pewee was also observed singing within the Dry-Fresh Sugar Maple-White Ash Deciduous Forest (FOD5-8) on the west side of the subject property adjacent to the golf course on September 1, 2015. This record is well outside of the breeding season and likely represents a migratory individual. This species favours deciduous forests, but can be found breeding in parks, small woodlots (OMNR 2000), and plantations (Nol 2015).

Table 2.1.6. Significant Bird Species Reported from the Study Area

Common Name	Scientific Name	SRANK[1]	COSEWIC[2]	SARO[3]	Regional Status[4]	Habitat Preference	Background Source	Suitable Habitats Within Subject Property	Observed by NRSI
Barn Swallow	Hirundo rustica	S4B	T	THR	Significant	Foraging habitat in Ontario includes farmland, lakeshore and riparian habitats, road right-of-ways, clearings in wooded areas, parkland and urban and rural residential areas, wetlands and tundra (Heagy et al. 2014; OMNR 2000; COSEWIC 2011). Nest sites often occur on human structures including buildings, barns, bridges, culverts, wells and mine shafts. Natural nest sites include caves, cliffs or other ledges (Heagy et al. 2014).	BSC 2006	Res Ag Golf course CUM1 OA MAM2 MAS2-1	Yes
Bobolink	Dolichonyx oryzivorus	S4B	T	THR	Significant	Large, open expansive grasslands with dense ground cover; hayfields, meadows or fallow fields. This species generally requires habitat >10ha in size although use of these areas may be influenced by other landscape attributes such as topography and patch shape (McCracken et al. 2013). In Ontario, hayfields and pastures are preferred but they are usually absent from grain fields and row crops (COSEWIC 2010).	BSC 2006 NHIC 2013	Ag	Yes
Eastern Meadowlark	Sturnella magna	S4B	T	THR	Significant	Open, grassy meadows, farmland, pastures, hayfields or grasslands with elevated singing perches. The minimum required grassland size is approximately 5ha (McCracken et al. 2013). This species breeds in Ontario, and favours well concealed grasslands and prairie habitats for nesting (Jaster et al. 2012).	BSC 2006	Ag	Yes
Eastern Wood-pewee	Contopus virens	S4B	SC	SC	-	Open, deciduous, mixed or coniferous forest; predominated by oak with little understory; forest clearings, edges; farm woodlots, parks (OMNR 2000). Breeds in virtually every type of wooded habitat in the east (Peck and James 1987). Size of forest fragments does not seem to be an important factor in habitat selection (Freemark and Collins 1992).	BSC 2006	FOD3-1 FOD5-8 FOD7 CUP1-3 CUP2 CUP3	Yes

2.1.5.4 Herpetofauna

According to the Ontario Reptile and Amphibian Atlas (Ontario Nature 2015), 17 species of herpetofauna are reported from the study area; however the majority of these records are historic. NRSI field investigations confirmed the presence of 5 species within the study area including: Midland Painted Turtle (Chrysemys picta marginata), American Toad (Anaxyrus americanus), Gray Treefrog (Hyla versicolor), Northern Green Frog (Lithobates clamitans melanota), and Spring Peeper (Pseudacris crucifer). A complete list of herpetofauna reported from the study area, based on background information and observations made as part of this study, is included in Appendix B. The results of species-specific surveys are detailed below.

Anurans (Frogs and Toads)

During anuran call surveys, 4 species of anurans were recorded: American Toad, Gray Treefrog, Northern Green Frog, and Spring Peeper. The results of the monitoring are shown in Table 2.1.7. Grey Treefrog and Spring Peeper were both recorded with full choruses from several monitoring stations.

Snakes

No snakes were observed during any field visits.

Turtles

A single species of turtle was observed during visual encounter surveys: Midland Painted Turtle. Five individuals were observed within the Hornby Glen Golf Course in a pond located at the southern corner of the property near the White Cedar-Hardwood Mineral Mixed Swamp (SWM1-1) on May 4, 2015. Conservation Halton reported an observation of Snapping Turtle (Chelydra serpentina serpentina) observed in 1989, crossing Hornby Road within the subject area.

Salamanders

No salamanders were observed during any site visit within the study area. Species specific surveys were not conducted and are outside the scope of the current study.

No herpetofauna SAR or SCC were observed by NRSI within the study area, and no regionally significant species were observed.

Table 2.1.7. Anuran Monitoring Results

ANR Station	April 16	May 18	June 16
1	SPPE 2(6)	AMTO 1(2) GRFR 1(1) GRTR 3 SPPE 3	GRTR 3
2	*none*	AMTO 1(2) GRTR 3 SPPE 3	GRFR 1(2) GRTR 3
3	*none*	GRTR 1(2)	GRFR 1(5)
4	*none*	AMTO 2(5) GRFR 1(2) GRTR 3	GRFR 1(5)
5	*none*	AMTO 1(1) GRFR 1(2) SPPE 2(2)	GRFR 1(2)
6	*none*	GRFR 2(4) SPPE 3	GRFR 1(3) GRTR 3
7	SPPE 3	GRTR 3 SPPE 3	GRFR 1(1) GRTR 1(1)
8	SPPE 3	GRTR 3	GRTR 2(3) SPPE 2(2)

Legend
AMTO – American Toad
GRFR – Green Frog
GRTR – Grey Treefrog
SPPE – Spring Peeper
First # indicates call code/level, 2nd #, in brackets, indicates number of individuals.
Call Level 1. Calls can be counted; not simultaneous
Call Level 2. Some simultaneous calls; yet distinguishable
Call Level 3. Calls not distinguishable; overlapping (i.e. “full chorus”); number of individuals is not estimated

2.1.5.5 Mammals

According to the Mammal Atlas of Ontario (Dobbyn 1994), 23 mammal species are reported from the study area, with several historic records. Of these species, 5 were observed within the subject area during the current study: Coyote (Canis latrans), Eastern Gray Squirrel (Sciurus carolinensis), Northern Raccoon (Procyon lotor), White-tailed Deer (Odocoileus virginianus), and a species of bat. Six bats were observed foraging June 16, 2015 during anuran call count surveys from station ANR-008, near 6th Line. Bats cannot be identified to species without specific acoustic surveys. Targeted surveys for bats have not been conducted as part of this study. A complete list of mammal species reported from the study area is provided in Appendix B.

No mammal SAR or SCC, nor any regionally significant mammal species were observed within the study area, however targeted surveys for bats were not completed. Little Brown Myotis (Myotis lucifuga) and Tri-colored Bat (Perimyotis subflavus) are reported from the Mammal Atlas (Dobbyn 1994). Little Brown Myotis is considered Endangered in Ontario, and Tri-colored Bat is a SCC in Ontario (MNRF 2015b). Based on their known extent in southern Ontario and their habitat preferences, they may be found in the study area. These species are generally dealt with through SWH and the protection of trees providing maternity roost sites, and are addressed in later sections of the report.

2.1.5.6 Butterflies and Odonata

Butterflies

According to the Ontario Butterfly Atlas (Jones et al. 2013), 26 butterfly species are reported from the study area. NRSI biologists observed 3 species during surveys completed during 2015. These species include Monarch (Danaus plexippus), Cabbage White (Pieris rapae), and Red Admiral (Vanessa atalanta). A complete list of species observed and reported from the area is provided in Appendix B.

Monarch is a SCC and was observed within the golf course lands on September 1, 2015 during fall vegetation surveys. The observation included a single adult and a single caterpillar. This species feeds exclusively on Milkweeds (Asclepias spp.) which are found abundantly throughout the subject area and adjacent lands. No regionally significant butterfly species were observed.

Dragonflies and Damselflies

During field surveys conducted within the subject property, 6 species of Odonata (dragonflies and damselflies) were observed. Of these 6 species, a single regionally significant species was observed: Beaverpond Baskettail (Epitheca canis) (Conservation Halton 2006). A complete list of species observed is provided in Appendix B. No other significant species were observed within the subject area.

2.1.5.7 Aquatic Habitats

The subject area and all surveyed tributaries are located in the Sixteen Mile Creek watershed. The watercourses as mapped through existing sources, are shown on Drawing E1. The reaches that were assessed are shown on Drawing E3. The watercourse mapping layer was corrected based on field work, recent air photos, and work completed by Parish Aquatic Services. Revised watercourse mapping is shown on all subsequent mapping (see especially Drawing E5). An initial aquatic habitat assessment was conducted on May 28, 2015 for most locations and additional sites were surveyed on November 18, 2015. All tributaries where property access was granted within the subject area at the time of the survey have been surveyed (Appendix B) and information has been recorded regarding available fish habitat. Information collected for each tributary is summarized in Table 2.1.8. The tributaries are described here, west to east.

Sixth001

Sixth001 tributary is located on the west boundary of the subject area and was surveyed on November 18, 2015. The upper half of this reach was dry at the time of survey, and consists of a man-made ditch that is maintained annually to facilitate the drainage of an agricultural field. There is no clearly defined channel and the topography of the channel varies substantially from the watercourse layer provided by LIO (ref. Drawing E1). The lower half of this reach has a well-defined channel that likely receives groundwater discharge from the middle sections of the reach (i.e. behind residential property numbers 8231, 8223, 8205 and 8199). The groundwater source could not be confirmed due to property access limitations, however the presence of watercress, which is an indicator of cold water and possible groundwater discharge, in the lower section of this reach suggests that the Sixth001 tributary has groundwater contributions.

Table 2.1.8. Aquatic Habitat Assessment Results

NRSI Reach Reference	PARISH Reach Reference	Survey Date and Time	Flow	Wetted Width (m)	Bankfull Width (m)	Width of vegetation next to creek (m)	Canopy Cover	Fish Cover *	Potential Fish Habitat	Substrate (%)	Watercress	Air Temp. (°C)	Water Temp. (°C)	Other
Sixth001	W-T1-2b	Nov 18 13:00	Low to none	0.0 to 1.0	0.5 to 2.0	0.0 to 2.0	None to Low	None to limited: WD, RF	Limited: restricted to lower portion of reach	Muck (100)	Yes: limited & restricted to lower portion of reach	8	NA	Upstream portion is dry man-made drainage channel, downstream portion has limited potential
Golf001	E-T1-3	May 28 7:15	Moderate (Depth 0.1-0.6 m)	1.2	2.0	5.0	Sparse	Limited: PL, RF, RK, WD, UB, IV (low)	Yes: adequate depth/flow, permanent feature, fish cover, fish observed	Cobble (10) Pebble (10) Gravel (20) Sand (40) Silt (10) Muck (5) Detritus (5)	Yes: substantial throughout reach	12	13.7	Meandering, several small bridge crossings
Golf002	E-T1-4	May 28 8:35	Dry	0.0	≤1.5	≤0.5	None	None	No: dry and not likely to support fish	Muck (100)	No	14	NA	Ephemeral drainage channel for golf course, buried under fairway
Golf003	E-T1-3	May 28 9:00	Moderate flow (Depth 0.2-0.5 m)	2.1	4.0	5.0	Sparse	Moderate: PL, RF, RK, UB (high), WD (mod), IV (low)	Yes: adequate depth/flow, permanent feature, fish cover, fish observed	Cobble (10) Pebble (10) Gravel (30) Sand (30) Silt (20)	Yes: but limited to confluence of Golf001 and Golf003	15	13.7	Relatively large and wide, several small bridge crossings
Golf004	HDF-4	May 28 9:30	Dry	0.0	≤1.5	≤0.5	Minimal	None	No: dry and not like to support fish	Muck (100)	No	15	NA	Ephemeral drainage channel for golf course, buried under fairway
Steeles001	Upstream portion of HDF-1	May 28 9:40	Dry	0.0	≤1.0	≤3.0	None	None	No: dry and not likely to support fish	Muck (100)	No	15	NA	Ephemeral drainage channel for golf course & agricultural field
Steeles002	Downstream portion of E-T1-1	May 28 10:00	Low (Depth 0.1-0.3 m)	1.0	2.0	0.0	None	Limited: RF, PL, UB, IV, RCK	Limited: not ideal but potential to support small bodied fish, fish observed	Gravel (40) Sand (20) Silt (40)	Yes: minimal and limited to shaded areas	17	20.2	Surrounded by agricultural fields and pasture, shallow and narrow, steep eroding banks, braided channel
Steeles003	Downstream portion of W-T1-2, W-T1-1	May 28 11:15	Low to moderate (Depth 0.1-0.3 m)	1.7	5.5	≤7.0	Minimal, limited to upper portion	Limited: RF, PL, UB, WD, IV, RCK	Yes: adequate depth/flow, permanent feature, fish observed	Gravel (40) Sand (20) Silt (40)	No	17	20.2	Surrounded by agricultural fields and pasture, upstream portion is wide with large buffer, upstream of reach appeared to be very natural

Table 2.1.8. Aquatic Habitat Assessment Results

NRSI Reach Reference	PARISH Reach Reference	Survey Date and Time	Flow	Wetted Width (m)	Bankfull Width (m)	Width of vegetation next to creek (m)	Canopy Cover	Fish Cover *	Potential Fish Habitat	Substrate (%)	Watercress	Air Temp. (°C)	Water Temp. (°C)	Other
Steeles004	Upstream portion of T1	May 28 10:20	Moderate (Depth 0.1-0.7 m)	3.5	8.0	5.0	Moderate	Moderate: RF, PL, UB (low), WD (low), IV (algae), RCK	Yes: adequate depth/flow, permanent feature, fish observed	Cobble (20) Gravel (20) Sand (20) Silt (40)	No	17	18.0	Surrounded by Hornby Park, relatively wide and deep reach, reach to south appears to be very natural and high canopy cover (no access)
Steeles005	NA	May 28 15:00	Moderate (Depth 0.1-0.5 m)	2.0	6.0	≥15.0	High	High: RF, PL, BW, UB, WD (high), RCK	Yes: adequate depth/flow, permanent feature, fish observed	Pebble (10) Sand (10) Silt (40) Clay (40)	No	27	26.0	Large amounts of woody debris causing backwater, has the potential to become intermittently dry, at base of large ravine
Hwy001	Upstream portion of T2	Nov 18 10:30	Low (Depth 0.1-0.6 m)	3.3	7.5	≥15.0 (excl. HWY 401)	Moderate	Moderate: RF, PL, BW, UB, WD, IV, RCK	Yes: adequate depth/flow, permanent feature, fish observed	Cobble (15) Gravel (30) Sand (25) Silt (10) Clay (10) Detritus (10)	Yes: fairly minimal but present	8	6.5	Tributary passes through large culvert at highway 401, surrounded by large natural wooded area, several tributaries converge upstream of highway 401
Trafalgar001	HT-2b-2	May 28 13:30	Dry	0.0	≤1.0	0.0	None	None	No: dry and not likely to support fish	Muck (100)	No	27	NA	Ephemeral drainage channel for agricultural fields and surrounding area
Trafalgar002	HT-2a-2	May 28 14:00	Moderate (Depth 0.1-0.5 m)	5.0	6.0	≥15.0 (excl. road)	High	Moderate: RF, PL, UB, WD, RCK	Yes: adequate depth/flow, permanent feature, fish observed	Cobble (20) Pebble (20) Gravel (20) Sand (20) Silt (20)	Yes: some watercress along shoreline	27	22.2	Relatively wide, surrounded by Coulson Regional Forest, large slightly perched box culvert at Trafalgar Road crossing

* Fish cover definitions: Pools (PL), Riffles (RF), Backwater (BW), Rock (RK), Woody Debris (WD), Undercut Banks (UB) and Instream Vegetation (IV)

Golf001

Golf001 tributary is located near the north boundary of the Hornby Glen Golf Course. Although no evidence of groundwater discharge was observed at the time of the survey (May 28, 2015), large amounts of watercress were present throughout the surveyed area, and anecdotal reports (by a golfer and local resident) suggest the location of a natural groundwater well on the adjacent property to the north. The cold water regime has been corroborated by water temperature measurements that were much cooler at Golf001 on May 28, 2015 compared to all other tributaries (13.7°C compared with an average of 21.3°C). Based on the habitat features at Golf001 tributary, it is anticipated that this tributary could support a cold water fish community. This was corroborated by fish community survey results, as a Brook Trout and Northern Brook Lamprey (Lampetra appendix) were captured, both of which are considered cold-water species.

Golf002

Golf002 tributary is an ephemerally flowing tributary that primarily serves as a drainage channel for Hornby Glen Golf Course. At the time of the survey, Golf002 tributary was completely dry. A small narrow channel was evident where the tributary normally flows, however large portions of the tributary are buried under golf course fairways. Given these characteristics, it is unlikely that Golf002 tributary provides any habitat for fish or aquatic organisms.

Golf003

Golf003 tributary is located below the confluence of the Golf001 and Golf002 tributaries at the eastern boundary of the golf course. Compared to other tributaries throughout Hornby Glen Golf Course, Golf003 tributary had a moderate amount of flow, was relatively wide and water temperature was comparable with Golf001. Watercress, which is an indicator of cold water and possible groundwater discharge, was present; however it was largely restricted to the outflow of the Golf001 tributary. Beyond the boundaries of the golf course, Golf003 tributary flows through an agricultural field. Based on habitat features and water temperature, it is anticipated that this tributary could support a cold to cool water fish community.

Golf004

Similar to Golf002 tributary, Golf004 is an ephemerally flowing tributary that primarily serves as a drainage channel for the golf course. At the time of the survey, Golf004 tributary was nearly dry with the exception of some stagnant water in small pockets. In some areas of the golf course, particularly where Golf004 transected a fairway, the tributary was buried and no watercourse was apparent. Golf004 appears to serve as an overflow drainage channel for irrigation and aesthetic ponds that are located on the west side of the Hornby Glen Golf Course. Given these characteristics, it is unlikely that Golf004 provides any habitat for fish or aquatic organisms.

Steeles001

Steeles001 tributary is located immediately south of the Hornby Glen Golf Course on the eastern tributary (downstream of Golf004). At the time of the aquatic habitat survey, Steeles001 was characterized by a small narrow swale with a defined low flow channel that was surrounded by agricultural crops. Steeles001 tributary was completely dry at the time of the survey. The tributary likely flows ephemerally and receives surface water runoff from the surrounding landscape such as the golf course and agricultural fields. It is unlikely that Steeles001 tributary supports fish.

Steeles002

Steeles002 tributary is located within the Greenbelt, north of Steeles Avenue and includes the confluence of the east and west tributaries on the golf course, which is located approximately 500 m to the north. Steeles002 tributary is surrounded by livestock pasture and agricultural crops and had a poorly defined braided channel. At the upstream end of Steeles002 the wetted width is relatively wide, but gradually narrows as it approached the confluence with Steeles003 north of Steeles Avenue. A small amount of watercress was also present throughout the surveyed reach, which is an indicator of cold water and possible groundwater discharge. Despite the agricultural disturbances and minimal amount of fish cover throughout the survey area, some fish were observed in the Steeles002 tributary.

Steeles003

Steeles003 is located within the Greenbelt and flows into the Middle Sixteen Mile Creek tributary just downstream of Steeles002. Although detailed observations could not be recorded due to site access restrictions, it was noted that the Steeles003 tributary had better quality natural features to the west of the survey area (e.g. tree cover, increased buffer size, etc.). Within the surveyed reach, Steeles003 tributary ran through a small gully with steep banks (60°) and was surrounded by agricultural crops and livestock pasture. There was evidence of active stream bank erosion throughout the Steeles003 tributary, which had a minimal amount of vegetation and shrubs to act as stabilizing features. Despite the lack of fish cover, tree canopy and bank instability, a large number of fish were observed in the Steeles003 tributary at the time of the survey.

Steeles004

Steeles004 tributary is located south of Steeles Avenue, adjacent to Hornby Park. The tributary was surrounded by a natural buffer that was approximately 5 m in width, beyond which is the recreational park. Although some large trees and small shrubs were included in the natural buffer, the majority of Steeles004 tributary had no canopy cover. Steeles004 tributary was relatively wide and deep compared to most other surveyed reaches. To the south of Hornby Park, Steeles004 tributary enters a large wooded area where natural features are more abundant. Site access restrictions prevented a thorough review of aquatic habitat within the naturally vegetated section of the channel. Although no fish were visually observed at the time of the survey, it is anticipated that the reach supports an abundance of fish given the habitat features.

Highway001

Highway001 tributary is a deep and slowly flowing reach that was surveyed on November 18, 2015. The tributary runs under Highway 401 through a large concrete box culvert, which was noted to act as a wildlife linkage. Immediately upstream of the box culvert, 3 tributaries merge, including the main stems of both tributaries on the east and west sides of the subject area (i.e. Hornby Tributary and Middle Sixteen Mile Creek Tributary). A smaller tributary flows from Sixth

Line South and converges with the main tributary immediately upstream of Highway 401. This tributary is the outlet from a stormwater management pond associated with the Halton Hills Generating Station. The surrounding landscape, apart from Highway 401, consisted mainly of meadow and scrubland with a moderate amount of canopy cover and a large natural area. Watercress was also present throughout the surveyed area, which is an indicator of cold water and possible groundwater discharge. Based on the habitat characteristics of Highway001 tributary, it is anticipated that adequate fish habitat exists within this tributary.

Trafalgar001

Trafalgar001 tributary is characterized as a small narrow swale that transects Trafalgar Road through a box culvert, approximately 400m northwest of Steeles Avenue. The surrounding landscape is dominated by grassy meadows and agricultural crops. At the time of the survey, Trafalgar001 was dry with only a small amount of water immediately downstream from the box culvert. It is unlikely that Trafalgar001 supports fish or aquatic organisms based on its habitat features.

Trafalgar002

Trafalgar002 tributary is a relatively large channel that flows through Coulson Regional Forest and transects Trafalgar Road through a box culvert, approximately 1.1km northwest of Steeles Avenue. This meandering tributary had a relatively low gradient, with a moderate amount of flow. Although the surrounding channel banks were relatively steep (80°) and high (1.1m), they were also relatively stable with a good amount of vegetation and root density, and trees throughout. In addition, watercress was observed along the banks throughout the tributary. Only the portion of Trafalgar002 upstream of Trafalgar Road was surveyed, however it was observed that the downstream reach had similar aquatic habitat features. Given these habitat features, as well as the number of fish observed, this tributary likely provides good fish habitat.

Steeles005

Steeles005 tributary was surveyed south of Steeles Avenue near the Toronto Premium Outlets shopping center. The creek runs through a large deep ravine and transects Steeles Avenue through a box culvert that was under construction at the time of the surveys. The surrounding landscape consisted of a meadow, as well as some trees and shrubs. Although Steeles005 tributary had an adequate amount of flow and depth at the time of these surveys, it did appear that it could become intermittently dry during low flow periods given that it is shallow and has several log jams creating backwater pools. Given these habitat features, as well as the number of fish observed, this tributary likely provides good fish habitat.

2.1.5.8 Fish Community

Table 2.1.9 lists the species found at each monitoring station during field surveys in mid-September, 2015 by NRSI biologists. Western Blacknose Dace (Rhinichthys obtusus) were captured at every site surveyed, while Creek Chub (Semotilus atromaculatus), White Sucker (Catostomus commersonii), and Johnny Darter (Etheostoma nigrum) were captured at 5 of the 6 sites. Species diversity was highest at site EMS-003 (located in the Steeles003 tributary, see

Drawing E3) where 10 different species were captured, and lowest at site EMS-001, where only 4 different species were captured. The only SCC that was detected was American Brook Lamprey that was captured at EMS-001 along with a Brook Trout that was captured at the same location. These species are indicative of cold water habitat. The eastern reach of watercourse through the golf course (Golf001), along which EMS-001 is located, was noted to have groundwater discharge.

The DFO Species at Risk distribution mapping (2015) indicates that Redside Dace (Clinostomus elongates), an Endangered species, is known from Sixteen Mile Creek just outside the study area, but does not identify any SAR from within the subject area. Recent correspondence with MNRF has confirmed that there is no know Redside Dace habitat within or downstream of the study area (ref. e-mail correspondence McAllister-Richter, March 2, 2016). Appendix B provides a complete list of fish species reported from the study area.

Table 2.1.9. Fish Community Assessment Results

Scientific Name	Common Name	Station ID					
		EMS-001	EMS-002	EMS-003	EMS-004	EMS-005	EMS-006
Petromyzontidae	**Lampreys**						
Lampetra appendix	American Brook Lamprey	X					
Cyprinidae	**Carps and Minnows**						
Chrosomus eos	Northern Redbelly Dace				X		
Luxilus cornutus	Common Shiner					X	X
Notropis hudsonius	Spottail Shiner			X	X		
Pimephales notatus	Bluntnose Minnow					X	X
Pimephales promelas	Fathead Minnow		X	X			
Rhinichthys obtusus	Western Blacknose Dace	X	X	X	X	X	X
Semotilus atromaculatus	Creek Chub		X	X	X	X	X
Catostomidae	**Suckers**						
Catostomus commersonii	White Sucker		X	X	X	X	X
Ictaluridae	**North American Catfishes**						
Ameiurus natalis	Yellow Bullhead			X			X
Salmonidae	**Trouts and Salmons**						
Salvelinus fontinalis	Brook (Speckled) Trout	X					
Gasterosteidae	**Sticklebacks**						
Culaea inconstans	Brook Stickleback		X		X		X
Centrarchidae	**Sunfishes and Basses**						
Micropterus dolomieu	Smallmouth Bass	X		X		X	
Percidae	**Perches and Darters**						
Etheostoma caeruleum	Rainbow Darter		X	X		X	X
Etheostoma exile	Iowa Darter		X				
Etheostoma flabellare	Fantail Darter		X	X		X	
Etheostoma nigrum	Johnny Darter		X	X	X	X	X
	Total	**4**	**9**	**10**	**7**	**9**	**9**

2.1.5.9 Brook Trout Spawning Survey

A Brook Trout spawning survey was conducted November 18, 2015 in Golf001. Water temperature during this time was 7°C, which is the optimal spawning temperature for Brook Trout (Witzel and MacCrimmon 1983). Although Brook Trout were observed within the reach during fish sampling, no Brook Trout, Brook Trout redds, or evidence of Brook Trout spawning was observed during the spawning survey within the reach surveyed. Furthermore, the majority of substrate throughout this section of creek did not appear to be suitable for Brook Trout spawning and mainly consisted of silt, sand, and clay. However, based on the potential groundwater contributions to this watercourse, this species may spawn upstream, outside of the subject area.

2.1.5.10 Benthic Invertebrates

Benthic samples were collected from 5 benthic monitoring stations (BTH) from within the subject area (Drawing E3). The results of the benthic macroinvertebrate identification are attached in Appendix B. Metrics of general environmental health and environmental water quality were calculated to assess the relative health of the monitoring sites as unimpaired, possibly impaired, or impaired. The calculation result tables are presented in Appendix B as well.

Overall, all monitoring stations had a fairly homogeneous benthic community with moderate taxa richness. However, all sites lacked Gastropoda and Oligochaetes, indicating impaired conditions. The proportion of Isopoda, a highly tolerant taxon, at all sites further suggests a possibly impaired environment. Furthermore, all sites had relatively low Shannon Wiener Diversity Index and Simpson's Diversity Index scores, indicating fairly poor, possibly impaired water quality conditions. The Hilsenhoff Biotic Index and the Family Biotic Index at all monitoring stations also suggest a poor and fairly poor environmental water quality as calculated by the family and genus level tolerance.

