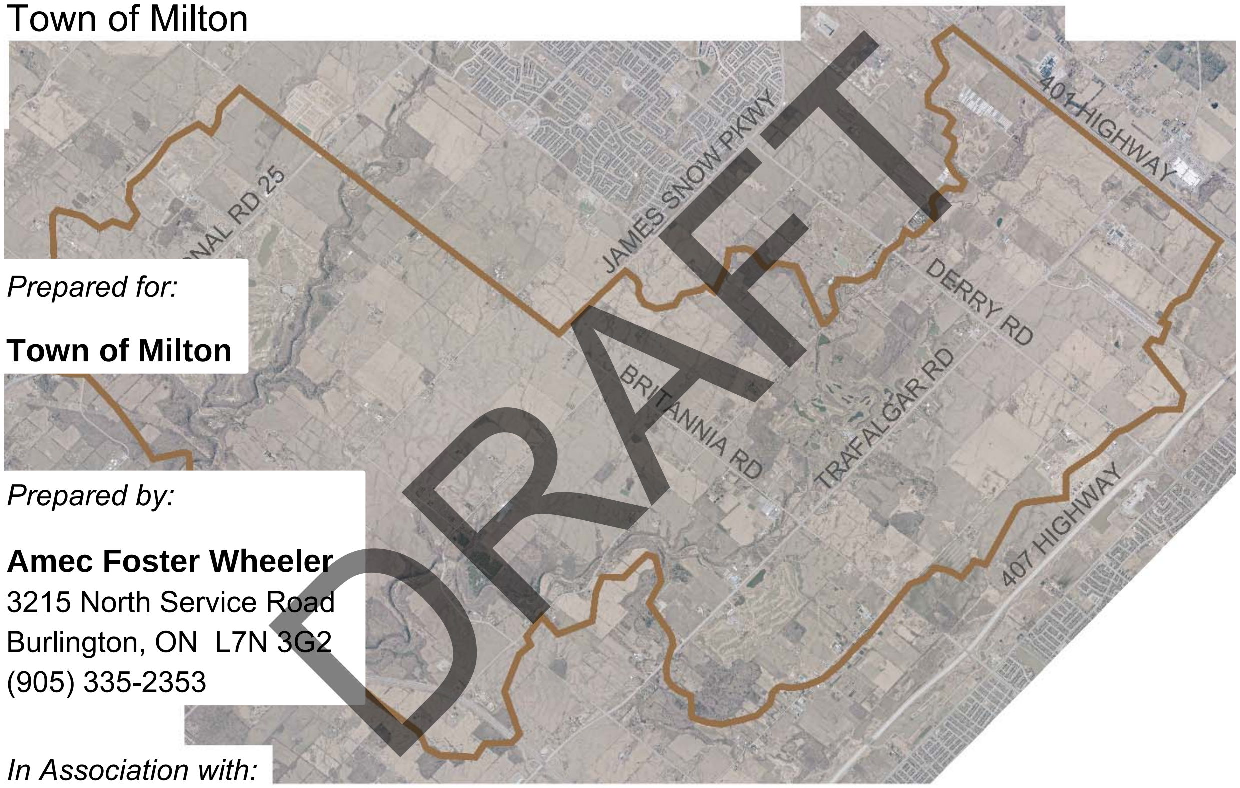
Phase 1: Background Review and Subwatershed Characterization

South Milton Urban Expansion Area

Town of Milton



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Project No. TP116007

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Town of Milton

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1.0 INTRODUCTION

1.1 Study Overview

As part of the approval of Regional Official Plan Amendment (ROPA) #38, additional lands were identified in the Town of Milton to accommodate population and employment growth from 2021 through to 2031. Referred to as the "Sustainable Halton Lands", the lands identified for growth will serve as Milton's next urban expansion area and next major Supplemental Plan Area(s). In order to gain a better understanding of some of the key opportunities and constraints to developing the area, the Town has initiated the planning process for these lands by officially commencing a Subwatershed Study (SWS) in January 2016. Town Council awarded the SWS to the Amec Foster Wheeler Team at its January 25, 2016 meeting (Staff Report CORS-006-16 & Proposal Award 15-527).