BTH-001

Monitoring station BTH-001 located within the Hornby Glen Golf Course (Golf001) had a general richness and percentage of sensitive taxa (EPT) that show a benthic community with a very limited collection of sensitive taxa suggesting an impaired benthic community, which is corroborated by the high proportion of tolerant taxa (Diptera average 70.19% and Chironomidae average 61.75%). The dominant taxa within the BTH-001 benthic sample were genuses of Chironomidae, occupying between 18% and 26% of the sample. Chironomidae or "non-biting midges" are a highly tolerant family of Diptera found throughout the world. The dominant functional feeding groups observed at BTH-001 varied between Collector-Gatherers and Predators, which both are functional feeding groups commonly comprised of members of the family Chironomidae, the highly tolerant group comprising the majority of each monitoring site.

BTH-002

Monitoring station BTH-002, located adjacent to Hornby Park, had a general richness and percentage of EPT that shows a benthic community with a very limited collection of sensitive taxa suggesting an impaired benthic community this is further corroborated by the high proportion of tolerant taxa (Diptera average 64.99% and Chironomidae average 58.36%). The dominant taxa within the BTH-002 benthic sample were genuses of Chironomidae, occupying between 9% and 11% of the sample. The dominant functional feeding group observed at BTH-002 was the Collector-Gatherers.

BTH-003

BTH-003 is located within Steeles003, in the Greenbelt. The general richness and percentage of EPT shows a benthic community with a very limited collection (average 3.3 and 6.320%) of sensitive taxa suggesting an impaired benthic community this is corroborated by the high proportion of tolerant taxa (Diptera average 69.78% and Chironomidae average 66.87%). The dominant taxa within the BTH-003 benthic sample were genuses of Chironomidae, occupying between 15% and 23% of the sample. The dominant functional feeding group observed at BTH-003 was the Collector-Gatherers.

BTH-004

Monitoring station BTH-004 is located along Steeles005 and has a general richness and percentage of EPT that shows a benthic community with a very limited collection (average 4 and 10.72%) of sensitive taxa suggesting an impaired benthic community this is further corroborated by the high proportion of tolerant taxa (Diptera average 72.37% and Chironomidae average 70.30%). The dominant taxa within the BTH-004 benthic sample were genuses of Chironomidae, occupying between 15% and 22% of the sample. The dominant functional feeding groups observed at BTH-004 varied between Collector-Gatherers and Predators.

BTH-005

BTH-005 provides a silty cobble habitat flowing within a fresh meadow habitat. The general richness and percentage of EPT shows a benthic community with a very limited collection (average 3.3 and 10.49%) of sensitive taxa, indicating an impaired benthic community. This is further corroborated by the higher proportion of tolerant taxa Diptera (average 40.57%), however this conclusion is somewhat offset by the more moderate proportion of Chironomidae (average 38.19%) which suggests a more moderately impaired habitat. The dominant taxa within the BTH-005 benthic sample were Gammaridae and Elmidae, occupying between 22% and 29% of the sample. The family Gammaridae or “Scuds” are a moderately tolerant group found in both salt and freshwater habitats throughout the world. The family Elmidae or “riffle beetles” are a moderately tolerant family of fully aquatic Coleoptera found throughout the world. The dominant functional feeding group observed at BTH-005 was Collector-Gatherer.

2.1.6 Significance and Sensitivity

This section provides an overview of the important natural heritage features in the subject area, an analysis of policies related to these features, and recommended buffers. This information, informed through a review of available background information, as well as results of field surveys of aquatic and terrestrial habitats, has been used to refine the boundary of the natural environment resources in the subject area. Analysis of the significance and sensitivity of existing natural features has been used to identify those features and habitats that are sensitive to disturbance and those that have been previously disturbed, impacted, or contain no natural features. Results of this analysis are intended to protect or manage the form and function of the natural heritage features in a Natural Heritage System as appropriate, in order to protect or manage these from future development impacts.

2.1.6.1 Significant Wetlands

Wetlands are important for many reasons including collecting and storing surface water and groundwater and providing habitat for plants, wildlife, and fish. Wetlands operate on a water balance, where the hydrologic character of the wetland is determined by the combination of water inflow and outflow, topography, and groundwater conditions (Mitsch and Gosselink 1993). Wetlands receive water through precipitation, surface water inflow, and groundwater discharge; and they lose water through evapotranspiration, surface water outflow, and groundwater recharge.

Wetland pockets within the subject area are very small, ranging in size from approximately 0.11 ha to 0.82 ha. Three different types of wetlands have been identified in the subject lands: White Cedar – Hardwood Mineral Mixed Swamp (SWM1-1), Graminoid Mineral Meadow Marsh (MAM2), and Cattail Mineral Meadow Marsh (MAS2-1). They have not been evaluated through the Ontario Wetland Evaluation System (OWES) (OMNR 2013e) and are too small to be evaluated on their own merit, as they are less than 2 ha in area. The nearest evaluated wetland is located 430 m northwest of the subject lands (ref. Drawing E1). That wetland is part of the Hornby Swamp Wetland Complex, evaluated as non-provincially significant. The closest PSW is the Levi's Creek Wetland Complex, located 4.3 km to the northeast. To be complexed with other wetlands, a wetland unit has to be within 750 m of another wetland, besides meeting other criteria. As such, the wetlands within the subject lands are not considered provincially significant. They are too small and too far away from a PSW to be included in another complex. In addition, they are highly impacted and do not contain any significant features.

2.1.6.2 Significant Woodlands

The Town of Halton Hills and the Region of Halton have identified the woodlands within the subject area as significant (Halton Hills 2008, Halton Region 2015a). The Official Plans set out the criteria for significance as:

- The woodland contains forest patches over 99 years old;
- The patch size of the woodland is ≥2 ha if it is located in an Urban Area, ≥4 ha if located outside an Urban Area but below the Escarpment Brow, or ≥10 ha if located outside an Urban Area but above the Escarpment Brow;
- The woodland has an interior core area of ≥4 hectares, measured 100 m from the edge of the woodland; or

- The woodland is wholly or partially within 50 m of a major creek or certain headwater creek, or within 150 m of the Escarpment Brow.

The woodlands in the subject area meet the 4 ha size criteria for woodlands outside the Urban Area. Mature plantations, such as found within Coulson Tract, are included within this definition. Significant Woodlands are included as Greenlands B on Schedule A1 of the Halton Hills Official Plan (2008).

2.1.6.3 Aquatic Resources

Watercourses within the subject area have been classified as permanent, intermittent, or ephemeral based on field observations, and are shown on Drawing E5. They have also been assigned a cold, cold-cool, cool, cool-warm, or warm water designation, based on surveys and background information, as shown on Drawing E5. Headwater drainage features (HDF) are identified as such, and are undergoing an analysis by Parish Aquatic Services (Spring 2016).

With the exception of the cold water designation for Golf001 and Golf003, which are the upstream and downstream portions of the same channel segment, all other channel segments where water was present have been designated as cool water. All ephemeral channel segments have been designated as warm water. The East Branch of the Middle Sixteen Mile Creek tributary showed some of the best habitat within the study area, with the observation of American Brook Lamprey and Brook Trout, as well as abundant watercress.

Benthic sampling indicated all the watercourses within the study area are impaired, with Steeles005, located along East Sixteen Mile Creek, being slightly less impaired than others. The greatest fish species diversity was observed within Steeles003, located along the West Branch of the Middle Sixteen Mile Creek tributary.

2.1.6.4 Significant Wildlife Habitat

The results of information collected through a background review, agency consultation, vegetation community mapping, and focused wildlife surveys were used to identify SWH within the study area. Results of the SWH screening are found in Appendix B and discussed below.

Seasonal Concentration Areas

Wildlife seasonal concentration areas are defined as areas where animals occur in relatively high densities for all, or portions, or their life cycle (OMNR 2000). These areas are generally relatively small in size, particularly when compared to areas used by these species during other times of the year.

Candidate Bat Maternity Colonies are present in the Dry-Fresh Sugar Maple-White Ash Deciduous Forest (FOD5-8) on the west side of the subject property. A large snag (approximately 100 cm dbh) was identified within this area that had numerous large cavities and could act as a maternity roost for bat species. Bat surveys and formal cavity assessments were outside the scope of this project. As this woodland is significant and is considered SWH for other reasons (habitat for a Species of Conservation Concern, see below), it will be retained. As such, further surveys to confirm bat use within this woodland are not considered necessary.

Five individual Midland Painted Turtles were observed May 4, 2015 in the western-most golf course pond. An observation of 5 Midland Painted Turtles qualifies as SWH of Turtle Wintering Areas, however, as the pond is man-made, it is not considered SWH as per the Ecoregion Criterion Schedule (MNRF 2015a). This pond, however, qualifies as Amphibian Breeding Habitat (Woodland), as discussed below.

Rare Vegetation Communities

The SWHTG (OMNR 2000) identifies rare vegetation communities as those which are designated provincially rare or rare within a planning area. Vegetation communities with the poorest representation within the planning area may also be considered significant, and those that are rare or could be lost due to development are considered highly significant. The highest priority sites are those that contain S1-S3 ranked vegetation communities. A vegetation community may also be considered locally rare if it represents less than 3% of the remaining natural area or if it is found at 5 or fewer sites within the local area. Higher quality sites are relatively undisturbed. Rare communities supporting other SWH are considered the most significant.

No rare vegetation communities were identified within the study area during either the background review or the 3 season vegetation inventories.

Specialized Wildlife Habitat

Specialized habitats include those that support wildlife species with highly specific habitat requirements, areas with exceptionally high species diversity, and/or areas that provide habitat that greatly enhances a species' chance of survival (OMNR 2000). The SWHTG indicates that most specialized habitats have not been formally identified or mapped by any agency (OMNR 2000).

Amphibian Breeding Habitat (Woodland) was identified in the subject area based on the results of the anuran call surveys carried out in April, May and June 2015. Point counts ANR-001, ANR-002, ANR-007, ANR-008 (ref. Drawing E2) recorded sufficient diversity and abundance of frogs to be confirmed significant. Tetraploid Gray Treefrog and Spring Peeper were both recorded from these sites in full chorus. The SWH is the wetland area plus woodlands within a 230 m radius of the wetland, as well as a travel corridor connecting the wetland to the woodland. Confirmed SWH is mapped on Drawing E6.

The pond at ANR-006 (Drawing E2) is located further than 120 m from a woodland. It does not meet the criteria for Amphibian Breeding Habitat (Wetland).

Habitat for Species of Conservation Concern

Confirmed habitat for SCC is considered SWH (OMNR 2000). Eastern Wood-Pewee and Monarch were observed within the subject area. Eastern Wood-Pewee was found to be probably breeding within the Mixed Plantation (CUP2) in the Halton Regional Forest based on the presence of a pair on June 29, 2015. Eastern Wood-Pewee is listed as Special Concern both provincially and nationally (MNRF 2015b; Government of Canada 2015). Suitable breeding habitat for this species is found throughout the subject area within forested habitats. Confirmed SWH for these species is included on Drawing E6.

A Monarch butterfly and one Monarch caterpillar were found within the golf course property on September 1 where small amounts of Common Milkweed (Asclepias syriaca) persist adjacent to the ponds. Monarch is listed as Special Concern both provincially and nationally (MNRF 2015b; Government of Canada 2015). SWH is not mapped for this species within the subject area, but instead it is recommended that Milkweed plants (Asclepias species) be seeded in buffer areas and open areas during and following development.

Animal Movement Corridors

Animal movement corridors are only addressed within Ecoregion 7E when Amphibian Breeding Habitat (Wetland) is confirmed. As this habitat was not identified, there are no Animal Movement Corridors within the subject area. Wildlife linkages are addressed separately below.

2.1.6.5 Habitat of Endangered and Threatened Species

A detailed screening was carried out for SAR with the potential to occur in the subject area based on habitat requirements and availability of these habitats within the study area (Appendix B). Field surveys were conducted to assess which SAR are found within the subject area.

Barn Swallows were observed on numerous occasions throughout the subject area foraging over the golf course, agricultural fields (AG), and meadows (CUM) (ref. Drawing E4). Barn Swallow are considered Threatened provincially and nationally (MNRF 2015b; Government of Canada 2015). In Ontario, Barn Swallows normally nest in human structures including buildings, barns, bridges, and culverts (Heagy et al. 2014). Although no nests were identified, suitable nesting sites exist throughout the subject area. Barn Swallow regulated habitat extends 200 m from the nest site where suitable foraging habitat exists, as per section 23.5 of Ontario Regulation 242/08 of the Endangered Species Act.

Bobolink and Eastern Meadowlark were both observed within the same general area north of Trafalgar Road (east of the Regional forest) in a grassy field adjacent to agricultural lands. Both species are considered Threatened provincially and nationally (MNRF 2015b; Government of Canada 2015). Bobolink was observed both during the migration period (May 4, 2015) and during breeding bird surveys (June 1, 2015). Eastern Meadowlark was observed during the migration period only (May 4, 2015). Habitats within the subject area are not considered optimal for either species due to the small, fragmented nature of the open fields, and as large fields are planted in soy and corn, unsuitable for these species.

During field studies, NRSI biologists identified 3 Butternut trees within the Halton Regional Forest in the Black Walnut Cultural Plantation (CUP1-3). Butternut are Endangered both provincially and nationally (MNRF 2015b; Government of Canada 2015). All 3 trees were completely dead. Despite further searches and vegetation inventories, live Butternut trees were not found.

It is likely that Little Brown Myotis and Northern Myotis (Myotis septentrionalis) may be found within the subject area based on their extent through southern Ontario and as the information in the Mammal Atlas (Dobbyn 1994) is dated and did not include extensive field surveys. Both species are Endangered provincially and nationally (MNRF 2015b; Government of Canada 2015). Targeted surveys for bats were not conducted as part of this study, but may be required in the future, especially for development activities where tree removal is proposed.

2.1.6.6 Linkages

A fundamental objective of a Natural Heritage System (NHS) is to provide linkages that are ecologically functional and maintain natural interactions between plants and animals. A linkage should contain high quality habitat that is suitable for the species that are intended to use the linkage (NSEI 2007). The Sustainable Halton document discusses and recommends a Regional NHS (RNHS), a large-scale system of natural features and linkages that provides a general framework for the development of a local NHS. Within Halton, there are several large scale natural features and linkages that include the Niagara Escarpment as well as 4 major watercourses and valley systems (Bronte Creek, Sixteen Mile Creek, Credit River, and Blue Springs Creek). These natural features were used as linkages to connect the RNHS with the larger, inter-regional framework (NSEI 2007). The RNHS sets out directives for linkage widths where they connect with the inter-regional framework, as well as local linkage width recommendations. In general, the minimum recommended width for a regional linkage is 300 to 400 m wide, while a local linkage is recommended to be a minimum of 60 to 100 m wide. The concept of redundancy has been followed in the development of the RNHS, which includes several linkages between natural features and assumes that not every linkage will be used by all species at all times. Providing multiple linkages in the RNHS increases the likelihood of plant and animal migration, and provides greater assurance that species will adapt to changes in the landscape and a changing climate (NSEI 2009). The RNHS as delineated by NSEI (2009) is shown on Drawing E1.

The Region of Halton incorporated the results of the Sustainable Halton studies into an Official Plan amendment (ROPA 38). According to ROPA 38, the overall goal for the NHS in Halton, which includes the Greenbelt NHS and the RNHS, is to increase the certainty that biological diversity and ecological functions within Halton will be preserved and enhanced for future generations (Halton Region 2015a). Map 1G of ROPA 38 identifies the RNHS, as well as the Greenbelt NHS, and key features within each NHS. Enhancement lands are part of the RNHS within the study area, as shown on Map 1G (see Appendix B).

The natural features and linkage opportunities within the subject area are very limited. There are much greater linkage opportunities outside the subject area, predominately through the Greenbelt Plan area to the west, along the East Sixteen Mile Creek corridor to the east, and through a series of natural features (woodlands, wetlands, watercourses) in close proximity to each other to the northwest of the subject area. The box culvert underneath Highway 401 was noted to provide wildlife movement. Tracks of Raccoon and White-tailed Deer were observed in the culvert, indicating these species, and potentially others, cross under the highway through this culvert. Cliff Swallow (Petrochelidon pyrrhonota) nests were observed within the culvert as well.

2.1.7 Natural Heritage System

The Sustainable Halton project was undertaken by the Region of Halton that included the identification of a NHS, which is intended to achieve long term protection of natural heritage features and functions (NSEI 2009). The RNHS developed through this project and identified in the Region's Official Plan (2014) and ROPA 38 (2015) is approximate, and it is recognized that additional studies will refine the boundaries through field verification (ref. Section 116.1 in ROPA 38). As such, the work completed through the Premier Gateway Phase 1B Employment Area Secondary Plan Scoped Subwatershed Study, will refine the RNHS. The current RNHS is shown in Drawing E1.

The areas included in the RNHS include woodlands, wetland, and watercourses, along with appropriate buffers, linkages, and enhancement areas identified by NSEI (2009) and shown on Map 1G of the Official Plan (Appendix B). Section 115.3 of ROPA 38 (Halton Region 2015a) lists the components of the RNHS as the following:

- Key features, including:
  - Significant habitat of Endangered and Threatened species
  - Significant wetlands
  - Significant coastal wetlands
  - Significant woodlands
  - Significant valleylands
  - Significant wildlife habitat
  - Significant Areas of Natural and Scientific Interest
  - Fish habitat
- Enhancements to key features, including Centres for Biodiversity
- Linkages
- Buffers
- Watercourses
- Wetlands

Sustainable Halton (NSEI 2009) established 30 m buffers from all features, which is consistent with Greenbelt buffers and what many other municipalities and agency partners are promoting.

The RNHS will be refined through the Secondary Plan Process. Refinements may include:

- Removal of the residences along Sixth Line and from within the Coulson Tract.
- Pending outcome of the Headwater Drainage Feature (HDF) analysis, potential movement of some linkages that are based on these features. The linkages may be moved to avoid existing residences; bolster larger, existing natural heritage features; and / or to provide further east-west linkage opportunities.
- Inclusion of SWH.
- Buffers will not cross roads.

2.1.8 Summary of Findings

The RNHS for the subject area is shown on Drawing E1. The NHS will be refined through the Secondary Plan process and will include Significant Woodlands, fish habitat, and SWH, as well as enhancement lands and linkages identified in the RNHS through Sustainable Halton (NSEI 2009). Features within the NHS will be protected with 30 m buffers. Once the HDF analysis is complete, this will factor into the protected areas within the subject area. SAR will need to be considered through more detailed study at the development stage, including survey for bats. Barn Swallows were observed and their foraging habitat needs to be protected along with nest sites.

2.2 Hydrogeology

2.2.1 Scope Overview

It is important to understand the interrelationship between the hydrogeologic conditions, the use of groundwater for anthropogenic needs and the subwatershed ecosystem in order to assess and develop targets and controls for potential impacts from land use changes and to enhance the linkages where appropriate.

The primary objectives for the groundwater component of the subwatershed study include:

- Identify water quality and quantity constraints associated with surface water and groundwater features within and adjacent to and downstream of the Primary Study Area, including their interaction and associated ecological and hydrologic functions.
- Identify groundwater resources and constraints to development to ensure functions are maintained during and following development.

A background review of reports and datasets has been conducted. The relevant reports are documented in Section 2.2.2. The groundwater component of this study includes a minor field component to carry out spot baseflow measurements at select sites within the study area to assess potential groundwater contributions. This minor field program was also integrated with the streamflow and groundwater discharge/seepage observations from the hydrology, geomorphological and aquatic field programs.

2.2.2 Background Information Review

The following reports were reviewed to obtain background hydrogeologic data and interpretation.

- Sixteen Mile Creek Watershed Plan.
- Ministry of the Environment and Climate Change (MOECC) Water Well Records.
- 401 Corridor Integrated Planning Project, Town of Halton Hills – Scoped Subwatershed Plan (Dillon Consulting 2000).
- Tier 1 Water Budget and Water Quantity Stress Assessment for Halton-Hamilton Source Protection Region and Tier 2 Water Budget and Water Quantity Stress Assessment for the Upper West Branch of Sixteen Mile Creek and Middle Spencer Creek Watersheds (Halton-Hamilton SPC 2010).
- Vulnerability Analysis for the Milton and Campbellville Wellfields, Regional Municipality of Halton, Ontario (Earthfx 2010).
- Assessment Report Halton Region Source Protection Area (Halton-Hamilton SPC 2015).

- Halton Aquifer Management Plan, 1995.
- Geotechnical Investigation Retail Diesel Station (Peto MacCallum Ltd. August, 2004)
- Geotechnical Investigation Proposed Generating Station TCP (Senes Consultants Ltd., July 2006).
- Geotechnical Investigation Proposed Industrial Development (Trow Associates Inc., September 2006).
- Geotechnical Investigation 13722 Steeles Avenue West (Trow Associates Inc., April, 2007).
- Halton Hills Hydro MTS#1 ESR (Senes Consultants Ltd., August 2008).
- Preliminary Geotechnical Investigation Commercial Development 13722 Steeles Avenue West (Golder Associates, May 2011).
- Technical Memorandum – Hydrogeologic Conditions, 13722 Steeles Avenue West (Golder Associates Ltd., May 2011).
- Water Well Survey – Trafalgar Road and Steeles Avenue (AMEC, October 2011).
- Private Well Monitoring Report Steeles Avenue Project Halton Hills (Terraprobe Ltd., January, 2006).
- Geotechnical Investigation Steeles Avenue Watermain Sanitary Sewer and Forcemains From East of 5th Line South to Trafalgar Road (Terraprobe Ltd., Sept. 2005).
- Hydrogeological Investigation for the Rural Community of Honby (Hydrology Consultants, July, 1983).
- Various Halton Region Memorandum concerning Halton Hills Pump Station No. 2 Construction Impact on Wells.

2.2.3 Field Reconnaissance

A limited field investigation has been carried out for the groundwater component including spot baseflow measurements and baseflow sampling.

General stream flow measurement locations were selected prior to the start of the field work to capture individual stream branches, as well as areas where evidence of groundwater discharge had been previously reported. The exact locations were selected by staff in the field, based on the availability of good quality sites (relatively vegetation and obstruction free, sufficient flow and water depth to collect readings, etc.). The stream flows were intended to capture baseflow conditions where possible and the dates selected for collecting these flows were based on the Ontario Ministry of Natural Resources standard protocol, requiring a minimum period of 72-hour with no precipitation preceding the collection of measurements.

At each location, the stream channel width was measured by using a tape measure suspended between two wooden stakes inserted on either side of the stream, perpendicular to the stream flow direction. The stream section was then divided into roughly 10 equal segments where measurements were then collected using a HACH FX950 Flow Meter.

Spot baseflow measurements carried out by Amec Foster Wheeler staff on August 26, 2015 are reported in Table 2.2.1. Locations are shown on Figure GW1.

Table 2.2.1 Spot Baseflow Measurements	
26-Aug-15	
Site	Flow l/s
1	28.5
2	11.7
3	36.2
4	18
5	27.9
6	dry
7	6.7
8	dry

Additionally, a grab sample grab sample was collected at Site 3 during a site visit on December 7th, 2015. The site was selected where evidence of groundwater discharged had been previously noted. Wading to take the sample from the center of the stream was not required due to the relatively narrow stream channels. The sample was collected while wearing nitrile gloves into bottles provided by the laboratory. Where sample bottles contained a preservative, the samples were collected using an additional bottle that did not contain a preservative and the contents were then transferred into the bottle with preservative. The collected samples were delivered to the laboratory for analysis within 24 hours of sample collection. Water quality results are shown in Table 2.2.2.

Table 2.2.2 Groundwater Quality Sampling Results

	UNITS			UNITS	
Calculated Parameters			**Metals**		
Anion Sum	me/L	7.75	Dissolved Aluminum (Al)	ug/L	<5.0
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	280	Dissolved Antimony (Sb)	ug/L	<0.50
Calculated TDS	mg/L	430	Dissolved Arsenic (As)	ug/L	<1.0
Carb. Alkalinity (calc. as CaCO3)	mg/L	4.8	Dissolved Barium (Ba)	ug/L	210
Cation Sum	me/L	8.47	Dissolved Beryllium (Be)	ug/L	<0.50
Hardness (CaCO3)	mg/L	390	Dissolved Boron (B)	ug/L	21
Ion Balance (% Difference)	%	4.43	Dissolved Cadmium (Cd)	ug/L	<0.10
Langelier Index (@ 20C)	N/A	1.29	Dissolved Calcium (Ca)	ug/L	110000
Langelier Index (@ 4C)	N/A	1.04	Dissolved Chromium (Cr)	ug/L	<5.0
Saturation pH (@ 20C)	N/A	6.98	Dissolved Cobalt (Co)	ug/L	<0.50
Saturation pH (@ 4C)	N/A	7.23	Dissolved Copper (Cu)	ug/L	<1.0
Inorganics			Dissolved Iron (Fe)	ug/L	<100
Total Ammonia-N	mg/L	<0.050	Dissolved Lead (Pb)	ug/L	<0.50
Conductivity	umho/cm	740	Dissolved Magnesium (Mg)	ug/L	30000
Dissolved Organic Carbon	mg/L	1.3	Dissolved Manganese (Mn)	ug/L	5.8
Orthophosphate (P)	mg/L	<0.010	Dissolved Molybdenum (Mo)	ug/L	<0.50
pH	pH	8.27	Dissolved Nickel (Ni)	ug/L	<1.0
Dissolved Sulphate (SO4)	mg/L	40	Dissolved Phosphorus (P)	ug/L	<100
Alkalinity (Total as CaCO3)	mg/L	280	Dissolved Potassium (K)	ug/L	1900
Dissolved Chloride (Cl)	mg/L	34	Dissolved Selenium (Se)	ug/L	<2.0
Nitrite (N)	mg/L	<0.010	Dissolved Silicon (Si)	ug/L	5300
Nitrate (N)	mg/L	4.45	Dissolved Silver (Ag)	ug/L	<0.10
Nitrate + Nitrite (N)	mg/L	4.45	Dissolved Sodium (Na)	ug/L	15000
			Dissolved Strontium (Sr)	ug/L	340
			Dissolved Thallium (Tl)	ug/L	<0.050
			Dissolved Titanium (Ti)	ug/L	<5.0
			Dissolved Uranium (U)	ug/L	2.6
			Dissolved Vanadium (V)	ug/L	<0.50
			Dissolved Zinc (Zn)	ug/L	<5.0

2.2.4 Characterization and Analysis

Physiography

The physiographic description of an area commonly includes summaries of topography, landform, drainage and the occurrence of surface soils types along with an overview of the depositional and erosional history that created the landform. Geologic descriptions commonly detail the overburden and bedrock composition and form below the surface as well as the relationship of the geology to the physiography of that area. Together these two descriptions are used to characterize the physical setting of a study area and form the basis of any groundwater interpretation. Within the study area, the physiography and geology are so very closely related that for the purposes of this study, the physical setting overview is a synthesis of both overall characteristics

The Gateway study area is situated within the Peel Plain physiographic region (Chapman and Putnam, 1984). The South Slope region is adjacent to the study area to the north. The shape of the bedrock surface as well as the occurrence of the overburden units, which make up the above region, is a result of the repeated glacial advances and retreats which have occurred in southern Ontario. The most recent glacial advance and retreat formed much of the land surface and geology present in the area today. This event is referred to as the Wisconsin Glaciation, and was accompanied by various meltwater lakes and channels. The last glacial retreat ended between 10,000 and 20,000 years ago, blanketing the area in glacial till sediments.

The Peel Plain is characterized by a gently sloping glacial till plain through the majority of the study area from north-west to south-east with the exception of an elevated area in the north at 8th Line.

Geology

Geologic mapping prepared by the Ontario Geological Survey (OGSEarth) and well records from the MOECC were reviewed and assessed to present the local surficial geology and stratigraphy in order to develop a conceptual model of the hydrostratigraphy and identify potential aquifers in the study area. A total of 235 MOECC well records for water wells and exploration wells within and 500 m adjacent to the study area were utilized. Well locations within and adjacent to the study area are presented on Drawing GW1 and GW5. The well records can be found in Appendix C.

Surficial and Overburden Geology

The surficial geology is presented in Section 2.5, Figure 2.5.2 (OGSEarth). The surficial geology within the study area consist primarily of fine grained sediments characterized by the silty clay to silty sand till (Halton Till) and glaciolacustrine silt and clay. This characterization is consistent with well records reviewed for this study. The thickness of overburden within the study area varies from 6 m to greater than 29 m. Three geological/hydrostratigraphic cross-sections were prepared (Drawings GW2, GW3, and GW4); the locations can be found on Drawing GW1. The thicker overburden is associated with a bedrock valley in the central portion of the study area that extends south of Steeles Avenue (discussed below). All three cross-sections demonstrate the following significant overburden characteristics.

- A significant thick sequence of fine grained material extending from the ground surface.
- Discontinuous sand lenses within this fine grained sequence.
- A more continuous basal sand and gravel unit at the bedrock interface with a thicker sequence within the bedrock valley.

Bedrock Geology

The underlying bedrock with the study area is the Queenston Shale. Bedrock was intercepted in 62 wells. The bedrock surface was encountered between 6 m and greater than 29 m below ground surface (mbgs) within and adjacent to the study area. Bedrock elevations interpreted from the well records are presented on Drawing GW6. Two minor bedrock valley systems appear to enter from the north and east of the study area and connect with main bedrock valley which appears to extend to the south-east along Hornby Road and deepening towards and past Steeles Avenue.

Hydrogeology

Local Groundwater Use

Groundwater supplies in the area are obtained from both overburden and bedrock wells. The wells are either drilled or bored. There are 155 overburden wells of which 69 are bored. There are 62 bedrock wells. The drilled overburden wells are completed within the more permeable sand lenses or the basal sand and gravel. The bored wells are generally restricted to being completed in the finer grained sediments.

The best well yields are found in the wells which are drilled in the basal sand and gravel unit but sufficient quantities exist within the wells completed in the sand lenses and the shale bedrock as previously reported in the "Hydrogeological Investigation for the Rural Community of Hornby", (Hydrology Consultants, July, 1983).

The average groundwater quality reported in the 1983 study indicates the bedrock water quality to be more mineralized as would be expected with elevated hardness (950 mg/l), chloride (260 mg/l) and sulphate (700 mg/l). The overburden water quality was better with values for hardness (300 mg/l), chloride (75 mg/l) and sulphate (90 mg/l). A private well survey carried out by Terraprobe Ltd. (January, 2006) shows similar results with the exception of elevated sodium and chloride in a number of bored wells which may reflect road salt.

Hydraulic Conductivity

The hydraulic conductivity for a particular overburden or bedrock unit provides an indication of the ability to transmit water. The hydraulic conductivities in the overburden units tend to correlate with the grainsize, with coarser grained sediments having a higher hydraulic conductivity. The hydraulic conductivity of the shale bedrock unit is generally low but can be higher where the rock is weathered and fractured which may occur within several metres of the bedrock surface.

Conceptual Groundwater Flow

Water from precipitation percolates or infiltrates into the ground until it reaches the water table. Areas where water moves downward from the water table are known as recharge areas. These areas are generally in areas of topographically high relief. Areas where groundwater moves upward to the water table are known as discharge areas. These generally occur in areas of topographically low relief, such as stream valleys. Groundwater that discharges to streams is the water that maintains the baseflow of the stream. Wetlands may be fed by groundwater discharge.

There are different types and rates of recharge and discharge. Water percolating into the ground at a specific location may discharge to a small stream a short distance away. This is local recharge and local discharge. Some water may recharge in a certain area and discharge to a larger river basin a long way from the source of recharge. This is known as regional recharge and regional discharge.

Permeable geologic materials that can transmit significant quantities of water are known as aquifers. Aquifers are "water bearing" formations meaning that water can be easily extracted from these units. The less permeable units are known as aquitards, and although water can move through these units, it moves slowly and it is difficult to extract water from these units. How these aquifers are connected within a hydrogeologic setting is what controls much of the movement of groundwater. Within the study area where the overburden is less permeable an aquitard exists and the basal sand and gravel and shallow bedrock acts as the primary aquifer. The sand lenses will act as limited aquifers but to a lesser extent if they are more discrete. These hydrogeologic units are present on the cross-sections (Drawings GW2, GW3, and GW4)

A delineation of the flow system(s) in this way will identify where groundwater originates, where it discharges and the most prominent paths it travels between these points (e.g., the aquifer pathways or more permeable hydrostratigraphic units). Having done this, one can assess the relative sensitivity of the linkage from the groundwater system to the aquatic or terrestrial systems. Knowing the level of sensitivity of the receptor, the impacts of particular types and scales of land uses or land use changes on the groundwater flow system and other linked ecosystem components can be assessed. Best management practices can then be developed to prevent unacceptable impacts from occurring.

Estimates of shallow groundwater flow directions have commonly utilized water well records where detailed monitoring wells are absent and usually reflect a groundwater flow trend that is averaged over many years and at a slightly greater depth. In order to present a water table map wells with depths less than 20 m were chosen. Although wells that are screened deeper may reflect lower water levels due potential downward gradients an areal sampling reflecting a higher number of wells was necessary to develop a potential water table map.

A water table map and directions of shallow groundwater flow is presented on Drawing GW6. The water table map shows horizontal groundwater flow converging from the north and west within the study area and subsequently flowing to the south-east with local components towards various stream reaches.. Water table depths within the Halton Till in other study areas are consistently within the upper 2 m with a 1 m – 2 m seasonal variation. The actual water table will likely reflect the local topography and hence any lateral flow will follow the local variations in topography as generally indicated on Drawing GW6.

A potentiometric water level surface was developed for the bedrock and is found on Drawing GW7. Flow within the shallow bedrock appears move from the north and west into the study area and then to the south-east generally following the bedrock surface.

Given that it is common to have the water table within the upper 2 m of ground surface in the Halton Till a comparison to the water levels in the overburden wells presented on the cross-sections indicates that there is generally a downward hydraulic gradient. It is also shown that significant upward gradients can also occur as demonstrated by the existence of flowing wells within the study area. These wells are marked on Drawing GW1. Additional flowing wells are known to exist in area located within the extension of the bedrock valley to the southeast.

It is proposed that a larger groundwater connection feeds the bedrock valley and associated basal aquifer in the study area thus providing the hydraulic gradient driving the flowing wells. This potential groundwater hydraulic connection within the study area was demonstrated during previous construction activities. A backfilled and sealed borehole originally drilled to investigate stratigraphy and groundwater conditions for Halton Hills Pumping Station No. 2 was believed to have failed during a subsequent excavation in the area in 2007. In order to control significant inflows of water to enable construction of the pumping station a dewatering program was enacted. This subsequent dewatering appeared to impact 56 private wells in the area north of Steeles Avenue from 5th Line to Trafalgar Road. Based on the material available for this study the locations and depths of the wells interfered with is not known.

On a more local scale shallow groundwater may be influenced by fractures within the Halton Till.
A significant amount of research has focused on the hydrogeology of fractured glacial tills and was obtained through a literature review carried out for a subwatershed study in Northwest Brampton (AMEC, 2011). The following are some of the hydrogeologic factors that potentially relate to fracturing in the till in the study area:

- Frequency and potential depth of fractures can depend on the clay/silt/sand content, average precipitation and temperature
- Fractures can occur up to 6 metres but they are likely more prevalent within the upper 2-3 m of till
- The lateral connection within the upper fractured till can be relatively significant, compared to the massive till, but is generally localized (10's of metres).
- Horizontal flow patterns in the upper fractured till will be controlled by local depressional topography and restricted by underlying more massive and less permeable till where it exists
- Vertical groundwater flow below the upper fractured till is generally low unless more permeable, interconnected lenses exist
- Evapotranspiration can significantly reduce water levels in the upper fractured till
- Potential lateral flow in the upper fractured till reduces more quickly as the water levels drop due to less fracture with depth
- Gradients can be reversed within the underlying massive till (downward to upward) as water levels in the upper fractured till lower thereby reducing recharge to depth

As presented above the local hydrostratigraphy may include more permeable sand lenses. These sand lenses not only provide sources of water for local domestic wells but can provide extended hydraulic pathways for groundwater movement if they are interconnected. If these interconnections are of a larger scale they could potentially a more direct connection from the lower basal sand and gravel and shallow bedrock unit through the overburden aquitard. This potential larger scale connection through the sand lenses can be seen in Cross-Section CC' (Drawing GW4) between Trafalgar Road and Steeles Avenue.

Recharge and Discharge

The amount of recharge within the study area is limited to a greater extent by the lower permeability of the surficial sediments. The range of recharge values associated with these surficial units has been reported on the order of 80-110 mm/year (Dillon Consulting 2000). The recharge values may be higher or lower depending the clay and silt content within surficial unit. Higher depressional focused recharge can also occur in topographic lows. Recharge within the study area is expected to provide a local shallow component flow but is likely limited to relatively short distances. Local recharge that does not discharge to local stream reaches will eventually recharge the deeper sand lenses potentially the basal aquifer and upper bedrock where downward hydraulic gradients persist.

Groundwater discharge appears to occur in various stream reaches based on stream flow and water temperature measurements (Drawing E5) and observations of water cress (Table 2.1.8). These reaches include Sixth001, Golf001, Golf003, Steeles002, Hwy001 and Traflgar002. Golf001 was observed to be the most significant area of groundwater discharge where spot baseflow measurements exhibiting significant gains in the upper and lower portion of this reach (Table 2.2.1). A number of these reaches also appear to have more permeable streambeds (Table 2.1.8). The baseflow water quality sample collected at the lower end of Golf001 exhibits the same general chemistry as the overburden well chemistry described previously indicating an overburden source for groundwater discharge. Given the perennial nature of a number of these reaches, in particular Golf001, it is proposed that there may be some level of connection through the upper overburden to the deeper system. The potential linkage of interconnected sand lenses combined with the strong upward gradients may provide this connection. Additionally, it is noted that the Hornby Golf Course is tiled (pers. com. J. Henderson) which may add to a component of the perennial nature of the Golf001.

2.2.5 Summary of Findings

A summary of the significant hydrogeologic findings for the preliminary characterization include the following:

- The study area is within the Peel Plain physiographic region.
- The surficial overburden consists primarily of the clay silt, silty sand Halton till and glaciolacustrine silt and clay. Within the Halton till discrete silt layers and sand pockets exist.
- The overburden is underlain by the Queenston shale. The upper portions of the Queenston shale can be extensively fractured.
- A buried bedrock valley is known to exist within and south of the study area.
- The overburden thickness ranges from 10 m to 30 m with the thickest sections correlating with the buried valley.
- A more extensive silty-sand to sand and gravel basal unit is present directly overlying the bedrock and appears to be thicker within the bedrock valley.

- Groundwater recharge values have been reported to be in the range 80 mm/yr-110 mm/yr.
- Groundwater supplies are obtained from both the over burden and the bedrock. Lager diameter dug or bored wells and drilled wells in the basal sand and gravel provide water in the overburden wells. The upper fracture shale provides water for the drilled bedrock wells. Wells generally provide sufficient quantities of quality water.
- Flowing wells in the basal sand and gravel and upper bedrock exist in the southern portion of the study area indicating significant upward gradients.
- Hydraulic connection of this lower unit to local wells, both overburden and bedrock, appears to have been demonstrated during a construction dewatering along Steeles Avenue east of Sixth Line.
- Groundwater discharge appears to occur in various stream reaches based on stream flow and water temperature measurements and observations of water cress.

2.3 Hydrology

2.3.1 Scope Overview

The baseline characterization of the surface water hydrology has been conducted in accordance with the approved work plan for the Scoped Subwatershed Study. The surface water component has involved a desktop review of available information from various sources (i.e. Town, Conservation Halton, Region, etc.), the implementation of a field program to address data gaps and to complement the currently available information databases and conducting hydrologic analyses to inform the characterization of the stream system within the study area, assess flood and erosion potential, and establish a water budget for existing baseline conditions.

2.3.2 Background Information Review

Background information has been provided for use in this study by way of reports and mapping. Additional information from Amec Foster Wheeler's internal resources have also been assessed and reviewed for use in the study. The following summarizes the key information received/gathered for developing the baseline characterization of the surface water hydrology.

Reports

The following reports represent the primary documents which are being referenced in developing this baseline characterization for the Premier Gateway Lands:

Sixteen Mile Creek Areas 2 and 7 Subwatershed Update Study (AMEC et. al., May 2015 Draft).

Ninth Line Lands 'Scoped' Subwatershed Study and Ninth Line District Floodplain Mapping (Phillips Engineering, January 2015 Draft).

Calloway Reit Halton Hills Subwatershed Impact Study Report -13722 Steeles Avenue West (Geomorphic Solutions, January 2012).

Halton Hills Hydro Municipal Transformer Station (MTS) #1 Environmental Study Report (Geomorphic Solutions, January 2012).

Calloway Reit Steeles Ave West and Trafalgar Road - Proposed Outlet Centre Transportation Impact Study - 13722 Steeles Avenue West (BA Group Transportation Consultants, April, 2011).

Subwatershed Impact Study Halton Hills Generating Station (Senes Consultants, March 2008).

Stormwater Management Facility Design Brief Halton Hills Power Generation (Phillips Engineering, October 2008).

Development Area C 401 Corridor Integrated Planning Area Subwatershed Impact Study (Sernas Associates, September 2007).

Final Environmental Review Report Halton Hills Generating Station (Senes Consultants, February 2007).

North 16 District 'Scoped' Subwatershed Study and Ninth Line District Floodplain Mapping (Philips Engineering Ltd., December 2004).

401 Corridor Integrated Planning Project Scoped Subwatershed Plan (Dillon Consulting Limited, March 2000).

Sixteen Mile Creek Areas 2 and 7 Subwatershed Planning Study (Philips Planning and Engineering Limited, January 2000).

Sixteen Mile Creek Watershed Plan (Gore and Storrie Limited, February 1995).

Mapping

The following mapping, provided for use in this study, has been used to develop the baseline characterization of the surface hydrology for the Premier Gateway Lands:

- 2013 Aerial Photography of Premier Gateway Lands
- 2011 Contour mapping (0.25 m) for Premier Gateway Lands
- Watercourse mapping provided by Town of Halton Hills
- Parcels provided by Town of Halton Hills
- Street layers provided by Town of Halton Hills
- Surficial soils (Ontario Geospatial Data Exchange)
- 2002 contour mapping of Sixteen Mile Creek Watershed
- Zoning Layers
- Generic Regulations
- Municipal Structure Inspection Form for Hornby and Sixth Line Bridge Crossings
- Culvert data for Hornby Road
- HEC-2 Cross Section Location Plan
- Rain gauge Layer

Models

- HSP-F Hydrologic model used for Sixteen Mile Creek Areas 2 and 7 Subwatershed Update Study (AMEC, November 2015).
- HEC-2 Hydraulic model used for developing floodline mapping for Sixteen Mile Creek (Conservation Halton).
- HEC-RAS Hydraulic model used for design of Hornby Tributary Bridge on Steeles Avenue (MMM Group Ltd., June 2013).

- SWMHYMO Hydrologic Model used for Stormwater Management of Halton Hills Power Generation Station (Phillips Engineering Ltd., October 2008).

2.3.3 Field Reconnaissance

Field Monitoring Program for rainfall and streamflow has been conducted to provide an understanding of the current hydrologic conditions within the study area. The location of the gauges was reviewed consultatively with Conservation Halton and the Town based on a variety of considerations which resulted in the selection of the open watercourse downstream of Premier Gateway Lands. Drawing WR1 presents the location of the rainfall and stream flow gauge installed as part of current study.

Surface water monitoring (including both rainfall and streamflow monitoring) commenced on June 17, 2015 and was concluded on November 30, 2015 when the equipment was removed from the field prior to freeze-up. A tipping bucket rain gauge and data logger are located on the roof of a storage shed in Hornby Park in Halton Hills logging data at a 15 minute interval. Due to an equipment malfunction the rain gauge did not properly record rainfall events during the events which occurred between August 2, 2015 and August 10, 2015.

A Solinst™ Levelogger sensor has been employed for data logging in the watercourse that runs throughout Hornby Park in Halton Hills. This unit recorded the total pressure head and temperature within the creek at 15 minute intervals. Velocity metering has been conducted to obtain in-stream velocities and corresponding water depths during the following storm events:

- ***June 24, 2015:*** No rainfall occurred on this day. The flow rate was measured at 0.18 m^3/s at a depth of 0.41 m.
- ***August 4, 2015 rainfall event:*** Rainfall was not recorded properly. Nearby Scotch Block Reservoir gauge recorded 2.6 mm rainfall over 4 hour period. Measured flow rate at Hornby Park gauge was 0.22 m^3/s at a depth of 0.43 m.
- ***August 20, 2015 rainfall event:*** 45 mm of rain over a time period of approximately 1 hour. The measured flow rate was 0.15 m^3/s at a depth of 0.45 m.
- ***September 11 to September 13, 2015 rainfall event:*** Approximately 78 mm of rain recorded over a time period of approximately 48 hours. The measured flow rate was 0.12 m^3/s at a depth of 0.44 m.
- ***October 28, 2015 rainfall event:*** Approximately 34 mm of rain over a time period of 17 hours. Two records were taken over this time period. The flow rates were measured at 0.47 m^3/s at a depth of 0.6 m, and 0.73 m^3/s at 0.65 m depth.
- ***October 29, 2015:*** No rainfall occurred on this day. The flow rate was measured at 0.68 m^3/s at a depth of 0.64 m.

Velocity metering has been conducted within the channel at the stream flow monitoring location during both dry and wet weather events to establish velocities at various depths. Corresponding flow areas have been calculated based upon field surveyed cross-sections at the gauge location and recorded flow depths at the time the velocity measurements were obtained. Instantaneous observed flows have been calculated as the product of the measured velocities during the event and the corresponding flow area. A local HEC-RAS hydraulic model has been developed for the monitoring location to develop a stage-discharge relationship at the site, and the roughness coefficients adjusted to best reproduce the observed depth at the corresponding discharge values. The rating curve for the continuous flow monitoring location is presented in Figure 2.3.1.

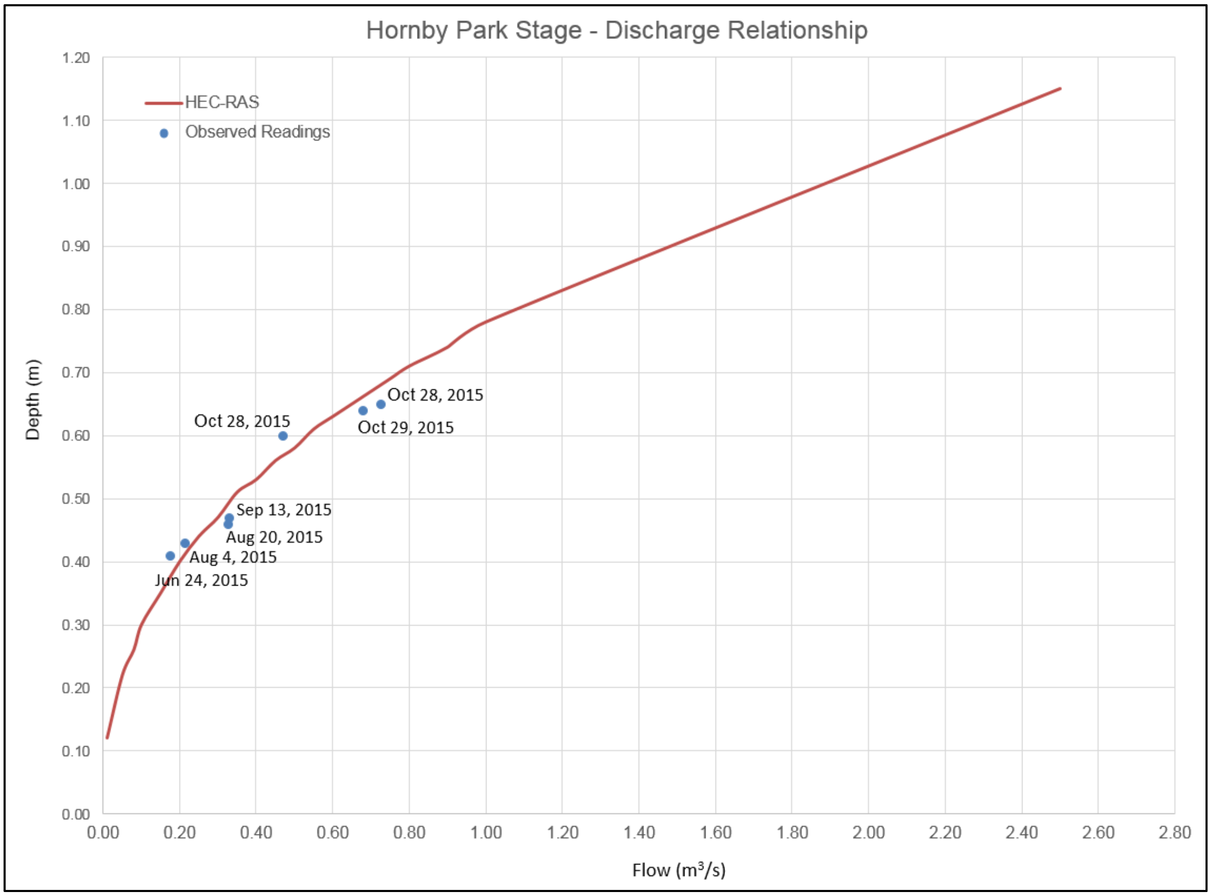

Figure 2.3.1: Stream Flow Monitoring Station Rating Curve

The rating curve presented in Figure 2.3.1 has been used to determine continuous flow rates at the flow monitoring site, based upon the continuous depth recordings at the gauge. A summary of rainfall and water level data collected to date is provided in Appendix D. The streamflow and rainfall data have been analyzed in order to verify whether the resulting hydrographs are representative of the anticipated hydrologic conditions, based upon the land use and soils within the contributing drainage areas. The hydrographs generated from the recorded flow depths converted by the rating curves have been reviewed to isolate the observed storm events corresponding to the observed rainfall; baseflow separation has been completed to isolate the runoff hydrograph at each gauge for the corresponding event, and the surface runoff volume calculated based upon the resulting hydrographs. The contributing drainage area to the temporary streamflow monitoring location has been determined based upon the topographic mapping provided for this study, and the average depth of runoff has been calculated for each event at each monitoring location based upon the calculated observed runoff volume and the size of the contributing drainage area. Runoff coefficients have been determined for each observed event at each location, based upon the ratio of the average runoff depth and the total depth of rainfall recorded for that event. The results of this assessment are presented in Table 2.3.2.

Table 2.3.2: Calculated Runoff Coefficients for Observed Storm Events

Event Date	Duration (hr:min)	Total [1.] Depth (mm)	Peak [1.] Intensity (mm/hr)	Max. Hourly Depth (mm)	Calculated Runoff Coefficient
June 27-28, 2015	32:15	54.6	11.2	4.6	0.12
July 7, 2015	01:40	18.6	36.8	16	0.04
September 11-13, 2015	21:50	18.0	5.6	2.8	0.05
September 19, 2015	01:20	20.2	40	19	0.02
October 9, 2015	05:05	13.2	6.4	4.2	0.04
October 24, 2015	12:25	10.2	12.8	4.4	0.01
October 28, 2015	17:10	34.2	8	7.4	0.04

The results in Table 2.3.2 indicate that the calculated runoff coefficients for the observed storm events are generally less than 0.30, with the majority of the runoff coefficients being below 0.10. The low runoff coefficients are attributable to the lower volume of rainfall that occurred over the large upstream area which is agricultural in nature during the monitoring period.

The low runoff coefficients are also considered attributable to the higher permeability soils within the headwaters of the contributing drainage area to the gauge, which yielded a higher infiltration and lower runoff volume for the storm events monitored.

2.3.4 Characterization and Analysis

The study area is situated within Subwatershed 4 (ref. Dillon, 2000) discharging to the tributaries of the Middle Branch of Sixteen Mile Creek (Ref. Drawing WR1). The headwaters of Middle Sixteen Mile Creek originate from the Niagara Escarpment flowing down through the base of the escarpment through Scotch Block Reservoir to join East Branch downstream of Britannia Road near Trafalgar Road.

The total contributing drainage area within the Premier Gateway Lands is 321 ha. Approximately 2890 ha lands from the headwater tributaries from the north discharge into the East Branch and West Branch of Middle Sixteen Mile Creek subwatershed through the Premier Gateway Lands (ref. subcatchments 203, 204 and 240). The external drainage area to the Hornby Tributary is 910 ha (ref. subcatchment 250).

The existing land use conditions within the Premier Gateway Lands are generally agricultural, golf course, and open space, with some isolated residential and utility land use fronting Steeles Avenue. The study area drains from the north to the south, and conveys runoff from lands to the north through the study area via open watercourses. Lands south of Premier Gateway Lands form part of the Highway 401 Corridor which either have been developed recently, or are approved for future development.

The soils within the study area consist of Chinguacousy clay loam, Jeddo clay loam and Oneida clay loam (ref. Drawing WR4), which are classified as SCS Type ‘C’ soils, exhibiting relatively low rates of infiltration and comparatively higher rates of runoff. Surface slopes within the Premier Gateway Lands are typically low, ranging from approximately 0.2% to 3.5%.

Hydrologic Modelling

Hydrologic modelling for the study area per the Terms of Reference, requires a continuous simulation approach. Based on consultation with the Town and Conservation Halton, the HSP-F model developed previously as part of the *May 2015 Sixteen Mile Creek Areas 2 and 7 Subwatershed Update Study, Town of Milton,* has been used as the base for the hydrologic assessment.

The HSP-F hydrologic model has been selected for application in this study, following a review of hydrologic models applied across the industry, in recognition the specific requirements of this Scoped Subwatershed Study. A summary of the model selection is presented in Table 2.3.3.

Specific for this study, the HSP-F model has been refined within the limits of the study area, as follows:

- Increased refinement of the drainage area to the Premier Gateway Lands (i.e. increased number of catchments based on available contour information).
- External areas draining to Premier Gateway Lands have been refined to establish flows at key locations coinciding with the boundary of the study area based on the 401 Corridor integrated Planning Project (Dillon Consulting Ltd., March 2000).
- The drainage areas and stormwater management facility rating curves within the recently constructed Halton Hills Power Generating Station and private properties (Lawrence Group and Giffels Lands) have been incorporated into the HSP-F model based on the Stormwater Management Facility Design Brief Halton Hills Power Generation (Phillips Engineering Ltd., October 2008) and Subwatershed Impact Study Halton Hills Generating Station (Senes Consultants Ltd., August 2008).