The overarching vision articulated in ROPA #38 is, in large part, that of an "environment-first" philosophy. In line with the Provincial Policy Statement (2014), and building off of the Province's Greenbelt Plan (2005), ROPA #38 established a Natural Heritage System (NHS) with the goal of protecting and enhancing the Region's natural features, functions and areas for the long-term. ROPA #38 also establishes that local municipalities are required to carry out, prior to, or as part of, a Secondary Plan process, a SWS. The requirements for a SWS are set out in ROPA #38 and, in general, it is intended to provide a more detailed assessment of the existing natural heritage and water resource features, functions, and areas that make up the Region's NHS, as well as identify potential impacts of future growth and development on the NHS. ROPA #38 allows for the refinements of the NHS but it can only be done in the context of a comprehensive environmental study, such a SWS.

Based on the foregoing, the overall purpose of this SWS is to:

a. Inventory, characterize and assess natural hazard, natural heritage and water resource features and functions within the study area (i.e., constraints to development);
b. Provide recommendations for the protection, conservation and management of natural hazard, natural heritage, and water resource features within the study area;
c. Provide sufficient detail to support the designation of NHS, through refinement of the Regional NHS, as well as identify areas for future development; and
d. Provide recommendations for a management strategy, implementation and monitoring plan to be implemented through the Secondary Plan(s) and future site/area specific studies.

The results of the SWS will be essential for informing the future Secondary Plan(s). The SWS will inform land use decision making so that it allows for urban systems to be integrated with natural systems in an area that is transitioning from predominantly rural to urban uses.

1.2 Study Area

The Subwatershed Study involves assessment work related to the following six (6) distinct but interconnected technical study disciplines:

- Hydrology / Hydraulics (Surface Water)
- Hydrogeology (Groundwater)
- Fluvial Geomorphology
- Surface Water Quality
- Aquatic Resources
- Terrestrial Resources

The scale and extent of study and analysis varies according to the study discipline, the specific analysis or activity being undertaken as part of that discipline, and the amount of existing information that is available, as well as the configuration of the respective subwatershed and watershed. In addition, disciplines tend to overlap and interact, hence as part of the assessment and related scale, there needs to be consideration of the influence of one discipline on the others building from existing data and policy. Nevertheless, the scale and extent of study can typically be classified under one of the categories as follows:

- "Subwatershed Study Area" or "Study Area" refers to the area shown on Figure 1.1 and consists of the subwatersheds of the Sixteen Mile Creek. The entire Subwatershed Study Area encompasses approximately 5260 hectares (13000 acres).
- "Primary Study Area" generally refers to the area shown on Figure 1.2 in 'blue' and consists of lands identified by the Region of Halton as the Town's urban growth area from 2021 to 2031 ("Sustainable Halton Lands"), as well as portions of the Regionally identified Natural Heritage System (as shown on ROPA 38). The majority of the SWS fieldwork, analyses and management recommendations will focus on the natural heritage and water resource features and areas within the Primary Study Area and the level of study will be more in-depth the in the Supplemental Study Area shown in 'orange' on Figure 1.2.
- "Supplemental Study Area" generally refers to the area shown on Figure 1.2 in 'orange' and consists of lands outside of the Primary Study Area but within the Subwatershed Study Area. The level of study in the Supplemental Study Area will be coarser than the Prime Study Area but is considered important for gaining a more complete understanding of the natural heritage and waters resources features and areas of the watershed. This area must be considered as part of the overall system-based approach to planning but is not currently contemplated for short-term future growth and development.
- "Subwatershed" refers to the area shown on Figure 1.1 and m consists of portions of Subwatersheds 2, 3, 4, 5, 6 and 7 of the Sixteen Mile Creek Watershed. Assessments at the subwatershed scale will principally consider and refine hydrologic and hydrogeologic considerations given the extent of assessment of the landscape setting through the development of the Regional NHS.
- "Watershed" refers to the area shown on Figure 1.3 and means the Sixteen Mile Creek Watershed. As with the subwatershed scale, assessments at the watershed scale will principally consider and refine hydrologic and hydrogeologic considerations given the

extent of assessment of the landscape setting through the development of the Regional NHS.