Table 2.3.3. Summary Table of Attributes and Comparison of Hydrologic Modelling Tools for Application to Sixteen Mile Creek Tributary Subwatersheds for Premier Gateway SP Town of Halton Hills

Attribute	HSPF	PCSWMM	QUALHYMO	OTTHYMO/ SWMHYMO/VOx	GAWSER	HEC-HMS
Has it been used previously for watershed/subwatershed scale analyses in the 16 MC Watershed?	Yes	No	Yes	Yes	No	No
Can a watershed scale assessment be completed for Sixteen Mile Creek?	Yes	No	Yes[5.]	No	No	No
Is it publicly supported?	Yes	Yes	No	No	No	Yes
Which organization maintains the model?	USEPA	USEPA/CHI[1.]	Charles Rowney	Civica (Currently)	Schroeter & Associates	USACE
Are revisions and updates rigorously documented?	Yes	Yes	No	No	No	Yes
Is it freely distributed?	Yes	Yes[2.]	Yes	No	No	Yes
Is it easily obtainable/readily available?	Yes	Yes	No	No	No	Yes
It is capable of both continuous and event methodologies?	Yes	Yes	Yes	No	Yes	Yes
Is it well suited to mixed land uses (urban/rural)?	Yes	Yes	Yes	Yes	No	Yes
Does it include a data management system?	Yes	No	No	No	No	Yes
Does it include a snowmelt routine?	Yes	Yes	Yes	No	Yes	Yes
Has it been applied to other Southern Ontario Watersheds?	Yes	Yes	Yes	Yes	Yes	Yes
Which?	Red Hill Creek Sheldon Creek Credit River Warren Creek Fletcher's Creek Huttonville Creek Toronto Wet Weather Flow Study	Fourteen Mile Creek Humber River Rouge River	Rouge River Tributaries of Welland River Watershed Borer's Creek	Humber River Rouge River Duffins Creek	Fourteen Mile Creek Credit River Grand River	Tributaries of the Welland River
Is it supported by MNRF?	Yes	Yes	Yes	Yes	Yes	Yes
Is it supported by MTO?	Yes	Yes	Yes	Yes	No	No
Can it be applied for full water balance modelling?	Yes	Yes[3.]	Yes[3.]	No	No	Yes[4.]

Notes:
1. EPASWMM maintained by USEPA (Public Agency); PCSWMM (developed by CHI) provides GIS pre- and post-processors to EPASWMM.
2. EPASWMM is freely available and downloadable; PCSWMM is purchased from CHI.
3. Water budget based upon simulated infiltration and evaporation (i.e. no groundwater recharge or transpiration calculation capabilities)
4. Water budget based upon simulated infiltration (i.e. no groundwater recharge)
5. QUALHYMO Model from 1996 no longer supported and not maintained.

The updated subcatchment boundary plans for these areas are presented in Drawings WR2 and WR3 respectively.

The subcatchment parameters for the subcatchments external to the study area have been retained from the parent HSP-F model. The subcatchment parameters within the limits of the study area have been established based upon the parameterization for the calibrated HSP-F hydrologic model for the Derry Green Secondary Plan Area, due to the common physiographic conditions within each area (i.e. soils, surface cover/land use, overland slopes).

The parameterization within the refined HSP-F hydrologic model has been validated using the rainfall and stream flow data collected from the 2015 monitoring program. Through this process, the interflow inflow parameter and interflow recession constant within the external subcatchments have been adjusted in order to more accurately reproduce the observed runoff response for the observed storm events. Hydrographs for the validation events are provided in Appendix D.

The refined HSP-F hydrologic model has been executed for a 42 year continuous simulation (1962 to 2003) using the updated meteorological time series, and frequency analyses have been completed based upon the simulated annual maximum flow rates using the Log Pearson Type III Distribution. As well, the HSP-F model has been executed to simulate the Regional Storm event as a discrete storm event in order to generate the peak flow rates at key target locations within the Middle Sixteen Mile Creek watershed. The resulting frequency peak flows and Regional Storm events flows are presented in Table 2.3.4.

Table 2.3.4: Simulated Peak Frequency Flows and Regional Storm Event Flows for Existing Land Use Conditions (m^3/s)

Reference Node	Location	Frequency (Years)							
		1.25	2	5	10	20	50	100	Regional
1.548	Downstream of Sixth Line	2.2	4.9	11.0	16.9	24.0	35.7	46.5	53.8
1.526	West Branch North of Steeles Ave	2.3	5.1	11.1	16.6	23.3	34.0	43.7	50.6
1.523	East Branch North of Steeles Ave	1.1	2.1	4.1	6.0	8.1	11.6	14.8	19.4
1.527	Middle 16 Mile Creek at Steeles Ave	3.6	7.3	15.3	22.6	31.3	45.2	57.8	71.2
1.542	Hornby Tributary at Trafalgar Road	0.5	0.7	0.9	1.1	1.3	1.5	1.7	6.5
1.545	Hornby Tributary at Steeles Avenue	1.9	3.5	6.3	8.6	11.2	15.0	18.2	48.6
1.532	HHGS Pond Inlet	1.9	2.6	3.3	3.7	4.1	4.5	4.7	8.3
1.533	HHGS Pond Outlet	0.1	0.2	0.3	0.5	0.7	1.2	1.7	8.3
1.563	Development Area E Outlet	0.0	0.1	0.1	0.2	0.3	0.4	0.6	2.0
1.564	Development Area F Outlet	0.1	0.1	0.3	0.4	0.6	1.0	1.5	5.0
1.529	Middle 16 Mile Creek at Highway 401	5.7	11.2	22.1	31.5	42.4	59.2	74.0	134.0
1.530	Subwatershed 4 of Middle 16 Mile Creek Outlet	5.9	11.4	22.2	31.4	41.8	57.7	71.7	124.0

The Regional Storm peak flows have been compared with the peak flows generated by the Regulatory flows provided in the HEC-2 hydraulic model for the regulated watercourses. Results are provided in Appendix D. The results indicate that the peak flows generated by the refined and updated model are generally 20 % lower than the peak flows generated by the parent HSP-F model for the reaches through the Premier Gateway Secondary Plan area, and approximately 40 % less at the mouth of the Subwatershed 4 to the Sixteen Mile Creek Middle Branch. Thus lower flows are considered attributable to the model adjustments to reproduce the low runoff volumes observed during the monitoring program. The results also indicate that the peak flows along the Hourly Tributary are approximately 12 % less than those within the 1986 FDRP HEC-2 model, however the flows along the regulated watercourses through the middle of the property are up to 70 % less than the HEC-2 flows. The differences are considered primarily attributable to the different methods and datasets used for each model, and the vintage of the data and modelling completed for the 1986 FDRP HEC-2 model.

The results of the continuous simulation have been used to assess the existing erosion potential along selected watercourses within the study area. For this assessment, duration analyses have been completed in order to determine the duration of time (in hours and percent to total time) during which the flows would be above the critical erosive flows. The results of this assessment are presented in Table 2.3.5.

Table 2.3.5: Erosion Assessment for Existing Land Use Conditions

Reach	Location	Duration of Erosive Flows	
		Hours	Percent of Total Time
W-T1-2b	West Branch of Middle 16 MC Trib.	25146	6.83
HDF-1	East Branch of Middle 16 MC Trib.	24472	6.65
E-T1-1	East Branch of Middle 16 MC Trib.	12070	3.28
HT-2	Hornby Trib. at Steeles Ave	16868	4.58

The results of the duration analysis indicate that the receiving watercourses would be susceptible to erosion flows for between 3.28 % and 6.83 % of the time under existing land use conditions. This suggests that the receiving watercourses are relatively erosion sensitive, which is consistent with findings and observations elsewhere within the Sixteen Mile Creek Watershed.

The HSP-F hydrologic model has also been used to complete a water budget for existing land use conditions. For this assessment, the simulated groundwater recharge, evapotranspiration, and surface runoff have been extracted from the model results, within the Secondary Plan study area and the subwatershed scale, and have been analyzed in order to determine the average annual water budget. The results of this assessment are presented in Table 2.3.6.

Table 2.3.6: Water Budget Summary (mm/year)

Location	Surface Runoff	Groundwater Recharge	Evapotranspiration
Secondary Plan Area	388	99	318
Subwatershed (at Hwy. 401)	350	243	213

The results in Table 2.3.6 indicate that the average annual groundwater recharge within the Secondary Plan Area is 99 mm/annum, which is comparable to findings from the studies. This is considered attributable to the lower permeability material found within the Secondary Planning Area. The results also indicate that the average annual groundwater recharge throughout the subwatershed is 243 mm/annum, due to the potential higher permeability found within the headwater areas external to the Secondary Plan Area. The potential higher permeability is likely related to a thinner Halton Till underlain by more permeable sands and gravel or shallower bedrock.

2.3.5 Summary of Findings for Hydrology

The study area is situated within Subwatershed 4 of the Sixteen Mile Creek Watershed and discharges to the tributaries of the Middle Branch of Sixteen Mile Creek. The total contributing drainage area within the Premier Gateway Lands is 321 ha. Approximately 2890 ha lands from the headwater tributaries from the north discharge into the East Branch and West Branch of Middle Sixteen Mile Creek subwatershed through the Premier Gateway Lands (ref. subcatchments 203, 204 and 240). The external drainage area to the Hornby Tributary is 910 ha (ref. subcatchment 250).

The existing land use conditions within the Premier Gateway Lands are generally agricultural, golf course, and open space, with some isolated residential and utility land use fronting Steeles Avenue. The study area drains from the north to the south, and conveys runoff from lands to the north through the study area via open watercourses. Lands south of the Premier Gateway Lands form part of the Highway 401 Corridor which either have been developed recently, or are approved for future development.

The soils within the study area consist of Chinguacousy clay loam, Jeddo clay loam and Oneida clay loam (ref. Drawing 5.3), which are classified as SCS Type ‘C’ soils, exhibiting relatively low rates of infiltration and comparatively higher rates of runoff. Surface slopes within the Premier Gateway Lands are typically low, ranging from approximately 0.2% to 3.5%.

The HSP-F hydrologic model for the Sixteen Mile Creek Watershed has been refined and validated for use in the Scoped Subwatershed Study. The hydrologic model has been executed for a 42 year continuous simulation, and peak frequency flows as well as Regional Storm event have been determined for the existing land use conditions. In addition, erosion analyses and water budget analyses have been completed for the existing land use conditions. The results of this baseline assessment will be used to assess the impacts of future land use conditions, as well as to establish stormwater management criteria for the future land use within the study area, as part of the next phase of the Scoped Subwatershed Study.

2.4 Hydraulics

The baseline characterization of the surface water hydraulics and flooodline mapping has been conducted in accordance with approved work plan for the Scoped Subwatershed Study. The surface water component has involved a desktop review of available information from various sources (i.e. Town, Conservation Halton, Region, etc.), the implementation of a field program to address data gaps and to complement the currently available information databases and conducting hydraulic analyses to inform the characterization of the stream system within the study area, and to establish floodline mapping through the study area to inform the characterization of the watercourses, constraints and opportunities for managing the open watercourse systems, and to establish the flooding hazard through the study area.

2.4.1 Scope Overview

The existing HEC-2 hydraulic models has been imported into HEC-RAS for the hydraulic analyses in order to establish the existing floodplain through the study area. The hydraulic models has been refined within the limits of the study area based upon the base mapping provided for this study, as well as the as-built and design information for existing hydraulic structures and the Field Survey for additional structures. The limits of the model has been extended to include any watercourses within the study area with drainage areas greater than 50 ha which are not currently included within the current floodline mapping as well as selected open features per direction of Conservation Halton (reference November 9, 2015, Veal-Marshall). The HEC-RAS hydraulic model has been updated to include the peak flows for the 2 year through 100 year and Regional Storm events as determined by the hydrologic analyses, and floodline mapping prepared to depict the Regional Storm Floodplain through the limits of the study area.

2.4.2 Background Information Review

The background information listed in Section 2.3.2 has been applied and referenced as appropriate for the hydraulic characterization and analysis.

2.4.3 Field Reconnaissance

A geodetic survey has been conducted to develop an inventory of hydraulic structures within the Premier Gateway Lands. A summary of the hydraulic structures surveyed is provided in Table 5.1 and the locations of the hydraulic structures are provided in Drawing WR-5.

Table 5.1: Hydraulic Structure Inventory

Crossing Number	Location	Crossing Type	Size of Opening (span x rise) (mm)	Upstream Invert (m)	Downstream Invert (m)	Age [2]
1	6th Line South of Steeles Avenue	Open Bottom Concrete Arch	9300 x 2100	190.55	190.7	
2[1]	Highway 401 Culvert 100 m East of Sixth Line	Open Bottom Concrete Bridge	12200 x 4000	188.2	188.13	
3	Steeles Avenue West of 6th Line	Open Bottom Concrete Arch (on skew)	9100 x 1700	190.77	190.89	
4	Steeles Avenue East of 6th Line	Open Bottom Concrete Arch	7000 x 1900	194.47	194.41	
5	Trafalgar Road 415 m North of Steeles Avenue	Concrete Box	3090 x 2740	201.15	201.04	
6	Trafalgar Road 1.1 km North of Steeles Avenue	Twin Concrete Box	2740 x 2440	200.15	200.13	

[1] Culvert information considered from 401 Corridor Integrated Planning Project Scoped Subwatershed Plan Final Report, Dillon Consulting Limited, March 2000.

[2] Data / Information collection is underway

2.4.4 Characterization and Analysis

Current floodline mapping for Sixteen Mile Creek, originally developed in mid-1980s by Proctor and Redfern Limited for the Halton Region Conservation Authority (now Conservation Halton), extends to the Premier Gateway Lands. The current floodline mapping has been developed using the HEC-2 methodology, which represents the most recent hydraulic model for the majority of the watercourses within the Sixteen Mile Creek Watershed, including the Sixteen Mile Creek Middle Branch and East Branch. The HEC-2 hydraulic model for the Hornby Tributary was recently imported into HEC-RAS as part of the detailed design for Steeles Avenue, completed by Marshall Macklin Monaghan. The most current hydraulic models (HEC-2 and HEC-RAS as applicable) have been provided for this assessment.

The current HEC-2 hydraulic model has been imported into HEC-RAS, and the HEC-RAS model for the Hornby Tributary have been retained for this assessment. The models have been refined within the limits of the study area, and the model domain extended as appropriate to establish floodlines for reaches with contributing drainage areas greater than 50 ha, in accordance with current practice by Conservation Halton as well as other open features sub-50 ha; the floodplain mapping for the unregulated feature will be refined as appropriate based upon the outcome of the headwater drainage features assessment, to include only these features which are recommended to remain as open watercourses in the future. The model cross-sections have been established in accordance with the HEC methodology, and the cross-section data have been obtained from the LiDAR mapping provided for use in this study. The hydraulic structures have been incorporated into the model as per the hydraulic structure inventory provided above, and the Regional Storm event peak flow rates as determined from the hydrologic modelling have been incorporated into the model. The cross-section location plan and the Regulatory floodplain are provided in Drawing WR-6, along with the current Regulatory Limit from Conservation Halton. Digital copies of the HEC-RAS models are provided in Appendix E. The updated Regulatory floodlines are noted to be generally consistent with the current floodline mapping through the study area, and are generally confined within the limits of the defined watercourses.

2.4.5 Summary of Findings

The Regulatory floodline mapping for the Premier Gateway Secondary Plan Area has been updated, based upon the best available mapping and hydraulic stormwater data, as well as the updated hydrologic analyses. The floodlines are noted to be comparable to the current floodline mapping developed as part of the 1986 Flood Damage Reduction Program (FDRP) for the Sixteen Mile Creek Watershed. The floodline mapping will be used in conjunction with the erosion assessment to establish the hazard limits for the regulated watercourses within the Secondary Plan Area.

2.5 Stream Morphology

2.5.1 Scope Overview

The stream morphology component of the Phase 1 Characterization Assessment establishes the existing and historic form and function of the watercourses within the study area. This includes an assessment of sediment movement within the system, channel planform evolution, and geometric characteristics. It is critical to gain both a qualitative and quantitative understanding of channel processes within the area such that guidance can be given to proposed land use changes, thereby ensuring continued stable channel dynamics, as well as ensuring that any potential impacts to downstream channels is avoided and/or minimized. To achieve this objective, the assessment has included the following components:

- Collect and review any pertinent background information, such as topographic mapping, historic aerial photographs and any previous reports that would pertain to the channel/road crossing.
- Use available mapping to delineate channel reach boundaries
- Delineate the meander belt on a reach basis in the vicinity of the study area
- Complete field reconnaissance to confirm existing geomorphic conditions, document evidence of active erosion and confirm desktop results

The Premier Gateway study area is located towards the upper portion of the Sixteen Mile Creek watershed, specifically in Subwatershed 4 (Dillon, 2000). Subwatershed 4 forms part of the overall drainage system associated with the Middle Branch of Sixteen Mile Creek. Within the Premier Gateway study area, the surface drainage features are associated with two tributaries to the Middle Branch: the Hornby Tributary in the east and the Middle Sixteen Mile Creek Tributary in the west (Figure 2.5.1.). The two tributaries converge immediately upstream of the Hwy 401 crossing of the Middle Branch of the Sixteen Mile Creek.

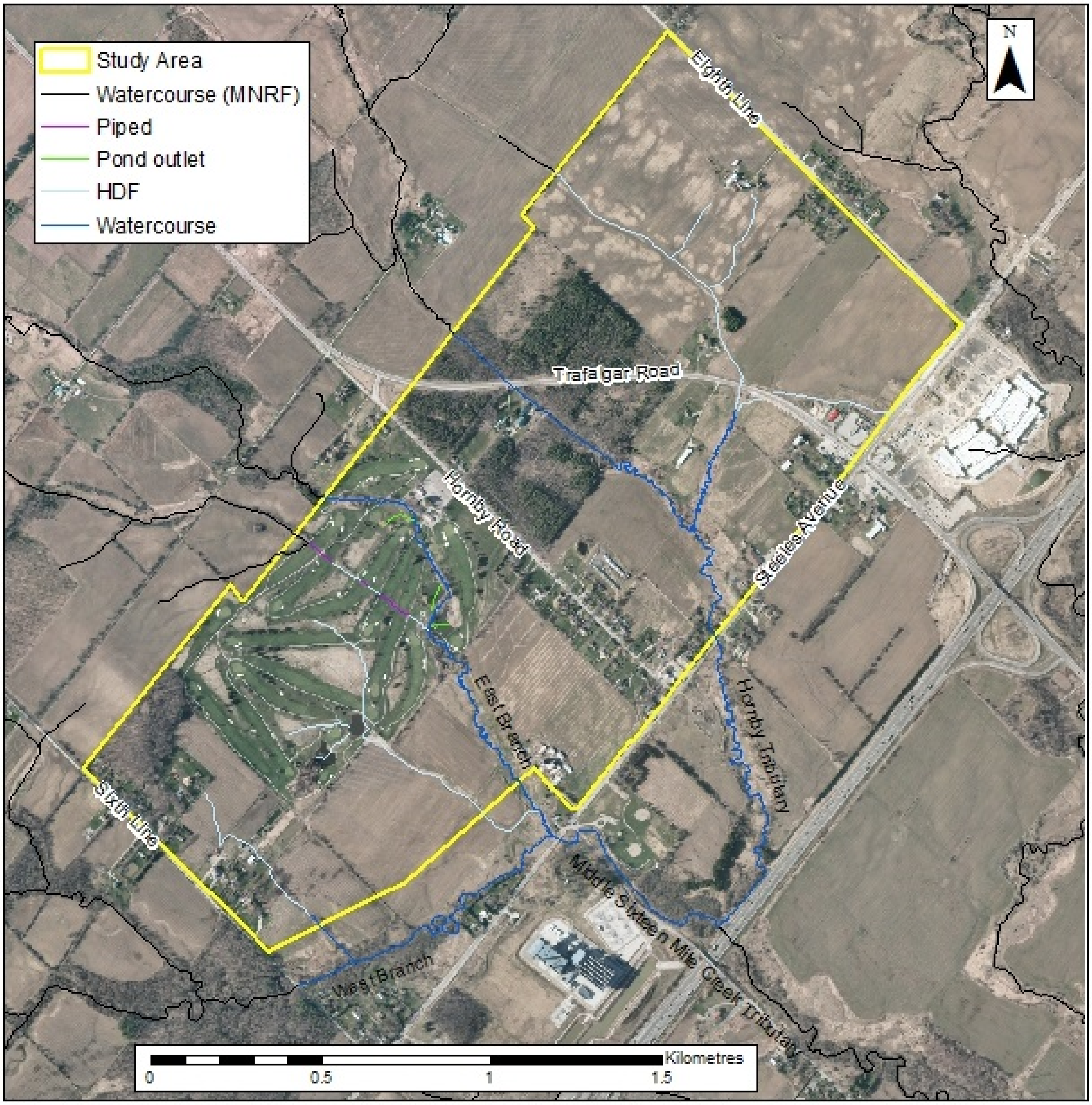

Figure 2.5.1. Premier Gateway Study Area

2.5.2 Background Information Review

A background review has been undertaken to gather information on the watercourses contained within the study area. Reviewed data included previous reports, historic aerial photos, and mapping resources, including information regarding physiography and surficial geology. This information forms the foundation of the initial characterization work, as well as the field program, ensuring proper focus on pertinent characteristics.

The geology of any area influences the characteristics of watercourses and their interactions with their floodplains. Geology influences channel geometry, rates of channel migration, and defines the quantity and type of channel sediments. The Premier Gateway study area falls within the Peel Plain physiographic region. The Peel Plain is a level to gently undulating clay plain with consistent grade sloping towards Lake Ontario (Chapman and Putnam, 1984; OGS, 2003). It consists of shale and limestone till covered by a layer of clay sediments. The surficial geology of the study area is heterogeneous with three different deposits: glaciolacustrine, till, and stratified ice-contact (Figure 2.5.2.). The material in the area consists of silt and clay, with minor sand and gravel deposits; fine textured clay/silt till; and an isolated mixture of sand, gravel, silt, clay and till.

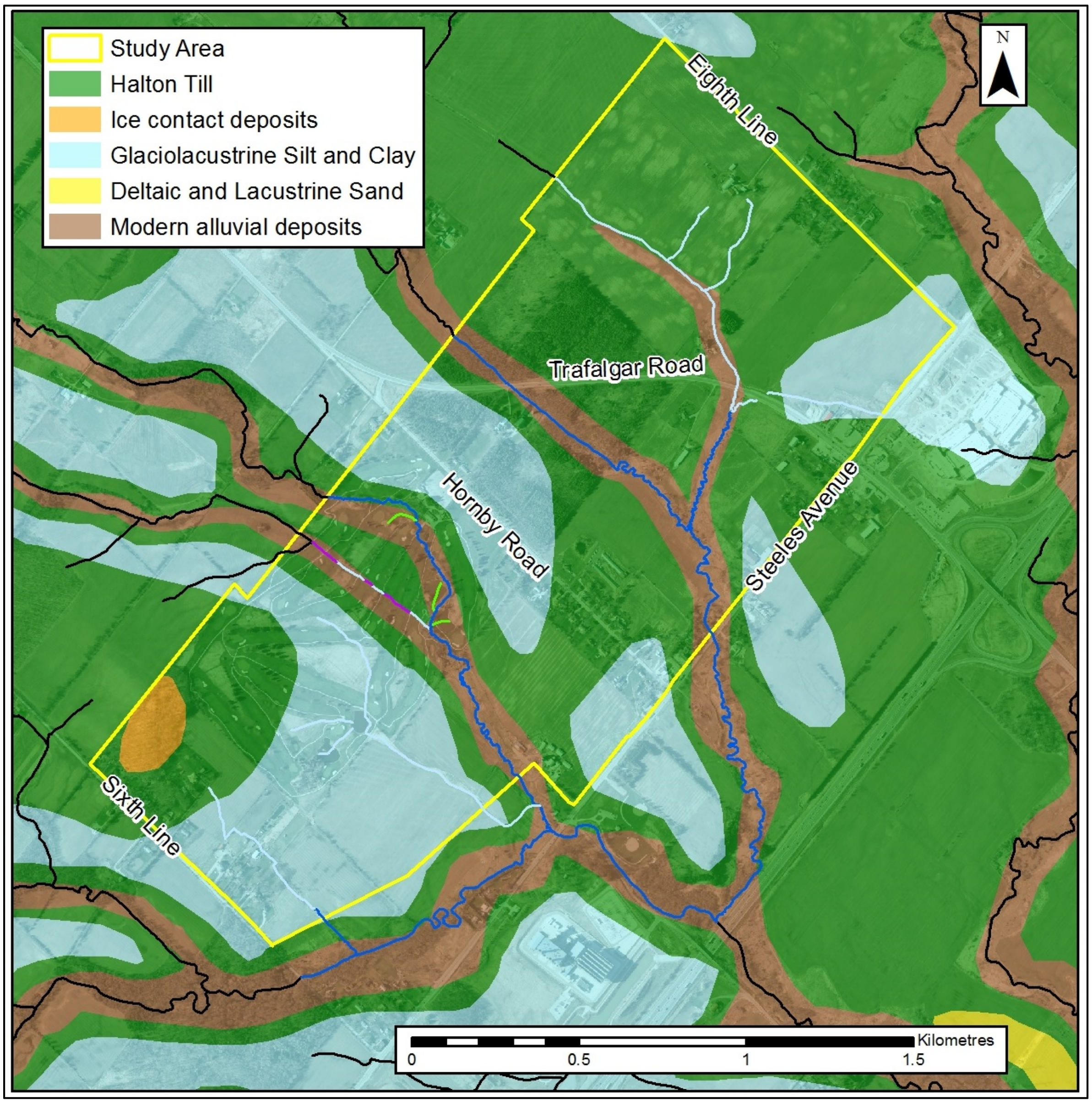

Figure 2.5.2. Surficial Geology of Premier Gateway Study Area

A number of studies have been conducted previously within the area downstream of the Premier Gateway Secondary Plan area. The following background reports have been reviewed:

- 401 Corridor Integrated Planning Project Scoped Subwatershed Plan (Dillion Consulting, March 2000)
- Sixteen Mile Creek Areas 2 and 7 Subwatershed Update Study, Town of Milton (AMEC et al., November 2015)
- Calloway Reit Halton Hill Subwatershed Impact Study 401 Corridor (Geomorphic Solutions, 2012)
- Ninth Line Lands Scoped Subwatershed Study Phase 1: Background Report and Study Area Characterization (Amec Foster Wheeler et. al., January 2015 Draft)
- Sixteen Mile Creek Tributary – Sixth Line and Highway 401 (Prepared for: AMEC, Prepared by: Parish Geomorphic Ltd., 2007)
- Fluvial Geomorphic Assessment of Stream Road Crossings Along Steeles Avenue (Prepared for: AECOM, Prepared by Parish Geomorphic Ltd., 2010)
- Steeles Avenue Hornby Pumping Station – Flow Dispersion (Prepared for: KMK Consultants Ltd., Prepared by: Parish Geomorphic Ltd., 2007)
- Steeles Ave Reconstruction – Bridge Crossing Details (Prepared for: AECOM, Prepared by: Parish Geomorphic Ltd., 2013)

The Scoped Subwatershed Plan prepared for the Highway 401 Employment Corridor (Dillon, 2000) represents the most pertinent study for the Secondary Plan Area. The purpose of that study was to provide a broad framework for development within the tract of land adjacent to the north of Highway 401, south of Steeles Avenue, between Winston Churchill Boulevard and James Snow Parkway. The study area for the Dillon 2000 Scoped Subwatershed Plan is located immediately downstream of the Premier Gateway Secondary Plan area and thus particularly relevant with respect to potential downstream impacts. Reach B and Reach C of the Dillon 2000 Subwatershed Study correspond with reaches T-1 and HT-1 of this study (Figure 2.5.2.2). For each of these reaches, the following has been completed: historic analysis (1954, 1979, and 1996); detailed field sites including measurement of cross sections, substrates, and bankfull gradient; mapping of erosion sites; determination of critical threshold values. Field data for the Dillon 2000 Scoped Subwatershed Study were collected in 1998, over 15 years ago. Due to the vintage of the information, the data will be presented in the current document for the sole purpose of comparison with the findings of the field investigations completed for the current study.

2.5.2.1 Reach Delineation

The parameters that influence channel form, amount and size of sediment inputs, valley shape, land use or vegetation cover vary over the length of a stream. Lengths of channel that exhibit similar characteristics with respect to these parameters are known as reaches. Reach lengths vary with the scale of the channel, often longer for a larger watercourse, while smaller watercourses exhibit more variability resulting in shorter reaches. Delineation of reaches is beneficial as it enables grouping and identification of general channel characteristics.

The process of delineating reaches considers external parameters such as local geology, topography and valley setting, hydrology, riparian vegetation, and land use. Consideration is also given to characteristics that reflect these external influences such as sinuosity, gradient, and dimensions (Parish Geomorphic Ltd., 2001). Reach delineation is completed as part of the desktop assessment and used to guide the subsequent field program. The reaches are then verified and finalized during the field assessment. Figure 2.5.3. displays the reach breaks for the Premier Gateway study area.

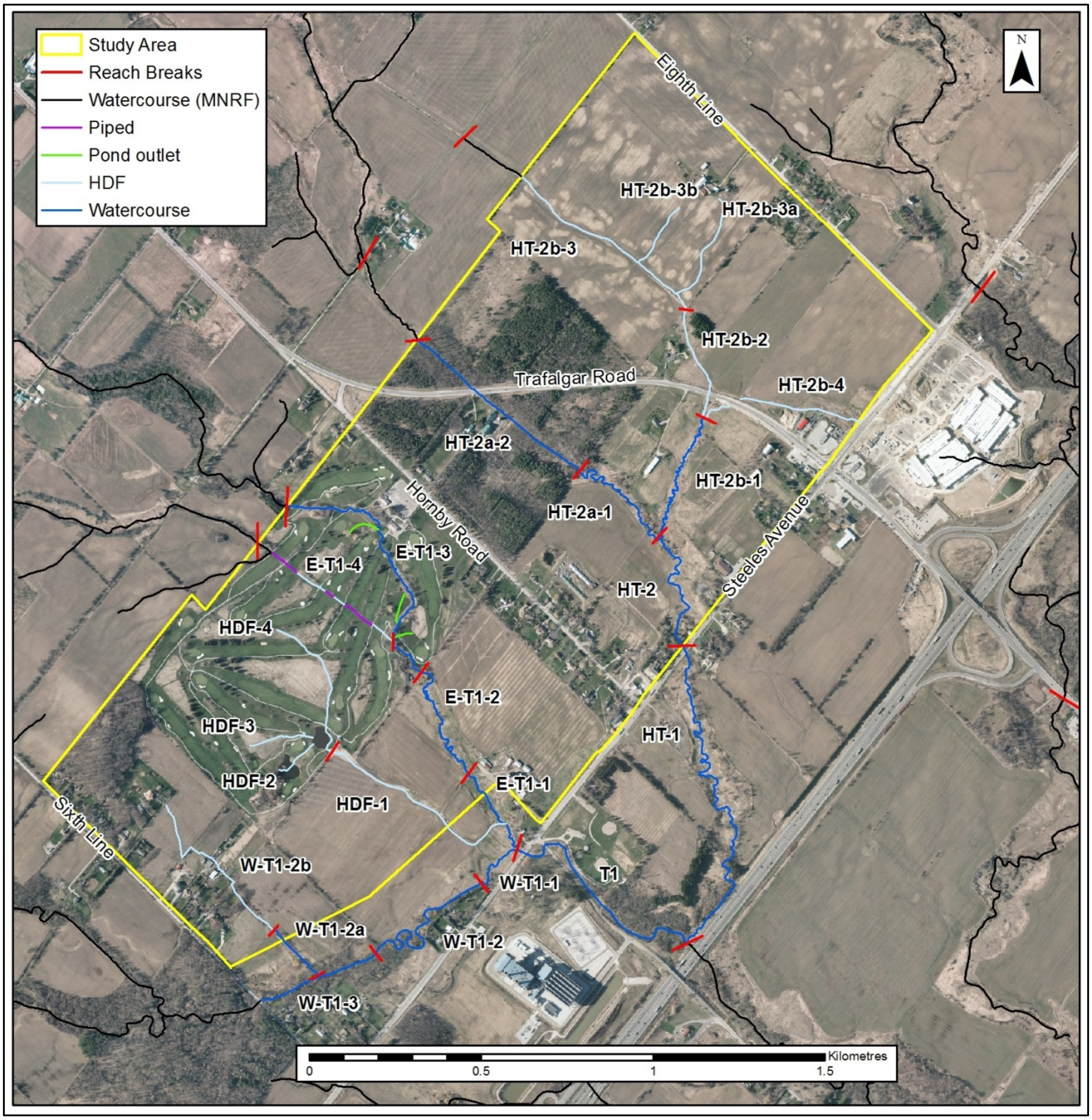

Figure 2.5.3. Reach map for Premier Gateway Study Area

2.5.2.2 Historic Assessment

Streams are dynamic landscape features, over time their configuration and position within the floodplain changes as a result of meander evolution, development, and migration processes. These lateral and down-valley planform adjustments can be observed and often quantified by reviewing historic aerial photographs. Depending on photograph quality and scale of the channel of interest, 100-year erosion rates may be determined by measuring the distance from known control points to a governing meander bend over the available historical record. Historic aerial photographs are also analyzed to determine changes in surrounding land use which may have impacted channel migration. For the Premier Gateway Subwatershed Study (SWS), historic photographs from 1954, 1978, 2002, 2007, and 2013 have been reviewed (Appendix F).

Circa 1954 and Prior

In 1954, the area was dominated by agricultural land use with a few associated residential properties along Hornby Road and Steeles Avenue. The 1954 photograph documented conditions prior to the development of Hornby Glen Golf Course (1964) and the extension of Trafalgar Road beyond Steeles Avenue. The 1954 channel alignments in these areas correspond well with the current channel alignments, indicating that the channels have not been significantly altered as part of the development of the golf course or the extension of Trafalgar Road. It should also be noted that reach HT-2a-2, which flows through the Halton Regional Forest, was straight where visible at the downstream end in the 1954 photograph. This may indicate that the reach was at least partially straightened by the property owner prior to 1954. It also suggests that the channel planform in this reach has not undergone any significant adjustment since 1954.

1954 to 1978

Between 1954 and 1978, the most significant development of the study area occurred. This included the extension of Trafalgar Road through the study area and the addition of associated residential properties, construction of Highway 401, construction of Hornby Glen Golf Course, construction of Hornby Park, and additional residential properties along Sixth Line and Steeles Avenue. It should also be noted that the agricultural property on Steeles Avenue adjacent to reach E-T1-1 significantly expanded between 1954 and 1978 (Figure 2.5.3). Planform development was noted in reaches HT-2a-1, HT-2b-1, HT-1 and HT-2. Planform alteration is noted in W-T1-1, where it appears that the channel was realigned northward to its current location to accommodate the addition of shoulders to Steeles Avenue. A few minor adjustments appear to have been made to reach E-T1-3 through the golf course but the planform for the most part is in the same location. The only exception was a short 100 m section that was moved westward to accommodate the clubhouse.

1978 to 2002

Between 1978 and 2002 changes to land use were minimal, consisting of the addition of a few properties along Hornby Road and Sixth Line. There was also ongoing expansion of the agricultural property on Steeles Avenue, as well as notable planform adjustments in both reach

E-T1-1 and E-T1-2. The 2002 photograph shows disturbance and vegetation clearing of the land surrounding reach E-T1-1. The most notable planform change during that time was the loss of a large bend near the downstream end of the reach. A new bend, not seen in the 1978 photographs, was seen near the upstream end of E-T1-1. There was also reduced sinuosity immediately upstream of this bend. It is unclear whether these changes were natural. Upstream of the farm lane crossing, in reach E-T1-2 active planform adjustment was noted as indicated by the formation of secondary channels and bend evolution near the downstream end of the reach. The large bend at the upstream end of E-T1-2 also increased between 1978 and 2002. This was the most significant period of planform development for the Hornby Tributary reaches, HT-2a-1, HT-2b-1, HT-1, and HT-2 (Figure 2.5.4). This consisted of adjustments to existing meanders such as enlargement, rotation, lateral extension, and down-valley migration. It also included development of new small meanders and secondary channels/chutes. The 2002 photograph also illustrated the initiation of a meandering planform at the upstream end of reach W-T1-1 which had been previously straightened. Gentle sinuosity is seen beginning to develop in Reach W-T1-3 in the 2002 photograph where it was primarily straight in the 1978 photograph. Downstream in reach W-T1-2 an oxbow can be seen in the 2002 photograph, it is unclear when this feature developed as channel alignment at this location was not visible due to dense vegetation in the previous photographs. The large bends near the upstream limit of W-T1-2 experienced substantial enlargement between 1978 and 2002, however it is difficult to quantify due to the poor visibility of the channel in the 1978 photographs.

2002 to 2007

There was minimal change with respect to land use and channel planform between the 2002 and 2007 photographs. The only notable change that occurred was in reach E-T1-1 where vegetation appears to have re-established and disturbance of the area ceased. The bend that appeared near the upstream end of the reach in the 2002 photograph no longer exists in the 2007 photograph. The minor variations in sinuosity immediately downstream are also gone. It is unclear why these changes occurred and how it relates to the disturbance seen in the 2002 photograph.

2007 to 2013

Between 2007 and 2013, there were no major land use changes. Planform adjustment during this time period consisted of minor ongoing changes in reaches which had already been identified as active in the previous photographs. This included continued evolution of the tortuous meanders at the upstream end of reach W-T1-2 and minor adjustment to the bends in the upstream section of W-T1-1. In reach E-T1-1, there appears to be some flow splitting due to outflanking and slumping of bank material, this is also occurring more significantly in reach E-T1-2. The large bend at the upstream end of E-T1-2 continued to erode and enlarge. For the Hornby Tributary portion, adjustment continued in the bends at the upstream end of reach HT-2a-1, where additional slumped material was noted in the channel resulting in small changes to the flow paths. One of the bends is also beginning to cut-off in this section. Similar minor changes were seen in reaches HT-2b-1, HT-1 and HT-2.

Most of the substantial planform changes and meander development in the study area occurred between the 1978 and 2007 photographs. Due to difficulty in georefencing the 1978 photograph, the photographs often did not properly overlap to allow for accurate calculation of migration rates. Changes between the 2007 and 2013 photographs consisted less of meander development and were more related to the development of secondary channels and islands as a result of bank slumping. Measurement of these types of changes does not constitute true rates of channel migration which is related to meander development. Additionally, the 2013 photograph appeared to have been taken during a higher flow event than the 2007 photograph. This enhances the perceived changes in channel width and it is difficult to separate true increases in cross-sectional width from increased flow width. Due to the above, migration rates analyses have not been completed for the study reaches, as the background information has been deemed unsuited for these analyses. In the absence of this analyses, alternative methods have been applied to incorporate the influence of migration rates into the fluvial gemophic assessment, as described further below.

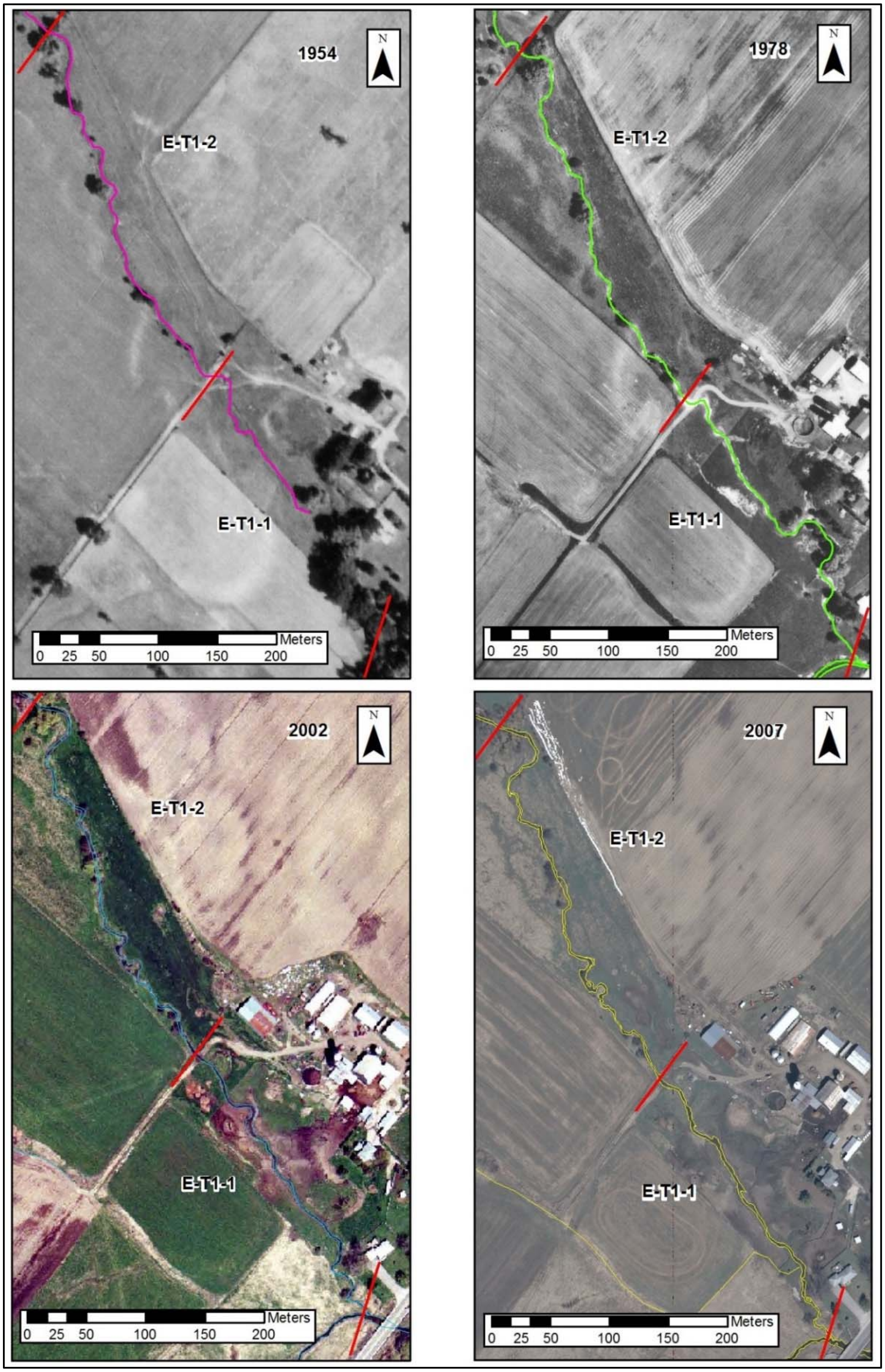

Figure 2.5.4. Comparison of historic air photographs for reaches E-T1-1 and E-T1-2

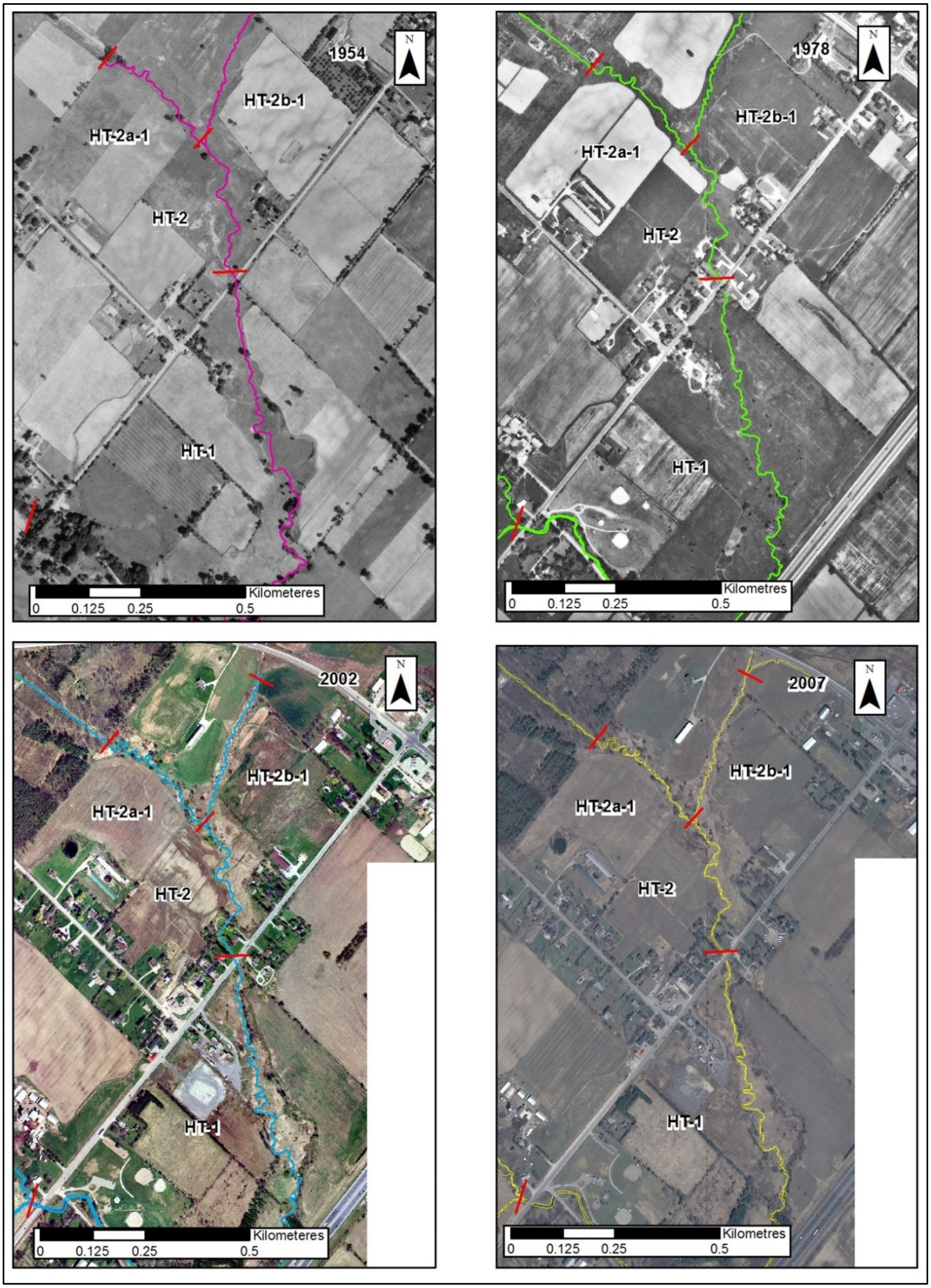

Figure 2.5.5. Comparison of historic air photographs for Hornby Tributary reaches

2.5.2.3 Meander Belt Width Delineation

The meander belt width is a designated corridor that is intended to contain all of the natural meander and migration tendencies of a channel based on historic alignment and potential future alignment. Outside of this corridor, it is assumed that private property and infrastructure will be safe from the erosion potential of the watercourse. The meander belt is determined using a process-based methodology based on background information, historic data (including aerial photography), degree of valley confinement, and channel planform (Parish Geomorphic Ltd., 2004). Due to the spatial variability of modifying and controlling influences on channel form, two reaches situated immediately up/downstream of each other could show marked differences in planform configuration. It is for this reason that meander belt width delineation occurs on a reach-by-reach basis. Empirical methods may be used in place of the procedure outlined above when the channel planform cannot be accurately delineated due to the small scale of the channel, or when the channel has been heavily altered through channelization.

A preliminary meander belt width has been delineated for all permanently flowing reaches within the study area. The meander belt axis was first identified, following the general down-valley orientation of the meander pattern. The meander belt is centered along this axis. Second, the preliminary meander belt is established by drawing lines parallel to the governing outermost meanders of the existing channel planform, following the meander axis. The step also considers historic channel planform and surrounding topography. The distance between the two lines is measured and used to represent the width of the preliminary meander belt (Figure 2.5.6 and 2.5.7).

From a geomorphic perspective, the 100-year migration rate quantifies the lateral and downstream movement of meander features. This value typically represents the erosion setback to be applied to either side of the meander belt width in order to account for bank erosion and channel migration over time. As explained in the previous section historic migration rates could not be accurately quantified for the study area. In lieu of accurate 100-year migration rates, a setback of 10% of the preliminary meander belt width is added to each bank as a factor of safety for future erosion. This determines the final meander belt width. Meander belt widths for the Premier Gateway study area are summarized in Table 2.5.1.

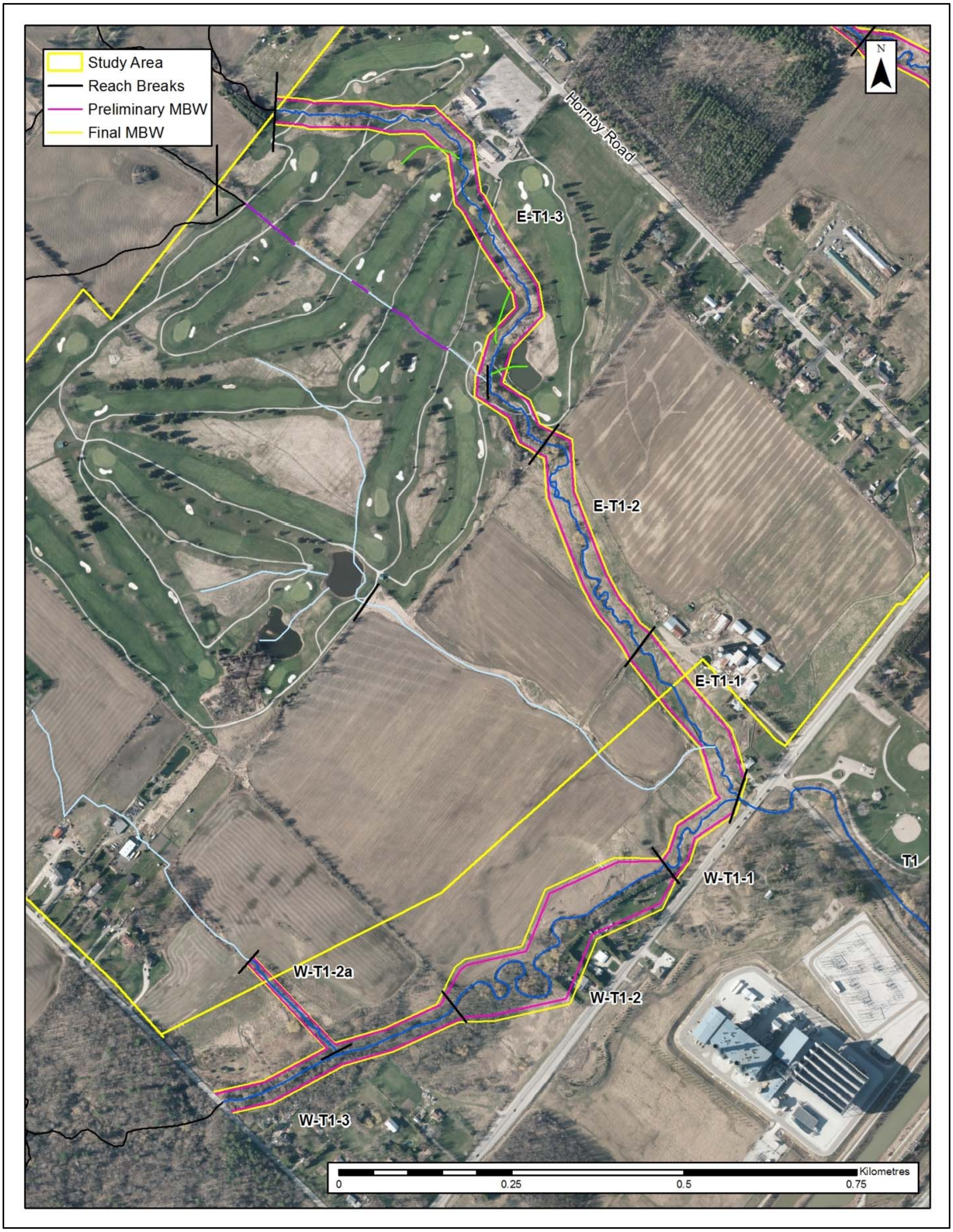

Figure 2.5.6. Meander belt widths for Middle Sixteen Mile Creek Tributary reaches

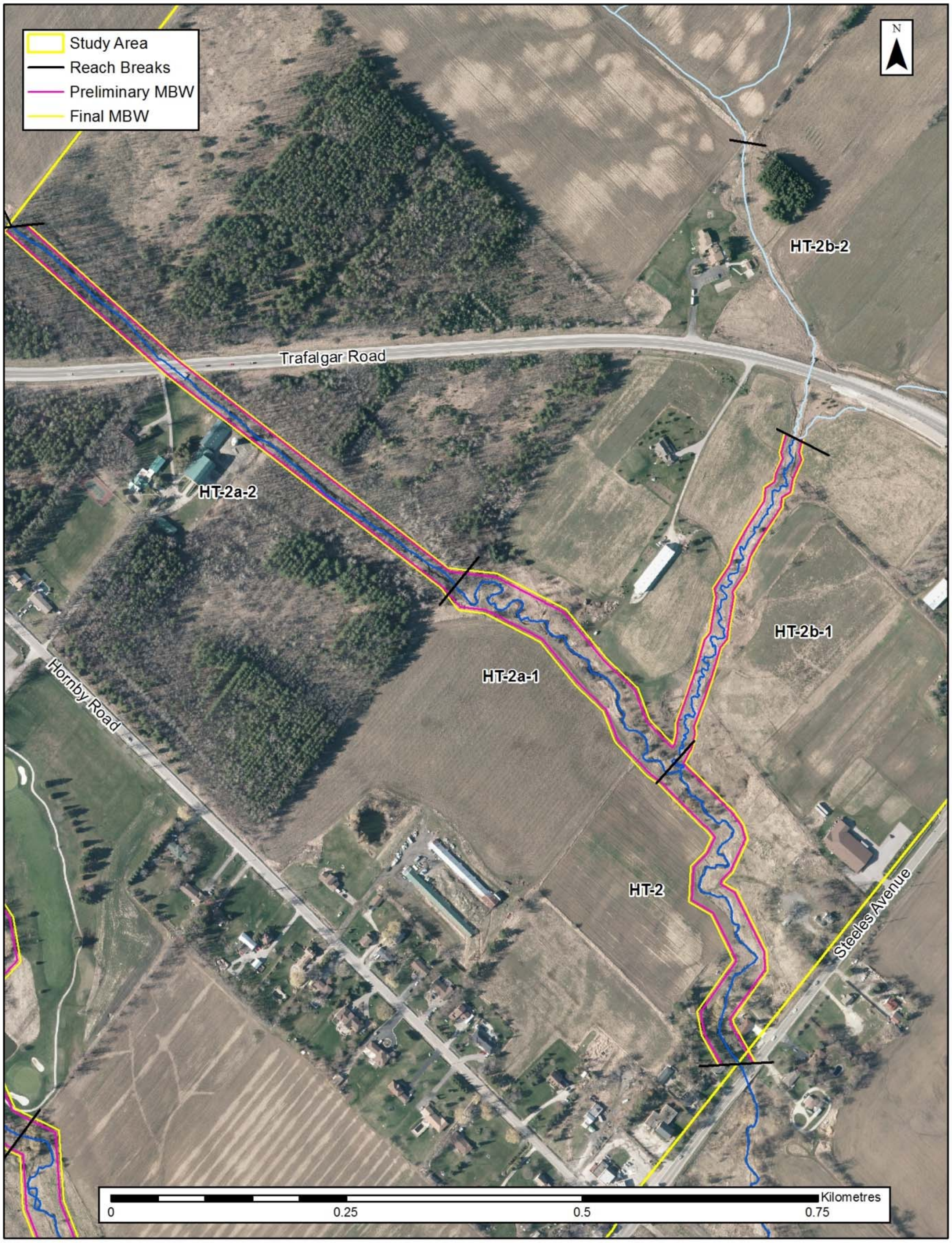

Figure 2.5.7. Meander belt widths for Hornby Tributary reaches

Table 2.5.1. Meander belt width parameters for study area

Reach	Preliminary Meander Belt Width (m)	Factor of Safety (10% applied to each bank) (m)	Proposed Meander Belt Width (m)
HT-2b-1	18	1.8	21.6
HT-2a-2	18	1.8	21.6
HT-2a-1	36	3.6	43.2
HT-2	30	3.0	36.0
E-T1-3	34	3.4	40.8
E-T1-2	36	3.6	43.2
E-T1-1	44	4.4	52.8
W-T1-3	30	3.0	36.0
W-T1-2a	14	1.4	16.8
W-T1-2	80	8.0	96.0
W-T1-1	28	2.8	33.6

2.5.3 Field Reconnaissance

The 2015 field program for the Premier Gateway Scoped Subwatershed Study consisted of three components: a Headwater Drainage Feature (HDF) assessment, rapid geomorphic and stream assessments, and detailed data collection at selected sites. These assessments were completed between May and November of 2015. Permission to enter (PTE) was provided for various properties on an on-going basis throughout this time period, and therefore features were assessed during different time periods; this does not have any impact on the results of the rapid and detailed assessments, however is considered worth stating to aid in the interpretation of the results. Due to the timing of the receipt of the PTE information, the HDF assessment was not initiated until after the spring freshet and therefore the 'first visit' under the HDF protocol (TRCA/CVC, 2014) was not completed in 2015. To establish a complete characterization of the HDFs, in accordance with the methodology specified in the HDF protocol, the spring freshet visit is proposed to be completed in early spring of 2016.