The level of detail required as part of the analysis at each scale is inherently related to the potential for impact which would be associated with proposed/planned urbanization of the Sustainable Halton Lands. Consequently, the level of detail and resolution required for the study and related analyses are typically greatest in the Primary Study Area scale. Nevertheless, Watershed scale analyses can provide some insights and input to management strategies that would be appropriate for the overall system.

Although site specific fieldwork was focused on the Primary Study Area, some fieldwork has taken place in the Supplemental, Subwatershed or Watershed Study Areas due to the presence of site specific features/areas of interest including road survey work needed for hydraulic modelling or the characterization of drainage outlets from the Primary Study Area. In addition, where access permissions were obtained for lands within the Supplemental Study Area, focused fieldwork was undertaken where it was considered to potentially provide useful natural heritage or water resources data.

The following provides a general indication of the scale of assessment being considered for each study discipline, with due recognition of overlap/integration between disciplines:

Hydrology

The subcatchments will be modelled in detail related to both existing and future proposed land uses. The approach will see the greatest detail in the Primary Study Area, followed by the Supplemental Study Area, and the Subwatershed scale. The effectiveness of management practices to meet study objectives and targets related to flooding and erosion will be considered beyond the limits of the Primary and Supplemental Study Areas, in the context of the larger/broader Sixteen Mile Creek (i.e. watershed scale) as well. Water balance (integrated with hydrogeology) will be largely assessed at the Primary Study Area scale, with due consideration of potential influences which future land use and management practices at the Supplemental Study Area scale will have on the systems of the subwatershed [Note: this latter perspective is highly contingent on the findings of the Land Base Analysis (LBA) and future Secondary Plan process and whether any lands outside of the currently defined Primary Study Area are contemplated for near-term development.

Hydraulics

All Conservation Authority regulated watercourses within the Primary Study Area proposed to remain in an ‘open’ condition post-development will be analyzed hydraulically to assist in defining the floodplain, needs for upgraded conveyance systems, and riparian storage. Some of the connection points and confluences influencing boundary conditions will be considered at the Supplemental Study Area scale. The influence of potential changes in Regulatory flows (off-site as far downstream Town of Oakville) will be assessed to determine the need, scale, and form of management appropriate to mitigate impacts from the Primary Study Area.

Water Quality

The assessment of impacts related to urbanizing the Primary Study Area will focus on those lands proposed to change in use and also their proposed management practices including effectiveness.

Hydrogeology

A background review of relevant hydrogeological data has been considered at the Subwatershed Scale. Detailed field work within the Primary Study Area will provide for refining the conceptual groundwater characterization with additional baseflow observations in the Supplemental Study Area. Observations and characterizations related to the ecosystem components will be integrated into the groundwater characterization. The groundwater characterization, water balance and assessment of impacts relating to future development will be assessed semi-quantitatively utilizing an integrated groundwater water budget within the Primary Study Area.

Stream Morphology

The assessment will characterize existing channel conditions, through monitoring and detailed fieldwork. Fieldwork will occur primarily in the Primary Study Area and secondarily at the Subwatershed Scale to consider the immediate contributing and receiving areas. This information will provide guidance to channel management and potential for enhancement within the Primary Study Area, in relation to future development and infrastructure. Detailed analysis to establish erosion targets for stormwater management will be undertaken for the more local (i.e. Primary Study Area and Supplemental Study Area) scale.