2.5.3.1 Headwater Drainage Feature Assessment

A number of the smaller features in the Premier Gateway study area are considered HDFs as defined in the TRCA/CVC protocol (2014). These features were first identified through a review of watercourse mapping and recent aerial photography. Features that were imperceptible on the aerial photo, but identified as watercourses in the GIS watercourse layer were initially identified as potential HDFs.

The HDF protocol (TRCA/CVC, 2014) requires three separate site visits, primarily to characterize the hydrologic function of the features under different seasonal conditions. The three visits also help determine the extent of fish habitat based on the amount of flow present. Under the 2014 protocol, all features are assessed during the “first visit” which takes place shortly after spring freshet (late March or early April). The assessment of flow condition and feature type as outlined in the OSAP protocol (Stanfield, 2010) represents the main focus of this first visit. Based on the results of the first visit, features may be classified as ‘limited function’ and receive the management recommendation of ‘no management required’ (TRCA/CVC, 2014); features receiving this classification do not need to be assessed beyond the first visit. This process of screening based on the flow condition and feature type continues through the “second visit” to determine which features require a “third visit”. The “second visit” is typically after the freshet is complete and before significant plant growth has occurred (late April to mid-May). The “third visit” is during the driest conditions of the summer, preferably after several days without significant rain, to determine which features continue to flow year round (July to mid-September). In addition to the data on flow condition and flow type, other aspects of OSAP protocol (Stanfield, 2010) are employed; this includes assessment of riparian vegetation, fish habitat, and terrestrial habitat.

The HDFs identified through the desktop assessment have been evaluated as part of the first round of rapid assessment fieldwork completed on May 28th 2015. This initial assessment confirmed several features, as HDFs and served as the “second visit” in accordance with the HDF protocol (TRCA/CVC, 2014). All features visited in May 2015 were dry or had minimal standing water present and therefore did not necessitate a “third visit”. However, because the features were dry the management recommendations cannot be determined without a ‘first visit’ after the spring freshet; this will be completed in spring of 2016. Only one HDF was not included in the initial May 2015 visit, HDF-1, which was visited on July 3rd 2015, thus coinciding with the beginning of the timing window for the “third visit” (July to mid-September) for the balance of the HDFs. During the time of the visit, there was standing water present sporadically throughout the length of feature HDF-1. Based upon these findings, a “second visit” to HDF-1 is not considered required, as it is presumed flow would be present during a “second visit” conducted as per the HDF protocols. Nevertheless, it is proposed to assess HDF-1 in the spring 2016, as part of the overall “first visit” for the HDFs to gain additional information.

Without the initial visit immediately following spring freshet, the HDFs cannot be fully characterized in accordance with the HDF protocols. Consequently, final characterization of the HDFs will be completed once the “first visit” has been conducted in the spring of 2016.

2.5.3.2 Rapid Assessments

The Rapid Geomorphic Assessment (RGA) was designed by the Ontario Ministry of Environment (MOE, 2003) to assess reaches in rural and urban channels. This qualitative technique documents indicators of channel instability. Observations are quantified using an index that identifies channel sensitivity based on the presence or absence of evidence of aggradation, degradation, channel widening, and planform adjustment. Overall the index produces values that indicate whether the channel is stable/in regime (score ≤0.20), stressed/transitional (score 0.21-0.40), or adjusting (score ≥0.40; Table 2.5.2).

Table 2.5.2. RGA Classification

≤0.20	In Regime or Stable (Least Sensitive)	The channel morphology is within a range of variance for streams of similar hydrographic characteristics – evidence of instability is isolated or associated with normal river meander propagation processes
0.21-0.40	Transitional or Stressed (Moderately Sensitive)	Channel morphology is within the range of variance for streams of similar hydrographic characteristics but the evidence of instability is frequent
≥0.41	In Adjustment (Most Sensitive)	Channel morphology is not within the range of variance and evidence of instability is wide spread

The Rapid Stream Assessment Technique (RSAT) was developed by John Galli at the Metropolitan Washington Council of Governments (Galli 1996). The RSAT provides a more qualitative and broader assessment of the overall health and functions of a reach. This system integrates visual estimates of channel conditions and numerical scoring of stream parameters using six categories:

- Channel Stability
- Erosion and Deposition
- Physical In-stream Habitat
- Water Quality
- Riparian Conditions
- Biological Indicators

Once a condition has been assigned a score, the total of these scores produces an overall rating which is based on a 50 point scoring system. The result of the assessment then categorizes the stream as Low (<20), Moderate (20-35), or High (>35) stream quality.

While the RSAT scores streams from a more biological and water quality perspective than the RGA, this information is also of relevance within a geomorphic context. This is based on the fundamental notion that, in general, the types of physical features that generate good fish habitat tend to represent good geomorphology as well (i.e., fish prefer a variety of physical conditions – pools provide resting areas while riffle provide feeding areas and contribute oxygen to the water

– good riparian conditions provide shade and food – woody debris and overhanging banks provide shade). Additionally, the RSAT approach includes semi-quantitative measures of bankfull dimensions, type of substrate, vegetative cover, and channel disturbance.

Rapid assessments have been completed for all accessible properties within the study area. Rapid assessments have also been completed on the two reaches immediately downstream of the study area (downstream of Steeles Avenue) to assess the potential for downstream impacts.

2.5.3.3 Detailed Characterization

The purpose of the detailed characterization is to confirm the characterization completed through the rapid assessments and obtain site-specific information that will aid in identification of constraints and opportunities for subwatershed planning. The detailed characterization also provides additional information for subsequent analyses to inform management recommendations, such as determination of erosion thresholds and stormwater management plans for erosion control.

The detailed field data collection has two main components, the first being cross-sectional measurements and the second being the longitudinal profile. The cross section measurements include width and depth dimensions, substrate size, and bank properties. The longitudinal profile component is a level or total-station survey of the bed morphology and bankfull gradient through the length of the site.

Detailed site selection focuses on selecting an appropriate reach based on existing instability (sensitivity to land use change), representative spatial distribution, and extent of channel alteration. The results of the rapid assessment inform this decision. Sensitivity is determined based on both the rapid assessment scores and the location within the study area. Reaches that are located further downstream are more frequently selected as they are more likely to be impacted by land use changes or potentially receive additional flow from stormwater management outlets. Channel alteration is also considered; unaltered reaches are preferred as they offer a more accurate depiction of channel processes under existing conditions.

The detailed site location within the reach is likewise selected. Air photos and rapid assessment results are consulted to select a section within the particular reach which is not impacted by local disturbances such as flow obstructions or minor changes in surrounding vegetation.

For the Premier Gateway Scoped Subwatershed Study, two detailed sites were completed as part of the 2015 assessment. The sites were located in reach W-T1-2 and HT-1 (Figure 2.5.8). Both reaches had minimal channel alteration, were considered ‘transitional’ and were located near the downstream end of the study area (HT-1 is downstream of the study area). A third detailed site will also be completed as part of the 2016 spring field program to provide supporting data. It is likely that this will be located in either reach E-T1-1, reach E-T1-2, or reach W-T1-3.

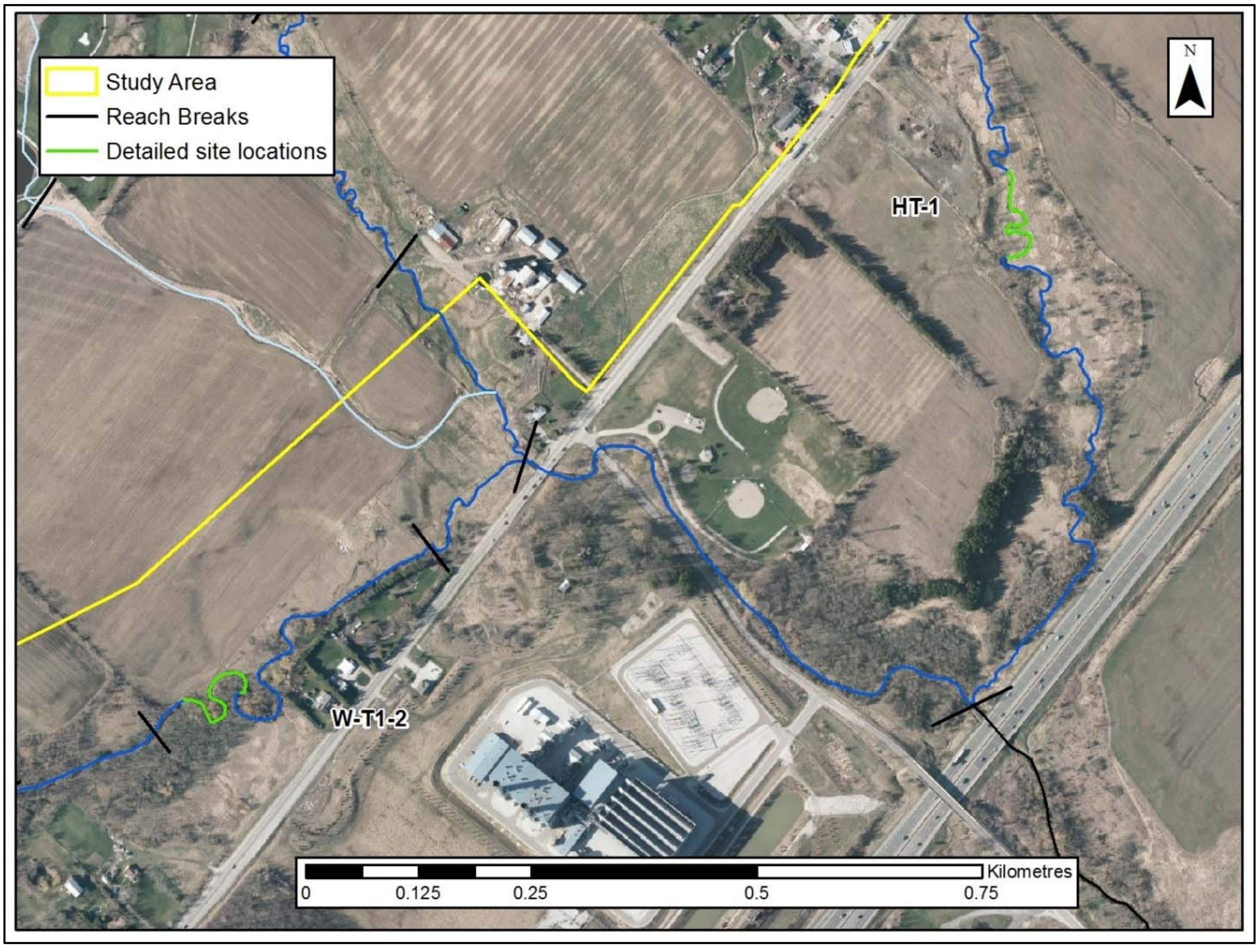

Figure 2.5.8. Detailed site locations

2.5.4 Characterization and Analysis

The watercourses in the study area are part of two systems, the Hornby Tributary in the east, and the Middle Sixteen Mile Creek Tributary in the west. The two watercourses converge upstream of Hwy 401 and flow southward towards the Middle Branch of Sixteen Mile Creek. The characterization presented in this section discusses the results of the field assessments with respect to these two systems. Results of the rapid assessments may be found in Table 2.5.3. and 2.5.4.

The Hornby Tributary consists of two branches: HT-2a and HT-2b. The main branch is HT-2a, while HT-2b was a smaller watercourse consisting mainly of HDFs. All the features within the area east of Trafalgar Road are considered to be HDFs and have been assessed using the HDF protocol (TRCA/CVC, 2014), with the exception of reach HT-2b-1 which was assessed using the rapid assessment. Reach HT-2b-1 was established at the confluence of HT-2b-2 and HT-2b-4. Both features began to gain channel definition and minimal surface flow approaching the confluence; downstream of confluence, channel dimensions were observed to be larger and flow was sustained.

The majority of reach HT-2b-1 was observed to have a well-established planform alignment which was highly sinuous flowing through dense grassy meadow vegetation. There was one section, located mid-reach immediately upstream of a ford in the channel, where the channel became diffuse as it flowed through a large area of cattails. With no hydraulic structure (i.e. pipe or culvert) to convey flow at this crossing, water was observed to be ponded in vehicle tracks. Approximately 10 m downstream of the ford the channel was observed to regain definition. On average, bankfull width was 1.80 m-2.00 m and bankfull depth was 0.45 m-0.65 m. Cross-sectional width was observed to be relatively consistent throughout the reach, due to the additional support and stability provided to the banks by the dense root structure of the surrounding grassy vegetation. Often dense grassy vegetation results in slumping of material in larger channels because the roots are too shallow to provide substantial support. The channel in reach HT-2b-1 is smaller with a shallow bankfull depth, allowing the banks to be better supported by the grass roots. Some undercutting was noted in select areas, but for most of the reach, the channel banks were observed to be vertical. This is indicative of the support provided by the grass roots which reduces selective erosion and scouring, resulting in a uniform vertical bank face. The vertical bank face also indicates that the channel is exerting some of its energy attempting to modify the lateral boundary. The channel profile was variable with steep riffles and low gradient pools with silt accumulation. Aggradation is considered the primary mode of adjustment, based upon the observed lateral bars, siltation in pools, and soft unconsolidated bed in some areas. As mentioned above, there were also some indications of widening (steep bank face). Overall, the reach was classified as ‘In Regime’ based on the RGA assessment. The RSAT assessment classified the reach as ‘moderate’ condition. The main limiting factor was in-stream habitat due to some shallower sections which may not be passable during low flow.

The west section of Hornby Tributary (HT-2a) within the study area begins upstream in a tract of Halton Regional Forest property; reach HT-2a-2. The channel in this reach is straight with minimal sinuosity and low gradient. At the upstream end of the reach there a small debris jam was observed, resulting in a backwater and silt deposits. Upstream of Trafalgar Road evidence of widening such as leaning trees, exposed tree roots, and scouring along the banks was noted. Exposed clay was noted in pools and along the margins of the channel. At Trafalgar Road, the channel passes through a double box culvert. Upstream of the eastern culvert the channel makes a slight bend in which a large scour pool has formed. On average, bankfull width was 5.50 m-7.50 m and bankfull depth was 0.40 m-0.50 m. Downstream of Trafalgar Road the channel was observed to be somewhat narrower and indicators of aggradation were noted such as siltation in pools and riffle material embedded with fines. Approaching the downstream end a small woody debris jam was observed, to forced flow against the right bank inducing sinuosity. On average, bankfull width was 4.50 m-6.50 m and bankfull depth was 0.40 m-0.60 m. The RGA assessment classified the reach as ‘Transitional’ with widening and aggradation as the primary modes of adjustment. The RSAT assessment classified the reach as ‘moderate’ condition. The main limiting factor was scour/deposition due to the silt deposition noted downstream of Trafalgar Road.

The channel flows out of the Halton Regional Forest property and onto a private residential property, where reach HT-2a-1 begins. Similar to reach HT-2b-1, the channel was observed to be surrounded by tall grassy vegetation with some isolated deciduous trees. In reach HT-2a-1, the channel was observed to be narrower than upstream with average dimensions of 3.50-4.00 m (width) and 0.45-0.65 m (depth). This is considered attributable to a transition in dominant vegetation from trees to grasses. The dominant form of adjustment in this reach is planform adjustment and aggradation. The channel planform was observed to be highly sinuous particularly at the upstream end of the reach. One of the indicators of planform adjustment that was noted was thalweg out of alignment with meander form, whereby flow would often split due to islands of slumped bank material or woody debris obstructions. Additionally, secondary channels were observed near the upstream end of the reach. These characteristics are also visible on the aerial photography. These frequent changes to the dominant flow path, and splitting of flow, are considered to result in inconsistent and highly variable dimensions. In some sections up to three flow paths were observed. The RGA assessment classified the reach as 'In transition'. The RSAT assessment classified the reach as 'moderate' condition. The RSAT score was limited by channel stability and the frequent narrowing of the wetted width due to the multiple flow paths.

The east and west sections of Hornby Tributary converge to form reach HT-2; this reach was not assessed as property access was not granted. Hornby Tributary reach HT-1 downstream of Steeles Avenue was assessed, and is considered an important reach for characterization as it appears unaltered and is located downstream of the study area. Furthermore, reach HT-1 It would be susceptible to impacts from development within the Secondary Plan area, and it also serves as a good surrogate for reach HT-2. In reach HT-1, the channel flows through a large open meadow area with sporadic deciduous trees. The channel was observed to exhibit characteristics that are reflective of this type of surrounding vegetation; severe undercutting and calving of bank material resulting in islands which split the flow. Channel dimensions were noted to be highly variable with steep narrow riffle sections (approx. 1.80 m-2.50 m bankfull width) sections and deep, wide pools with accumulation of silts and fines (approx. .3.50 m-4.50 m bankfull width). The range of substrate sizes was also to be broad, with coarse to very coarse gravel in the riffles as compared to sands and silt accumulation in pools and slower sections. The dominant mode of adjustment was noted to be widening with aggradation as a secondary process. Widening was indicated by steep bank angles, undercutting, and leaning trees. Aggradation of silts and sands was noted in pools and large unconsolidated deposits. This occurs as a result of the frequent bank failure supplying additional fine material from the soil. According to the RGA assessment the reach was classified as 'Transitional'. The RSAT assessment classified the reach as 'moderate', with water quality as a limiting factor. This was due to high suspended sediment load as a result of the additional fine materials.

The Middle Sixteen Mile Creek Tributary consists of an east branch, west branch, and HDF branch. The east branch begins upstream on Hornby Glen Golf Course. Reach E-T1-3 begins at the upstream end of the golf property and continues to the end of the property. Surrounding vegetation was typical of a channel flowing through a golf course; minimal riparian corridor consisting of small woodlots and manicured lawn. Numerous crossings for the cart paths were observed, which were mainly flat bottomed bridges with minimal clearance. A pair of undersized

CSPs were also observed at the upstream end. The CSPs were partially blocked at the time of investigation, with material resulting in an upstream backwater and accumulation of unconsolidated fine material. Downstream of the CSPs, the channel was observed to be overwidened with erosion on both banks as a result of the flow constriction. Where there was no riparian buffer and the channel was adjacent to golf course vegetation, undercutting and bank slumping were common. Silt accumulation was noted in these sections. In the woodlot areas, there were clay exposures in the deeper pools and along the margins. On average, bankfull width was 1.20 m-3.50 m and bankfull depth was 0.40 m-0.80 m. The dominant mode of adjustment was aggradation with minor indicators of the other three types of adjustment. Aggradation was primarily due to accumulation of silt and fines, but it also included development of mid-channel and lateral bars. Degradation was noted as a result of the exposed clay, but this was isolated to select areas. The RGA assessment classified the reach as 'Transitional'. The RSAT assessment classified the reach as 'moderate' condition with riparian condition as a limiting factor.

Reach E-T1-4 was determined to be an HDF and therefore was not assessed using the rapid assessments. The feature was piped beneath the fairways and was only open for short distances. Reach E-T1-2 is located downstream of the golf course on a private active agricultural property. In this reach, the channel flows through a cattle pasture where cattle have unrestricted access to the creek. The surrounding vegetation was short grass with one isolated patch of trees along the bank which was used as refuge by the cattle. The channel was strongly impacted by land use; dimensions were wider and shallower due to frequent bank slumping and trampling, dense algae was growing in the channel as well as aquatic vegetation. Substrates were dominantly finer material such as pebbles, sand and silt, which often overlaid the coarser material (medium gravels). There were two large eroding bends, one at the upstream end when the channel first entered the property and one near the downstream end on the west side. The channel was relatively sinuous, particularly at the downstream end where the channel had developed a secondary channel while the previous flow path appeared to be cutting off. It was notable that the channel planform was actively adjusting in this area. Bankfull width was variable ranging from 2.80 m-5.50 m, while average bankfull depth was 0.45 m-0.70 m. The channel has been classified as 'transitional' based on the RGA assessment, with the dominant forms of adjustment being widening, aggradation, and planimetric. This is a result of the land use type. The RSAT classified the channel as in 'low' condition. The limiting factors were the lack of riparian vegetation, poor instream habitat due to widening, and poor water quality indicated by the dense algae and accumulation of fine sediments.

The channel exits the cattle pasture and flows across a farm lane. There is no culvert to convey the water so the flow widens and ponds in the farm lane. This serves as a reach break between E-T1-2 and E-T1-1. Downstream of the farm lane, in reach E-T1-1, the channel flows through an unutilized meadow area, although it appears that the channel has been altered in the past as discussed in the historic assessment. Downstream of the farm lane, a pool was observed with exposed hard pan till. Areas of unconsolidated silt accumulation were common, often from 15-20 cm but up to 40 cm in depth. Frequent bank slumping and undercutting were observed. Similar to reach E-T1-2, aquatic vegetation and large mats of algae were noted, likely a result of nutrient loading from the surrounding agriculture. Near the downstream end of the reach is the confluence with the HDF branch to the west. The exact location of the confluence was difficult to discern in the field due to lack of flow from the HDF at the time of assessment (July). On average, bankfull width ranged from 1.60 m-3.20 m while bankfull depth ranged from 0.45 m-0.75 m. The results of the RSAT assessment classified the channel as 'In Regime', with the dominant mode of adjustment being aggradation. The RGA results determined the channel was in 'moderate' condition. The limiting factor was primarily instream habitat due to the aggradation and aquatic vegetation.

Assessment of the west branch of the Middle Sixteen Mile Creek Tributary began at the western boundary of the study area, Sixth Line. The west branch is a larger system than the east branch. Downstream of Sixth Line, the channel flows through a mixed deciduous forest with tall grasses and herbaceous vegetation. Through this reach the channel was characterized by regularly spaced alternating lateral bars. Bank sloughing, undercuts and erosion were noted on the banks opposite the lateral bars, with the undercuts typically near the top of the bank profile. Observed undercutting near the top of the bank indicates that the higher flows are not accessing the floodplain and that the channel is entrenched at that location. This combination of alternating bars and undercutting/erosion along the opposite bank is the initial stage in the development of a meandering planform. Indications of degradation were also noted. These were exposed till along the margins and in pools, elevated tree roots, and increased bank heights. On average, bankfull widths were 5.85 m-7.2 m and bankfull depths were 0.63 m-0.85 m. The RGA assessment identified the dominant form adjustment as widening due to the erosion on the outer banks, steep bank angles, and leaning trees. The channel has been classified as 'Transitional'. The RSAT assessment determined the channel was in 'moderate' condition.

A small tributary, reach W-T1-2a, joins the channel mid-reach in W-T1-3. Reach W-T1-2a begins on the downstream side of a farm lane. On the upstream side, water could be seen flowing into a CSP; however on the downstream side an outlet could not be found in a dense phragmites stand. It was assumed that the outlet may be buried or blocked on the downstream side. The channel gained definition as it flowed out of the phragmites stand and into a woodlot. Throughout the reach the channel transitioned through small woodlots and open meadow areas, resulting in variable channel widths. Near the confluence with W-T1-3, the channel had a steeper gradient as it transitioned down across the tableland to the main channel. Woody debris was also prominent through this transition resulting in small drops in elevation. The average bankfull widths were 1.50 m-3.60 m, while the average bankfull depths were 0.35 m-0.60 m. The RGA assessment classified the channel as 'In Regime' with the dominant modes of adjustment as aggradation and degradation. This was indicated by soft, unconsolidated bed and bank height increasing through the downstream end. The RSAT identified the channel as in 'moderate' condition, with limiting factors of instream habitat and biological indicators. This was primarily due to the shallow depth and accumulated organic material.

Reach W-T1-2 begins as the channel exits the wooded area and flows into an area with active farming to the north and residential properties along the south. Mixed deciduous forest remains the dominant surrounding vegetation, however the vegetation is less dense and the riparian corridor is narrower. At the upstream end of the reach there is a large woody debris jam. The channel was observed to flow through two tortuous meander bends before flowing relatively straight along the residential property boundaries to the south where the riparian buffer is minimal. The channel was observed to be entrenched throughout the length of the reach with bank heights on average of 1.25 m-2.00 m. Fallen woody debris was frequently observed throughout the sinuous section resulting in deep backwater areas and silt accumulation. Within the straighter sections, exposed clay on the bed was prevalent overlain by a thin layer of gravel. Exposed clay was also noted in the banks. On average, bankfull width ranged from 4.00 m-6.00 m and bankfull depth ranged from 0.40 m-0.60 m. The RGA classified the channel as 'Transitional' with degradation as the dominant process and aggradation/widening as secondary processes. The RSAT identified the channel as in 'moderate' condition with instream habitat and scour/deposition as limiting factors. This was due to the aggradation in the backwater areas and shallower sections with exposed clay.

Reach W-T1-1 begins where the channel flows into an open grassy meadow area downstream of the residential properties. This is a short reach as the channel approaches the crossing with Steeles Avenue. The channel was observed to be entrenched through this reach with bank heights up to 2.00 m. The banks were observed to be vertical for the majority of the reach with frequent slumping and undercutting in the bends. Bankfull width was observed to be narrower, 3.00-5.00 m, due to the change in surrounding vegetation. The channel was observed to be low gradient through this reach resulting in low velocities, instream aquatic vegetation, and accumulation of silt. Based on these characteristics, the RGA identified the dominant mode of adjustment as aggradation; the channel was classified as 'In Regime'. The RSAT identified the channel as in 'moderate' condition, with limiting factors of water quality and in-stream habitat due to the low velocities and accumulation of fines.

Reach T1 begins at the confluence of the east and west branches of the Middle Sixteen Mile Creek Tributary. This is located just upstream of Steeles Avenue; the reach extends through the length of Hornby Park until the confluence with the Hornby Tributary just upstream of Hwy 401. The channel flows through arch span bridges for Steeles Avenue and Sixth Line, less than 100 m apart. Through this section, the channel was observed to be very low gradient resulting in substantial siltation up to approximately 0.30 m depth which was particularly severe beneath the Sixth Line bridge. The section downstream of Sixth Line through the southern extent of Hornby Park has been previously altered using natural channel design principles. Oversized rip-rap was observed on the channel bed through the bend downstream of the bridge. Through the straight section there was a series of constructed riffles, with vegetated rip-rap on either bank. Some evidence of erosion was documented along the banks but it was not substantial. Bed material through the design section was observed to be very coarse consisting of cobbles and small boulders in the riffles. The design ends with a riffle where the channel flows into the wooded area south of the park. Downstream of the riffle a large, overwidened pool has formed with a bankfull width of approximately 7.00-8.00 m as compared to the bankfull width at the riffle of approximately 4.00-5.00 m. In the woodlot, the channel primarily flows against the valley wall which forms the road embankment for Sixth Line. There was evidence of slope instability along the valley wall such as gullying, loss of vegetation, and a concave profile. Bed material was smaller than that found upstream in the design section, with medium gravel as the dominant substrate size. The channel makes a sharp turn away from the valley wall and flows eastward for a short section before making another sharp, nearly 90 degree turn to flow southward towards Hwy 401. Severe erosion was observed along the south bank through the straight section as well as exposed clay on the bed. Erosion was also severe along the outer (east) bank in the 90 degree bend. Immediately upstream of the confluence with the Hornby Tributary, the channel was observed to be undergoing active planform adjustment. There is a small island that is splitting the dominant flow path, as well as a woody debris jam that is also impacting flow. Bankfull width was noted to be variable ranging from 4.50 m-8.00 m, bankfull depth varied from 0.45 m-0.85 m. The channel was classified as 'In Regime' based on the RGA score with widening as the dominant process in the downstream half of the reach and aggradation as the dominant process in the upstream half. The RSAT score identified the channel as in 'moderate' condition with instream habitat, biological indicators, riparian condition, and water quality as liming factors.

Table 2.5.3 Summary of RGA Results

Reach*	Factor Value				Stability Index	Condition
	Aggradation	Degradation	Widening	Planimetric Adjustment		
HT-2b-1	0.33	0.00	0.25	0.00	0.15	In Regime
HT-2a-2	0.44	0.29	0.38	0.00	0.28	Transitional
HT-2a-1	0.33	0.14	0.00	0.57	0.26	Transitional
HT-2	Property not accessed					
HT-1	0.22	0.14	0.38	0.14	0.22	Transitional
E-T1-3	0.56	0.14	0.13	0.14	0.24	Transitional
E-T1-2	0.33	0.14	0.38	0.29	0.28	Transitional
E-T1-1	0.33	0.14	0.00	0.14	0.15	In Regime
W-T1-3	0.25	0.43	0.50	0.00	0.29	Transitional
W-T1-2a	0.125	0.14	0.00	0.00	0.07	In Regime
W-T1-2	0.33	0.43	0.25	0.14	0.29	Transitional
W-T1-1	0.33	0.14	0.12	0	0.15	In Regime
T1	0.22	0.14	0.38	0.00	0.19	In Regime

*Reaches not included in the table were not assessed using the RGA method due to classification as headwater drainage features

Table 2.5.4. Summary of RSAT Results

Reach*	Factor Value						Overall Score	Condition
	Channel Stability	Scour/ deposition	In-stream Habitat	Water Quality	Riparian Condition	Biological Indicators		
HT-2b-1	7	5	3	4	5	4	28	Moderate
HT-2a-2	8	4	5	5	7	5	34	Moderate
HT-2a-1	5	4	5	5	4	4	27	Moderate
HT-2	Property not accessed							
HT-1	5	5	5	4	4	4	27	Moderate
E-T1-3	5	5	5	4	3	4	26	Moderate
E-T1-2	4	4	2	3	2	3	18	Low
E-T1-1	5	3	3	4	5	4	24	Moderate
W-T1-3	6	5	5	5	4	4	29	Moderate
W-T1-2a	6	3	2	3	3	2	19	Low
W-T1-2	5	3	3	3	4	3	21	Moderate
W-T1-1	6	4	3	3	5	3	24	Moderate
T1	6	5	3	4	4	3	25	Moderate

*Reaches not included in the table were not assessed using the RSAT method due to classification as headwater drainage features.

2.5.4.1 Detailed Characterization

The detailed field assessment has been completed at two sites in reaches HT-1 and W-T1-2, as outlined in the previous section. Known field indicators, such as changes in vegetation and inflection points in the bank profile, have been used to quantify bankfull cross-sectional dimensions. The 'bankfull' channel area generally represents the maximum capacity of the channel before it spills onto the floodplain. If a channel is entrenched and does not have access to its floodplain, it can be more difficult to determine the 'bankfull' elevation within the cross-section.

Bed material was sampled at each of the cross sections surveyed during the field assessment using a modified Wolman (1954) pebble count procedure. The pebble counts for each cross section have been compiled to establish the grain size distribution for the extent of the field site (Appendix F).

Bankfull channel dimensions are formed through repeated events of similar magnitude which possess the highest potential energy for modifying the channel boundaries. These events constitute the 'bankfull' discharge for the channel. Bankfull channel dimensions, in conjunction with bankfull channel gradient, can thus be used to calculate the bankfull discharge. Other important flow characteristics can also be determined such as shear stress and velocity, which are critical in understanding sediment entrainment processes within a given section of channel.

Reach HT-1

Existing average bankfull channel dimensions for reach HT-1 are provided in Table 2.5.5. Average bankfull width was 3.14 m, with a range of 2.62 m to 3.65 m. Average bankfull depth was 0.50 m, ranging from 0.44 m to 0.62 m. The average maximum depth was 0.71 m, with a range of 0.64 m to 0.83 m. These dimensions produced an average cross-sectional area of 1.60 m^2 with a range of 1.20 m^2 to 2.27 m^2. These measurements were similar to those documented for the same reach (reach C) in the Hwy 401 Corridor Study (Dillon, 2000).

Table 2.5.5. Bankfull Channel Geometry – Reach HT-1

Cross-section Parameter	Average Reach HT-1 (2015)	Average Reach C (Dillon 2000)
Bankfull Width (m)	3.14	3.43
Average Bankfull Depth (m)	0.50	0.45
Maximum Bankfull Depth (m)	0.71	NA
Bankfull Width: Depth	6.49	7.9
Cross-sectional Area (m^2)	1.60	NA
Wetted Perimeter (m)	3.95	NA
Hydraulic Radius (m)	0.40	NA
Left Bank Angle (^{o})	47.04	NA
Right Bank Angle (^{o})	60.70	NA

*NA – not available in the Dillon, 2000 report

For reach HT-1, the smallest material consisted predominantly of silt with some fine sand (D10 = 0.0007 cm). This corresponds with the additional inputs of fine material from the slumping bank material. The dominant bed material ranged from pebbles to medium gravel (0.50 cm-1.59 cm) resulting in a D50 of 1.10 cm. This material was seen in transition areas and riffles where velocities were sufficient to flush away fines. The coarsest material consisted of small and large cobbles (D90 = 10.02 cm) found as keystones in the riffles.

Based on the measured cross sections, bankfull flow estimates in reach HT-1 are provided in Table 2.5.6. The average bankfull discharge was 1.75 m^3/s (at 0.30% slope and n = 0.035), with a range of 1.22 m3/s to 2.83 m^3/s. At the average bankfull flow, the channel produces average and maximum velocities of 0.87 m/s and 1.28 m/s, respectively. Average and maximum shear stresses are 11.88 N/m^2 and 20.83 N/m^2, respectively. The calculated bankfull discharge and associated hydraulics for reach C in 2000 are higher than those calculated for the same reach in 2015 as part of this study. Because channel dimensions were comparable, this difference can be attributed to the steeper gradient measured in 2000 (0.56%) as opposed to the 2015 gradient (0.30%).

Table 2.5.6 Bankfull Channel Hydraulics – Reach HT-1

Cross-section Parameter	Average Reach HT-1 (2015)	Average Reach C (Dillon 2000)
Bankfull Discharge (m^3/s)	1.75	2.18
Bankfull Gradient (m/m)	0.30%	0.56%
Average Bankfull Velocity (m/s)	0.87	1.41
Maximum Bankfull Velocity (m/s)	1.28	NA
Average Shear Velocity (m/s)	0.11	NA
Stream Power (W/m)	51.42	NA
Stream Power per unit Width (W/m^2)	16.23	35
Average Shear Stress (N/m^2)	11.88	NA
Maximum Shear Stress (N/m^2)	20.83	NA

*NA – not available in the Dillon, 2000 report

Reach W-T1-2

Existing average channel dimensions based on the detailed characterization work in reach W-T1-2 are provided in Table 2.5.7. Results from reach B (Dillon, 2000), which corresponds with reach T-1 of the current study, have also been included for comparison. Average bankfull channel width was 4.79 m, with a range of 3.90 m to 5.50 m. Average bankfull depth of 0.32 m, ranging from 0.29 m to 0.37 m. The average maximum depth was 0.53 m, with a range of 0.45 m to 0.64 m. These dimensions produced an average cross-sectional area of 1.58 m^2 with a range of 1.29 m^2 to 1.90 m^2. The dimensions for reach W-T1-2 are comparable to those for reach B measured in 2000. Reach B has larger dimensions which are expected because of a major tributary input.

Table 2.5.7 Bankfull Channel Geometry		
Cross-section Parameter	**Average Reach W-T1-2 (2015)**	**Average Reach B (Dillon, 2000)**
Bankfull Width (m)	4.79	5.48
Average Bankfull Depth (m)	0.32	0.54
Maximum Bankfull Depth (m)	0.53	NA
Bankfull Width: Depth	14.97	10.3
Cross-sectional Area (m^2)	1.58	NA
Wetted Perimeter (m)	5.07	NA
Hydraulic Radius (m)	0.31	NA
Left Bank Angle (^{o})	25.59	NA
Right Bank Angle (^{o})	15.54	NA

*NA – not available in the Dillon, 2000 report

For reach W-T1-2, the finest material consisted predominantly of exposed till with some accumulation of silt (D10 = 0.019 cm). The dominant bed material was a mixture of pebbles, medium gravel, and coarse gravel ranging in size from 0.50 cm-2.39 cm. The resultant D50 was 1.78 cm. The coarsest fraction consisted of very coarse gravel and small cobbles (D90=7.10 cm). Overall the distribution is narrower and slightly coarser in reach W-T1-2 than that of reach HT-1.

Bankfull channel hydraulics for reach W-T1-2 are provided in Table 2.5.8. Results from reach B (Dillon, 2000), which corresponds with reach T-1 of the current study, have also been included for comparison. The average calculated bankfull discharge is 0.85 m^3/s (at 0.12% slope and n = 0.035). For the individual cross-sections, the calculated bankfull discharge was relatively consistent and varied from 0.65 m^3/s to 1.07 m^3/s. At the bankfull flow, the channel produces average and maximum velocities of 0.43 m/s and 0.68 m/s, respectively. Average and maximum shear stresses are 3.68 N/m^2 and 6.30 N/m^2. The calculated bankfull discharge and associated hydraulics for reach B are higher than those calculated for reach W-T1-2. This can partially be attributed to the tributary input which would result in increased discharge in reach B. The difference in discharge is also be exacerbated by the difference in measured bankfull gradient (0.12% and 0.39%). The low gradient measured in 2015 is likely a result of the location of the survey within the torturous meander bend. Large meanders result in low gradient because the channel length is longer than if it were to take a more direct path over there same distance.

Table 2.5.8 Bankfull Channel Hydraulics		
Cross-section Parameter	**Average Reach W-T1-2 (2015)**	**Average Reach B (Dillon, 2000)**
Bankfull Discharge (m^3/s)	0.85	2.31
Bankfull Gradient (m/m)	0.12%	0.39%
Average Bankfull Velocity (m/s)	0.43	0.78
Maximum Bankfull Velocity (m/s)	0.68	NA
Average Shear Velocity (m/s)	0.06	NA
Stream Power (W/m)	10.03	NA
Stream Power per unit Width (W/m^2)	2.10	16
Average Shear Stress (N/m^2)	3.68	NA
Maximum Shear Stress (N/m^2)	6.20	NA

*NA – not available in the Dillon, 2000 report

Erosion Thresholds

Data from the detailed field assessment has been used to complete the erosion threshold analysis. This analysis determines the hydraulics (discharge, channel depth, average channel velocity) at which the channel produces sufficient shear stress to initiate mobilization of a given particle size (D_{crit}), i.e., the 'threshold' condition at which sediment will start to mobilize. It is then assumed that if this 'threshold' flow is sustained erosion will eventually occur, therefore the flow is referred to as the 'erosion threshold'.

A number of different established entrainment relationships have been used to establish the critical shear stress or velocity, in order to consider a range of results. Once these values have been established, a model has been run that incrementally raises the water level within the channel until the depth and slope produce hydraulic values that are equal to the critical values. The model results have been examined for convergence and compatibility with field observations. Selection of the appropriate threshold has also been based on an understanding of site conditions and the assumptions and ranges of conditions under which the entrainment equations are applicable. This analysis helps to evaluate the reach's erosion sensitivity by comparing the boundary shear stress associated with the modeled flows to the critical shear stress required to entrain sediment.

The goal of the erosion threshold analysis is to determine a threshold discharge for various reaches above which boundary materials are entrained. Where changes are to occur to the contributing drainage area of a channel, a typical objective is to ensure that the future hydrological conditions do not result in channel flow exceeding the threshold discharge more frequently than with existing conditions. This is done to minimize potential post-development channel degradation.

The selected method for reach HT-1 was Komar (1987), an equation of fit based on the relationship between particle diameter (cm) and mean channel velocity. The equation produces a critical velocity threshold based on the index grain size.

$$\bar{u}_c = 57D^{0.46}$$

Where $\bar{u}_c$ is mean channel velocity (m/s) and D is particle diameter in cm. The equation was developed for entrainment of particles from deposits of mixed sizes. The Komar (1987) equation is more refined than traditional shear stress-based equations. Most shear stress-based equations are rooted in the original Shields equation (1936), based on deposits with material of uniform size, and can often over estimate the amount of force required to mobilize larger grain sizes. This is because the equation assumes that all particles are equally exposed to the flow based on a uniform packing structure, whereas in mixed sediment deposits (such as those occurring in natural environments) the packing structure is variable with larger particles more exposed to the flow than smaller hidden particles allowing them to be more easily transported. Therefore an equation based on mixed sediment deposits produces a more accurate, realistic threshold value.

The erosion threshold assessment has been completed for each cross-section and then averaged to determine the governing threshold for the reach. The results are presented in Table 2.5.9. The calculated critical discharge in HT-1 is 0.38 m^3/s. This indicates that bed load transport is initiated at 22% of the bankfull discharge. Based on the Komar (1987) equation, the critical velocity is 0.60 m/s for a particle size of 11.00 mm. This threshold is higher than that calculated for the same reach in the Dillon (2000) study (Reach C). The Reach C threshold was much lower at 0.11 m^3/s; this is because the grain size was much finer with a D_{50} of 3.0 mm. The Reach C threshold is more representative of the finer fraction of material (silts and sands). This type of material is frequently mobilized and flushed through the system, resettling during low flow periods. The 2000 work may have been completed during one of these low flow periods resulted in an overly fine distribution. The fine material often represents a surficial layer of material over coarser gravels. Once the fine material is mobilized, the coarse gravel may remain immobile and therefore true erosion of the channel boundaries would occur at a higher flow. Therefore a threshold for this fine material is often not truly representative of erosive risk. The medium gravels measured in the 2015 field work are more representative of the channel boundary material and provide a more accurate estimate of erosive flows.

A different approach has been used for reach W-T1-2, to account for both the exposed till in the bed and the gravel material overlying it. Thresholds have been determined for both types of material to most accurately characterize the erosive risk to the channel.

The Komar (1987) equation has been used to determine the threshold for the gravel material based on the D_{50} (17.78 mm). The calculated critical discharge for reach W-T1-2 is 1.49 m^3/s. Based on this, bed load transport of the gravel material would be initiated at 174% of the bankfull. This generally indicates that a reach is ‘armoured’ in that the bed material has sufficiently coarsened to the point that it requires flows larger than bankfull to mobilize it. For reach W-T1-2, the D_{50} is not overly coarse given the size of the channel; the channel should have sufficient capacity to mobilize the gravel at bankfull or lower. The issue in W-T1-2 is not that the material is too coarse; it is that the channel has become inefficient due to the overly sinuous planform and the resulting low gradient. Because shear stress is primarily derived from slope and depth of flow, the channel needs a higher flow to compensate for the low gradient.

A threshold has been determined for the till. Till is a type of glacial deposit consisting of coarse materials (gravel and boulders) suspended in a matrix of finer material (clay and sand). Due to the high percentage of fine material, cohesion is an important factor in erosive resistance. To accurately determine the erosion threshold, the cohesive nature must be taken into consideration. Contrary to non-cohesive sediment erosion, which occurs through the entrainment of discrete particles, cohesive sediment is eroded through the entrainment of aggregates. When considering the cohesive nature of materials, other factors must be taken into account. One such factor is the degree of compactness of the sediment deposit. The exposed till in the reach was fairly loose in some areas and could be considered an ‘active’ layer. It is expected that the deposition and erosion of these looser particles will occur in the channel as part of the natural cyclic nature of the system, similar to the silts and sands in reach HT-1. Therefore, it is likely that loose deposited materials do not exert a strong control on the overall morphology of the watercourse. Alternatively, there were a number of locations in the reach where exposed hard-packed till was observed, which would suggest that it also underlies the areas of looser fine material. This hard-pack till represents the channel boundary material which if mobilized would result in altered channel dimensions. The till which can be considered fairly compacted clay, was the focus of a secondary erosion threshold analysis for reach W-T1-2.

To determine the critical shear stress, Chow (1959) has been used. This study provides an estimate of net tractive force for a range of cohesive soil compositions and considers the compactness of the material. For reach W-T1-2, the critical shear stress was determined to be 11.25 N/m^2. The channel requires an average discharge of 4.02 m^3/s to produce this amount of force on the bed. This is much higher than the critical discharge for the gravel material in the reach due to the strong cohesion of the till.

The governing threshold for the reach will be the more conservative of the two; the threshold for the gravel which was 1.49 m^3/s. These types of channels which have incised into underlying glacial material (till) are restricted by sediment supply and lack alluvial material such as gravel. Once an overlying layer is eroded, exposing the till surface, it can be difficult to re-establish. It is important to maintain the gravel layer because it helps to protect the underlying till from erosion. While the strength of the till as a cohesive unit is higher than that of the individual gravel particles, it can become weakened and softened by weathering from the flow of the channel. Over time the fine particles that compose the till matrix are systemically eroded away. Eventually, aggregate pieces of till may break off, or individual grains of coarse gravel protruding from the surface may be eroded out and transported. This can create a divot or pit, an inconsistency in an otherwise relatively smooth surface, which can lead to further scour. Through this process, erosion of the till surface will lead to changes in the overall channel dimensions. Therefore to minimize changes to the channel cross-section, the erosion threshold for the gravel (1.49 m^3/s) should be utilized to ensure the surficial gravel layer is maintained and the till remains covered. Additionally the reaches upstream and downstream of W-T1-2 had less exposed till and therefore the gravel threshold is more widely applicable to other reaches along the western branch of the Middle Sixteen Mile Creek Tributary.

Table 2.5.9 Average Bankfull Characteristics and Erosion Threshold Hydraulics by Reach

Parameter	Reach W-T1-2 (2015)		Reach B (Dillon, 2000)	Reach HT-1 (2015)	Reach C (Dillon, 2000)
Bankfull Geometry					
Average Bankfull Width (m)	4.79		5.48	3.14	3.43
Average Bankfull Depth (m)	0.32		0.54	0.50	0.45
Bankfull Gradient (%)	0.12		0.39	0.30	0.56
Bed Material					
D_{50} (mm)	17.78		22.1	11.00	3.0
D_{84} (mm)	58.64		NA	65.10	NA
Bankfull Hydraulics					
Bankfull Discharge (m^3/s)	0.85		2.31	1.75	2.18
Average Bankfull Velocity (m/s)	0.43		0.78	0.78	1.41
Average Shear Stress (N/m^2)	3.68		NA	11.88	NA
Thresholds					
Method of Analysis	Chow (1959)	Komar (1987)	Not specified	Komar (1987)	Not specified
Critical particle size	Fairly compact clay	D_{50}	D_{50}	D_{50}	D_{50}
Critical Discharge (m^3/s)	4.02	1.49	2.08	0.38	0.11
Critical: Bankfull Discharge	477%	174.4%	90.04%	22%	5.04%
Critical Velocity (m/s)		0.74	0.82	0.60	0.33
Velocity at critical flow – average (m/s)	0.93				
Critical Shear Stress (N/m^2)	11.25				
Shear Stress at critical flow (N/m^2)		7.65	NA	6.90	NA
Depth at critical flow – average (m)	0.85	0.46	0.25	0.27	0.05
Depth at critical flow – maximum (m)	1.14	0.66	NA	0.35	NA

*NA – not available in the Dillon, 2000 report

2.5.5 Summary of Findings

The Phase 1 SWS characterization has applied a combination of desktop analysis and field reconnaissance to characterize the channel morphology in the Premier Gateway Study Area. This has included review of background studies, historic aerial photographs, delineation of meander belt widths, rapid field assessments and detailed field sites.

Within the study area there are two drainage systems, the Hornby tributary and the Middle Sixteen Mile Creek Tributary. The Hornby tributary is a smaller tributary to the Sixteen Mile Creek Tributary. Both systems have a number of small headwater drainage features that have been identified first through desktop assessment and then confirmed through the rapid assessment field visits. Due to the timing of the 2015 field program beginning after the spring freshet, the initial visit which is required in accordance with the HDF protocol could not be completed. Data has been collected primarily during the timing window of the second visit for the HDF protocol. The initial visit after the freshet is required in order to obtain a complete characterization of the HDFs. As such, it is recommended that a spring freshet visit be completed in 2016. After this visit, it will be determined if an additional second and third visit is required in 2016 or if the 2015 data paired with the new 2016 data is sufficient.

The Hornby tributary reaches were located in the eastern section of the study area and consisted of two separate branches. The eastern branch consisted primarily of HDFs upstream of Trafalgar Road, which consolidated downstream of Trafalgar to form a permanently flowing watercourse in reach HT-2b-1. The western branch was the larger of the two, consisting of two reaches of permanent flow (HT-2a-1 and HT-2b-2). The east and west branches combines to form the main branch, reach HT-2. Reach HT-1 located downstream of the study area was also assessed to provide additional context for downstream impacts and serve as a surrogate for reach HT-2, which was not assessed in the field. The permanently flowing reaches of the Hornby Tributary, with the exception of reach HT-2a-2, exhibited similar dominant processes as a result of the consistent surrounding land use and vegetation. The surrounding vegetation consisted of dense meadow grasses, localized woody scrub vegetation, and sporadic deciduous trees. Channels that flow through this type of vegetation often have widening identified as the dominant process with aggradation as a secondary process. Widening is indicated by the severe scour and undercutting which occurs due to the dense, yet shallow grass root systems. Undercutting leads to additional fine material in the channel which accumulates as unconsolidated silt deposits, aggradation. Once undercuts are severe enough, it leads to calving of the bank material and large blocks of vegetated material sitting on the channel bed. The vegetated blocks often remain at the base of the bank and the channel will flow behind the block outflanking it. Eventually the block may be incorporated into the channel as an island resulting in splitting of the primary flow path. This is considered to account for the planimetric adjustment also identified for these types of channels, as was seen in reach HT-2a-1. These channels may also be highly sinuous, as the Hornby tributary reaches are, because they are capable of modifying their lateral boundaries with ease. The historic photos provided good documentation of this process, with the most substantial development seen between 1978 and 2002. Between these two photos there is evidence of substantial growth of meanders through extension, rotation, and down-valley migration. Bends became tighter with smaller radiuses of curvature leading to the beginnings of cutoff formations in some of the more recent photos. Reach HT-2a-2 is considered an anomaly because it was completely straight and flowed through a Halton Regional Forest property with surrounding vegetation consisting of mixed deciduous trees. The channel was likely historically straightened and does not appear to have had any substantial planform development since 1954 based on the historic photo. Dimensions were wider than those found downstream as a result of the different dominant vegetation. Overall, the Hornby tributary is a relatively active channel within the study area which exhibits ongoing minor changes to its planform and dominant flow paths.

The Middle Sixteen Mile Creek tributary is located in the western half of the study area and consists of two permanently flowing branches (east and west) and an HDF branch located between the two. The watercourses in this system experience more variability in terms of channel processes as a result of the differing land uses and vegetation. The western branch consists of three reaches (W-T1-3, W-T1-2, and W-T1-1) and a small tributary that joins reach W-T1-3 from the north. These reaches flow primarily through mixed deciduous woods which thins progressing downstream until reach W-T1-1, which flows through mixed meadow vegetation on an agricultural property off of Steeles Avenue. Both upstream reaches exhibited evidence of degradation, incision, as indicated by elevated, steep banks, exposed clay on the bed, and exposed elevated tree roots. For reach W-T1-3, this was paired with widening as the channel was in the early stages of meander development and experiencing erosion along outer banks inducing sinuosity. Regularly spaced alternating lateral bars were another indication of early meander development in the reach. For reach W-T1-2, meander development was much further advanced with tortuous meanders at the upstream end. The secondary process was aggradation because the meanders have grown so large they have become inefficient at transporting flow and sediment. Areas of slower flow and woody debris have resulted in large silt deposits. The historic photos indicate that erosion on the outside of the bends, while still occurring, is reduced and erosion is now concentrated at the base of the meanders. This will result in eventual avulsion of the bend. The most downstream reach W-T1-1 was less active due to the changes in vegetation. Undercutting was noted, and degradation was indicated by increased bank height and isolated clay exposures. However, the dominant process was observed to be aggradation due to very low velocities and additional silt from the bank material.

The reaches of the eastern branch of the Middle Sixteen Mile Creek tributary were observed to be variable as a result of the different land uses. In the upstream, the channel flowed through the Hornby Glen golf course (E-T1-3). While widening was noted, through slumping in areas of manicured lawn, it was not as prevalent as it tends to be for channels flowing through golf courses. Aggradation was observed to be the dominant process which suggests that the channel is low gradient and has less energy for erosion and widening. A number of HDFs were also present on the golf course. In particular, E-T1-4 was difficult to characterize because it was piped beneath the fairways and only sporadically open to the surface. It is anticipated that the additional data collection recommended for 2016 would provide the information needed for characterization. The other HDFs drained to the golf course pond which then outlets to HDF-1. The reaches downstream of the golf course (HDF-1, E-T1-2 and E-T1-1) flow through a large agricultural property; channel processes were directly reflective of this land use type. Both E-T1-2 and E-T1-

1 exhibited active historic planform adjustment. In E-T1-1, this was a result of the reach flowing through a grass cattle pasture where cattle had unrestricted access to the creek. Slumping and widening has been noted to be widespread throughout the reach, and over time secondary channels formed in a several locations. Sinuosity increased at the downstream end as a result, primarily between 1978 and 2002. Alternatively in reach E-T1-2, historic planform adjustment seemed to be related to disturbance of the surrounding area and channel alterations. The historic photos indicate that straightening likely occurred near the downstream end between 1978 and 2002. In other sections of the reach, it is unclear what caused the development and subsequent loss of minor bends. Both reaches were noted to exhibit issues common to channels which flow through active agricultural land such as algae growth, long dense mats of instream aquatic vegetation, and silt accumulation.

Overall, the Hornby tributary reaches are functioning through natural processes of erosion and deposition with minimal impacts from the surrounding area. Their dominant processes are considered a reflection of the surrounding vegetation which is dense mixed meadow with woody shrubs. The west branch of the Middle Sixteen Mile Creek tributary is similarly subjected to minimal impacts from the surrounding area. Dominant vegetation and processes however differ from the Hornby tributary reaches. Both of these groups of reaches should be protected with appropriate setbacks to ensure that any impacts from development of the area are minimized. The east branch of the Middle Sixteen Mile Creek tributary is noted to be more negatively impacted by the surrounding land use (golf course and active agricultural) which infringes upon the channel. These reaches provide opportunity for enhancement as part of any redevelopment of the area.

2.6 Water Quality

A characterization of the surface water chemistry provides an indication of the quality of aquatic habitat within the study area, as well as potential interactions and influences from other sources of water (i.e. groundwater). The following section summarizes the characterization of the surface water quality within the watercourses through and surrounding the Premier Gateway Secondary Plan area.

2.6.1 Scope Overview

The surface water quality characterization has been completed based upon a review and analysis of background information provided for use and reference in this study. Requirements for more detailed investigations and studies in support of the proposed development within the Secondary Plan area will be established as part of subsequent phases of the Scoped Subwatershed Study.

2.6.2 Background Information Review

The following information has been provided for use in characterizing the surface water quality within the Premier Gateway Secondary Plan Area:

- Sixteen Mile Creek Long Term Environmental Monitoring Program (LTEMP) Temperature Sampling Site Maps for 2009, 2011, 2013.
- Water Quality Data.

Water quality monitoring has been completed by Conservation Halton as part of the Authority's Watershed Monitoring Program. The monitoring conducted by the Authority under this program has included four (4) stations in the vicinity of Premier Gateway (Ref. Appendix G). These include:

- Middle Sixteen Mile Creek at Fifth Line (SXM-349)
- Hornby Tributary at Trafalgar Road (SXM-40)
- West branch of Middle Sixteen Mile Creek Tributary at 5 Side Road (SXM-45)
- Middle Sixteen Mile Creek Tributary at Steeles Avenue (SXM-152)

Water quality samples from site SXM-349 (ref. CH station 06006301402) have been received from Conservation Halton as part of the Scoped Subwatershed Study. The status of the water quality samples from three other locations are not known at the time of preparation of the report. Therefore, the characterization analyses have been completed based upon samples from site SXM-349, which is located on an adjacent tributary west of the Premier Gateway lands.

2.6.3 Characterization and Analysis

The water quality monitoring at site SXM-349 has been conducted between 2002 and 2013. The monitoring has been completed by obtaining grab samples on a monthly basis between spring and fall, however the collected data have not distinguished between wet weather and dry weather conditions. The following key water quality indicators have been analyzed for characterizing surface water chemistry:

- Total Phosphorus
- Total Kjeldahl Nitrogen (TKN)
- Total Suspended Solids (TSS), sampled as Particulate Residue (RSP)
- Nitrate and Nitrite (NO_3 – N and NO_2 - N)
- Zinc (Zn)
- Total Copper (Co)
- Calcium (Ca)
- Lead (Pb)

Statistical analyses have been completed for the Event Mean Concentrations (EMC's) calculated based upon the sampled data. Literature reviews of EMC's for different land uses have been compared to values documented in the Toronto Wet Weather Flow Study, as well as for the multi-year Red Hill Creek Watershed in the City of Hamilton for wet weather flow conditions, and the Sixteen Mile Creek Areas 2 & 7 Subwatershed Update Study (November 2015) for dry weather conditions in the Town of Milton. The EMC's derived from the field monitoring program for the dry weather flow conditions have been compared with those EMC's applied in the water quality models for the same land use condition (i.e. agricultural and open space) in order to verify the results of the sampled data. EMC's have been presented for which literature values have been secured. Results of this assessment are provided in Table 2.5.9 for the water quality monitoring at the study site.

Table 2.5.9 Comparison of Event Mean Concentrations for Site SXM-349 With Literature Values from Water Quality Models/Studies for Similar Land Use Conditions (mg/L unless otherwise noted)

Contaminant	2002-2013 Monitoring Results			Water Quality Models (Wet Weather Data)		Sixteen Mile Creek Subwatershed Update Study (2015)[2]
	Range	Mean	Median	TWWF	RHCWP	
BOD/CBOD	Not Analyzed				2	3
E.coli (#/100mL)	Not Analyzed			100,000	-	126
TKN	0.05 – 1.89	0.53	0.47	1.0	2.8	1.2
Total P	0.01 – 0.44	0.047	0.031	0.2	0.5	0.205
TSS[1]	1.3 – 307	15.13	6	100	400	10
Copper (ug/L)	0.45 – 6.31	1.35	0.99	8	5	3
Zinc (ug/L)	0.15 – 20.9	2.38	0.98	18	10	8
Lead (ug/L)	0.33 – 9.92	3.71	3.95	4	-	0.6
Nitrate+Nitrite	0.002 – 2.06	0.37	0.17	2.5	-	0.25
Calcium	29.1 – 94	64.24	64.9	-	-	-

[1]Particulate Residue samples from Water Quality Data has been considered as TSS
[2]Dry weather sampling results from Site Q3 located within Derry Green Corporate Business Park in the Town of Milton

Based on the results, that following observations have been made:

- Mean and median concentrations of TKN are below literature values for comparable land use conditions for wet and dry weather.
- Mean and median concentrations of Total P are below literature values for comparable land use conditions for wet and dry weather.
- Mean and median concentrations of TSS are below literature values for comparable land use for wet weather flow conditions, but comparable to the TSS concentrations observed from dry weather samples obtained from the adjacent Derry Green lands.
- Mean and median concentrations of copper are below literature values for comparable land use conditions for wet and dry weather.
- Mean and median concentrations of zinc are below literature values for comparable land use conditions for wet and dry weather.
- Mean and median concentrations of lead are comparable to literature values for comparable land use conditions for wet and dry weather.
- Mean and median concentrations of nitrate+nitrite are below literature values for comparable land use conditions for wet weather flow conditions; but comparable to dry weather samples obtained from the Derry Green lands.

The monitoring information suggests that the water quality within the open watercourses through Middle Sixteen Mile Creek are generally of higher quality compared to literature values, based upon the findings from the monitoring date as provided by Conservation Halton. The higher quality of runoff is considered potentially attributable to the increased infiltration of the surrounding soils, as well as informal stormwater quality treatment which may be afforded by the well vegetated open watercourses through the area.

2.6.4 Summary of Findings

The water quality monitoring samples received from Conservation Halton indicate that the existing surface water quality within Middle Sixteen Mile Creek is generally of higher quality, with lower concentrations of nutrients, microorganisms, TSS, and most metals compared to literature and reported values for similar land use conditions.

3.0 INTEGRATION SUMMARY

The foregoing assessment and investigations of the existing systems has proceeded on a discipline-specific basis, working toward an integrated characterization and assessment of the existing systems. This integration allows the stakeholders to more fully understand the fundamental environmental components and systems within the study area. The integrated characterization and assessment of each study discipline fundamentally occurs on two levels, namely: i) integrated characterization to validate or confirm the findings of respective disciplines, and ii) an integrated characterization of key environmental features and systems to define the functions, attributes, and interdependencies, and to thereby provide guidance for establishing future land use management opportunities and requirements.

3.1 Approach

The process of integration occurs at each stage in the study process (i.e. characterization of existing systems, quantification and qualification of impacts from proposed land use change, establishing requirements and opportunities to mitigate and manage impacts, and developing a framework and program for monitoring and adaptive management post-development). As such, the integration process represents a fundamental component to the overall scoped subwatershed study process rather than being associated with one particular stage of the process.

The fieldwork and accompanying assessments, associated with subwatershed characterization, has been used to establish various principles, specific to the study area. These principles reflect unique properties and characteristics of the Sixteen Mile Creek Subwatershed 4, which depending on their nature, lead to certain implications for management associated with proposed future land use changes.

The following provides an overview of some of the key functional attributes and features within the study area, as well as their interdependencies premised upon the various discipline-specific studies and observations.

Aquatic Habitat

Observations of possible groundwater discharge were reviewed by the Study Team Ecologist and Hydrogeologist for consistency. This effort included observations of watercress, watercourse temperature, and fish data. Reaches indicative of potential groundwater discharge include Sixth001, Golf001, Golf003, Steeles002, Hwy001 and Trafalgar002. Golf001 was observed to be the most significant area of potential groundwater discharge, with significant groundwater discharge also noted from Golf003. These reaches are characterized by coldwater perennial flow and more permeable streambeds. Chemical analysis of a baseflow sample taken from Golf003 is indicative of groundwater discharge.

Data from the hydrologist on surface water quality were compared with the Study Team Ecologist's observations on water quality based on benthic sampling, fish sampling, and aquatic habitat assessments. The findings of these assessments suggest relatively higher quality surface water through the study area, compared to findings from other studies in similar settings.

Headwater drainage features represent a key point of integration in the subwatershed characterization. They are critical to maintaining proper flow and sediment conveyance across the landscape but are also seen as important elements for terrestrial linkages, fish habitat, and areas of groundwater infiltration or discharge. It is necessary to ensure that all important functions of the headwater drainage features are adequately characterized as they are often removed or consolidated as a result of land use changes. The headwater drainage feature assessment is primarily undertaken as part of the geomorphic characterization. Fully integrated consultation with other disciplines (surface water, ecology, and groundwater) ensures a complete characterization which facilitates appropriate management recommendations.

Terrestrial Features and Watercourse Corridors

There does not appear to be any significant groundwater discharge connection to terrestrial features within the study area. On this basis, the terrestrial features within the study area appear to be more reliant upon surface water contributions than groundwater contributions.

Streams require a sufficient corridor to allow for lateral migration across their floodplain to ensure the maintenance of stream form and function. The geomorphic characterization delineates the meander belt width corridor for the channels within the study area. These corridors can be integrated into the Natural Heritage System as part of the terrestrial characterization. This also requires consideration of the floodline limits, in order to ensure that protection from natural hazards is considered in establishing the future developable area.

Surface Water and Groundwater Interactions

The hydrogeologic setting within, and adjacent to, the study area is characterized by lower permeability surficial sediments generally consisting of clays of the Halton till and silty sands. These sediments tend to reduce recharge, lateral and vertical groundwater flow and associated groundwater discharge. If sufficient groundwater gradients exist and more permeable discrete pathways exist within the Halton till and silt sands, groundwater discharge may occur. Discrete sand lenses are known to exist within the Halton till. A bedrock valley exists within the central portion of the study area and is infilled with more permeable sediments. This hydrostratigraphic combination within the regional setting provides for significant upward gradients and the potential for hydraulic connections to local stream reaches. There is currently no site specific hydrostratigraphic data indicating direct linkages to the stream reaches.

It is expected that the more regional groundwater system may provide for discharge potential within the study area and to add to the lateral shallow component provided by the local recharge and tile drains.

The observed runoff volumes indicate the presence of higher permeability material within the overall subwatershed study area, resulting in generally lower surface runoff volumes during storm events. The potential higher permeability is likely related to a thinner Halton Till underlain by more permeable sands and gravel or shallower bedrock within the upper subwatershed.

The observed runoff volumes indicate the presence of higher permeability material within the study area, resulting in generally lower surface runoff volumes during storm events. The hydrogeologic characterization suggests that these areas with higher permeability tend to be located within the upper reaches of the subwatershed.

Watercourse Erosion and Stormwater Management

Erosion and deposition within a channel can occur as a result of the balance of between the sediment supply and the hydrologic regime. An imbalance between the two will result in increased erosion or deposition. This inherent connection between the sediment and hydrologic regimes requires integration between geomorphology and surface water to fully understand the potential for morphologic change under altered land use conditions. In this study area, geomorphic characterization identifies the critical flows (erosion thresholds) under the existing regime which are integrated into the surface water assessment to determine the system's capacity for accommodating potential land use alterations and changes in flow regime. Application of the erosion thresholds as stormwater management targets should limit the rates of erosion to pre-development conditions.

Site Servicing and Stormwater Management

The stormwater management system for the future development should maintain the pre-development distribution of water to the extent possible, in order to sustain aquatic systems at a local or broader regional scale with due consideration of peak flows and volumes as well as seasonal variations in the delivery and timing of runoff. This may be achieved through the siting and distribution of end-of-pipe facilities for stormwater management and/or the implementation of Low Impact Development (LID) infiltration BMP's to promote groundwater recharge and sustain baseflow conditions. The ability to infiltrate stormwater may be restricted in the natural hydrogeologic setting due to the height of the water table and areas where the surficial sediments are finer grained.

The installation of subsurface infrastructure can potentially intercept shallow groundwater flow and disrupt associated groundwater discharge. Given the strong upward gradients, and possible shallow connection, there is a potential for significant dewatering and aquifer depressurization during construction. A reduction in water levels and storage of groundwater water may reduce available groundwater within shallow dug wells.

3.2 Application

The integrated assessment of the functional attributes of integration noted above is ultimately applied to develop the stormwater and environmental management system for the study area. The application of the approach premised on the functional attributes are used to derive the Natural Heritage System, the watercourse management system, and the stormwater management facility siting for the study area.

Drawing E1 depicts the RNHS. Refinements to the RNHS will be made by the Study Team Ecologist based on work completed for the scoped subwatershed study.

The Headwater Drainage Features assessment will be taken into consideration in the development of the Natural Heritage System. Additional investigation is required in order to complete the Headwater Drainage Features assessment. Final analysis and management recommendations on the Headwater Drainage Features may impact the delineation of the Natural Heritage System.

The stormwater management system for the future development area is anticipated to consist of traditional end-of-pipe facilities for stormwater quality, erosion, and quantity control, combined with LID infiltration BMP's to promote groundwater recharge locally within the study area. The end-of-pipe facilities will be initially sited on the basis of minimizing the extent of fill required on the site, and will thus coincide with existing low points in the terrain adjacent to regulated watercourses and the preliminary Natural Heritage System, and will be refined in order to maintain the supply of treated runoff toward the receiving watercourses. The application of LID infiltration BMP's will serve to maintain the supply of baseflow to the receiving watercourses, as well as mitigating thermal enrichment of storm runoff within the end-of-pipe facilities and from impervious surfaces. While the siting of stormwater management facilities represents a component of the next phase of this study, the findings of the characterization presented herein, combined with the results of the Headwater Drainage Features assessment once completed, will serve to provide guidance for the siting and selection of stormwater management facilities and infrastructure.

4.0 NEXT STEPS

The foregoing presents the Study Area Characterization, based upon the field reconnaissance and analyses completed between the Scoped Subwatershed Study initiation in spring 2015 through to the completion of the field program in December 2015. Additional field work is scheduled for completion in the spring of 2016, in order to conduct the headwater drainage features assessment shortly after the spring freshet and to finalize the headwater drainage features assessment accordingly.

The findings of the headwater drainage features assessment, once completed, will be used to finalize the characterization of the watercourse systems and to establish management strategies in accordance with the assessment protocol. This will inform the refinement of the Natural Heritage System, as well as the hazard assessment for the regulated watercourses within the Premier Gateway Secondary Plan Area.

The final characterization and refined Natural Heritage System will be integrated into the Secondary Planning Process for the Premier Gateway area, along with the findings from the other supporting studies (i.e. servicing, transportation, etc.). Through this integration process, a future land use plan will be developed, which will be assessed as part of the next phase of the Scoped Subwatershed Study to determine the impacts from development and associated requirements and opportunities for mitigation and management.

References

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Barton, D.R. 1996. The use of Percent Model Affinity to assess the effects of agriculture on benthic invertebrate communities in headwater streams of southern Ontario, Canada. Freshwater Biology 36-2: 397-410.

Bird Studies Canada, Environment Canada's Canadian Wildlife Service, Ontario Nature, Ontario Field Ornithologists and Ontario Ministry of Natural Resources. 2006. Ontario Breeding Bird Atlas Database. Square 17NJ92. http://www.birdsontario.org/atlas/aboutdata.jsp?lang=en

Bird Studies Canada. 2009. Marsh Monitoring Program Participant's Handbook for Surveying Amphibians. 2009 Edition. Published by Bird Studies Canada in Cooperation with Environment Canada and the U.S. Environmental Protection Agency. February 2009.

Bird Studies Canada, Environment Canada's Canadian Wildlife Service, Ontario Nature, Ontario Field Ornithologists and Ontario Ministry of Natural Resources. 2006. Ontario Breeding Bird Atlas Database, 31 January 2008. http://www.birdsontario.org/atlas/aboutdata.jsp?lang=en

Chapman, L.J. and Putnam, D.F. 1984. Physiology of southern Ontario. Ontario Geological Survey Special Volume 2. 270p.Dillon Consulting, 2000. 401 Corridor Integrated Planning Project Town of Halton Hills. Scoped Subwatershed Plan, March 2000.

Chow, V.T. (1959). Open Channel Hydraulics. New York, NY: McGraw-Hill Book Co.

Chu, C., N.E. Jones, A.R. Piggott, and J.M. Buttle. 2009. Evaluation of a simple method to classify the thermal characteristics of streams using a nomogram of daily maximum air and water temperatures. American Journal of Fisheries Management 29: 1605-1619.

Committee for the Status on Endangered Wildlife in Canada (COSEWIC). 2012. Canadian Wildlife Species at Risk. Last updated July 10, 2012. http://www.sararegistry.gc.ca/sar/index/default_e.cfm (Accessed January 27, 2014).

Conservation Halton. 2006. Halton Natural Areas Inventory: Volume 2 Species Checklists.

Dillon Consulting. 2000. 401 Corridor Integrated Planning Project – Town of Halton Hills – Scoped Subwatershed Study.

Dobbyn, J.S. 1994. Atlas of the Mammals of Ontario. Don Mills, Federation of Ontario Naturalists.

Environment Canada. 2011. Canadian Aquatic Biomonitoring Network (CABIN) Field Manual, Wadeable Streams.

Galli, J. 1996. Rapid stream assessment technique, field methods. Metropolitan Washington Council of Governments. 36 pp.

Government of Canada. 2015. Species at Risk Public Registry: Species Index. Last updated May 29, 2015. http://www.sararegistry.gc.ca/sar/index/default_e.cfm (Accessed November 2015)

Halton Hills. 2008. Town of Halton Hills Official Plan. Adopted September 18, 2006. Consolidated May 2008.

Halton Region. 2014. Halton Region Official Plan Package – October 2, 2014.

Halton Region. 2015a. Halton Region Official Plan [2009] Interim Office Consolidation Based on Amendment No. 38. September 28, 2015.

Halton Region. 2015b. Regional Forests Background Information. Available at: http://www.halton.ca/cms/one.aspx?portalId=8310&pageId=37824

Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution. The Great Lakes Entomologist. Vol. 20, No. 1.

Imhof, J. 2010. Salmonid Spawning Survey: Methodology. Trout Unlimited Canada. Guelph, Ontario.

Jones, C., K.M Somers, B. Craig, and T.B Reynoldson. 2007. Ontario Benthos Biomonitoring Network: Protocol Manual. Environment Canada, Queen's Printer 2007.

Jones, C., R. Layberry, and A. Macnaughton. 2013. Ontario Butterfly Atlas Online. Toronto Entomologists' Association. Last updated February 7, 2013. http://www.ontarioinsects.org/atlas_online.htm

Komar, P.D., 1987. Selective grain entrainment by a current from a bed of mixed sizes: A reanalysis, Journal of Sedimentary Petrology, 57(2), 203-211.

Kowal, E. 2015. Personal communication. Email from Erik Kowal, Landowner and Steering Committee member to Curtis Marshall, Senior Planner, Town of Halton Hills, October 28, 2015.

Layberry, R.A., P.W. Hall, and J.D. Lafontaine. 1998. The Butterflies of Canada. University of Toronto Press, Toronto, Canada.

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, Science Development and Transfer Branch. SCSS Field Guide FG-02.

Merritt, R.W., K.W. Cummins, and M.B. Berg. 2008. An Introduction to the Aquatic Insects of North America – 4th edition. Kendall Hunt Publishing Company. Dubuque, IA.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands. Second Edition. Van Nostrand Reinhold, New York, NY.

Nol, E. 2015. Presentation by Dr. Erica Nol at the Latornell Conservation Symposium, "The Habitat Squeeze for Migratory Songbirds in Southern Ontario: Identifying the Stressors, Winners and Losers." November 19, 2015.

North-South Environmental Inc. (NSEI). 2007. Sustainable Halton – Options for a Natural Heritage System in Halton.

North-South Environmental Inc. (NSEI). 2009. Natural Heritage System Definition & Implementation. Phase 3, Sustainable Halton Report 3.02. April 7, 2009.

Novak, M.A., and R.W. Bode. 1992. Percent Model Affinity: A New Measure of Macroinvertebrate Community Composition. Journal of the North American Benthological Society. 11(1): 80-85.

Ontario Breeding Bird Atlas (OBBA). 2001. Guide for Participants. Atlas Management Board, Federation of Ontario Naturalists, Don Mills.

Ontario Geological Survey. 2003. Digital Map of the Surficial Geology of Southern Ontario (GIS format). Queens Printer, Ottawa, Canada.

(Ontario) Ministry of the Environment. 2003. Stormwater Management Planning and Design Manual, Ontario Ministry of Environment, March 2003.

Ontario Ministry of Municipal Affairs and Housing (OMMAH). 2014. Provincial Policy Statement. Queen's Printer for Ontario, 2014.

Ontario Ministry of Natural Resources (OMNR). 2000. Significant Wildlife Habitat Technical Guide. October 2000.

Ontario Ministry of Natural Resources (OMNR). 2010. Natural Heritage Reference Manual for Policies of the Provincial Policy Statement, Second Edition. March 18, 2010.

Ontario Ministry of Natural Resources (OMNR). 2012. Significant Wildlife Habitat Ecoregion 7E Criterion Schedule: Addendum to Significant Wildlife Habitat Technical Guide. OMNR, Draft February 2012.

Ontario Ministry of Natural Resources (OMNR). 2013a. General Habitat Description for the Barn Swallow (*Hirundo rustica*). July 2, 2013.

Ontario Ministry of Natural Resources (OMNR). 2013b. Natural Heritage Information Centre: Biodiversity Explorer. Last updated October 7, 2015. https://www.biodiversityexplorer.mnr.gov.on.ca/nhicWEB/mainSubmit.do (Accessed March 30, 2015).

Ontario Ministry of Natural Resources (OMNR). 2013c. Species at Risk in Ontario (SARO) List. http://www.mnr.gov.on.ca/en/Business/Species/2ColumnSubPage/MNR_SAR_CSSR_SARO_LST_EN.html Last updated May 14, 2013. (Accessed March 30, 2015).

Ontario Ministry of Natural Resources (OMNR). 2013d. General Habitat Description for the Silver Shiner (*Notropis photogenis*). December 2, 2013.

Ontario Ministry of Natural Resources (OMNR). 2013e. Ontario Wetland Evaluation System: Southern Manual. 3rd Edition, Version 3.2.

Ontario Ministry of Natural Resources and Forestry (MNRF). 2015a. Significant Wildlife Habitat Criteria Schedules for Ecoregion 7E. January 2015.

Ontario Ministry of Natural Resources (MNRF). 2015b. Species at Risk in Ontario (SARO) List. Accessed November 2015. http://www.ontario.ca/environment-and-energy/species-risk-ontario-list

Ontario Ministry of Natural Resources and Forestry (MNRF). 2015c. Species at Risk in Halton region. Accessed March 2015. https://www.ontario.ca/environment-and-energy/species-risk-region?name=Halton

Ontario Nature. 2013. Reptiles and Amphibians of Ontario Range Maps. Last Updated February 26, 2013. http://www.ontarionature.org/protect/species/reptiles_and_amphibians/index.php (Accessed March 30, 2015).

Parish Geomorphic Ltd. 2001. Geomorphological protocols for subwatershed studies. Submitted to: Regional Municipality of Ottawa-Carleton.

Parish Geomorphic Ltd. 2004. Belt Width Delineation Procedures. Submitted to: Toronto and Region Conservation Authority.

Reznicek, A.A., E.G. Voss, and B.S. Walters. 2011. Michigan Flora Online. University of Michigan, February 2011. Accessed November 2015. http://www.michiganflora.net/home.aspx

Sebastien, R., Rosenberg, D., Wiens, A. 1988. A method for subsampling unsorted benthic macroinvertebrates by weight. Hydrobiologia. 157:69-75.

Shields, A. (1936). "Anwendung der ahnlichkeits-mechanik und der turblenzforschung auf die geschiebebewegung," Mitt. Preuss. Versuchsanst. Wasser. Schiffsbau, 26, 1-26 (in German).

Stanfield, L. (Editor). 2013. Ontario Stream Assessment Protocol. Section 4: Module 10 Assessing Headwater Drainage Features. Version 9.0. Fisheries Policy Section. Ontario Ministry of Natural Resources. Peterborough, Ontario.

Toronto and Region Conservation Authority and Credit Valley Conservation. 2014. Evaluation, classification, and management of headwater drainage features guideline. TRCA Approval July 2013 (Finalized January 2014).

Varga, S., editor. August 2000. Distribution and status of the vascular plants of the Greater Toronto Area. Ontario Ministry of Natural Resources, Aurora District. 103 pp.

Weber, C.I. 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. Cincinnati, Ohio, U.S. Environmental Protection Agency. EPA-670/4-73-001.

Witzel, L.D. and H.R. MacCrimmon. 1983. Redd-site selection by brook trout and brown trout in southwestern Ontario streams. Transactions of the American Fisheries Society. 112: 760-771.

Wolman, M.G. 1954. A method of sampling coarse bed material. Transactions of the American Geophysical Union, 35(6): 951-956.

Wormington, A. 2006. The Butterflies of Halton Region: A preliminary list. In J. K. Dwyer (Ed.), In Halton Natural Areas Inventory 2006. Volume 2. Milton, Ontario: Conservation Halton.

Appendix A

Consultation

amec foster wheeler

Appendix B

Terrestrial and Aquatic Ecology

Appendix C

Hydrogeology

Appendix D

Hydrology

Appendix E

Hydraulics

Appendix F

Stream Morphology

Appendix G

Water Quality