Terrestrial Ecology

Detailed terrestrial assessments will take place within the the Primary Study Area, with some additional observations completed in the Supplemental Study Area where impacts are expected to stress terrestrial resources (e.g. where infrastructure is predicted to be required that twill cause impacts) and / or where terrestrial ecological resources (e.g. species occurrences and associated habits) occur within and adjacent to the Primary Study Area/areas proposed for urbanization, with demonstrated sensitivity to the effects of urbanization.

The NHS context will be considered in relation to those terrestrial resources assessed to ensure ecological relationships are understood as they may affect planning and impact assessment.

Fisheries

Characterization of fish and fish communities in the principal watercourses will be at the subwatershed scale, and based largely on existing data sources. The watershed scale will be considered where appropriate (i.e. with migratory species). More detailed characterization and fieldwork of habitat was conducted in the Primary Study Area for features such as barriers to migration, observable groundwater discharge areas and water temperature. The fish community and habitat, including contributing habitat, will be assessed for the smaller tributaries and headwater drainage features. Potential impacts (e.g. stormwater management facilities, road crossings, etc.) will be assessed at the scale at which they may occur. Some will be very localized, while others could bring about changes for a considerable distance downstream or, for example in the case of barrier removal, upstream. The potential impacts of land uses in the subwatersheds, including development within the Primary Study Area, will be considered as they relate to fish and fish habitat (e.g. increased in impervious cover within catchments; opportunities for restoration and enhancements).

Approved Development in Neighbouring Municipalities

Portions of the Subwatersheds which drain part, or all, of Milton South Phase 4 also drain portions of the neighbouring municipalities of Town of Halton Hills and City of Mississauga. Where these lands have an approved and designated management plan (Environmental and/or Stormwater), those recommendations and strategies will need to be embedded as "givens" within the structure of the current Subwatershed Study. Where neighbouring lands have been designated as "urban" but no management plan exists (or not approved), it is suggested that this Subwatershed Study consider them as "undeveloped", allowing for the neighbouring municipalities to prepare the requisite land use and management plans in the future when the need arises. The rationale for this approach relates to the inability for the current Subwatershed Study to establish/develop appropriate management plans for lands which have yet to proceed to the next level of planning and design, hence to consider any form of development or management would likely introduce further uncertainty or at best be speculative.

1.3 Planning Process for South Milton Urban Expansion Area

The Town is required to plan for the Sustainable Halton Lands comprehensively. The Town's Official Plan (Section 5.4) and the Region of Halton's Official Plan (Section 77(5)) outline the requirements for the preparation of Secondary Plans/Area Specific Plans for major growth areas, as well as requirements for the Secondary Planning process. Following the direction outlined in these Plans, the Town initiated the planning process for the Sustainable Halton Lands via two key studies, including this SWS and a Land Base Analysis (LBA).

The purpose of the SWS is outlined in Section 1.1 of this report. The SWS is to be completed prior to the approval of any Secondary Plan(s) for the Sustainable Halton Lands. The SWS is to provide technical support to the Secondary Planning process and is to outline the preferred stormwater and environmental management strategy for the Supplemental Plan Area(s).

A LBA was initiated in October 2016 and is meant to serve as one of the initial background steps in the Secondary Plan process. The purpose of the LBA is to identify the key opportunities and constraints to development, as well as inform and provide direction to the Secondary Plan process. The LBA is intended to be a high-level study, wherein a preliminary land use concept, depicting broad land use categories, as well as a framework for future studies will be prepared to inform early phases of other studies (e.g., SWS). The LBA will serve as the basis and background for the preparation of future required Secondary Plan studies. The LBA is not intended to be a detailed analysis; rather, it is to provide direction and guidance for the planning process.

Figure 1.4 shows the components of the LBA, as well as highlights how it contributes to the Secondary Plan process, in relation to the SWS.

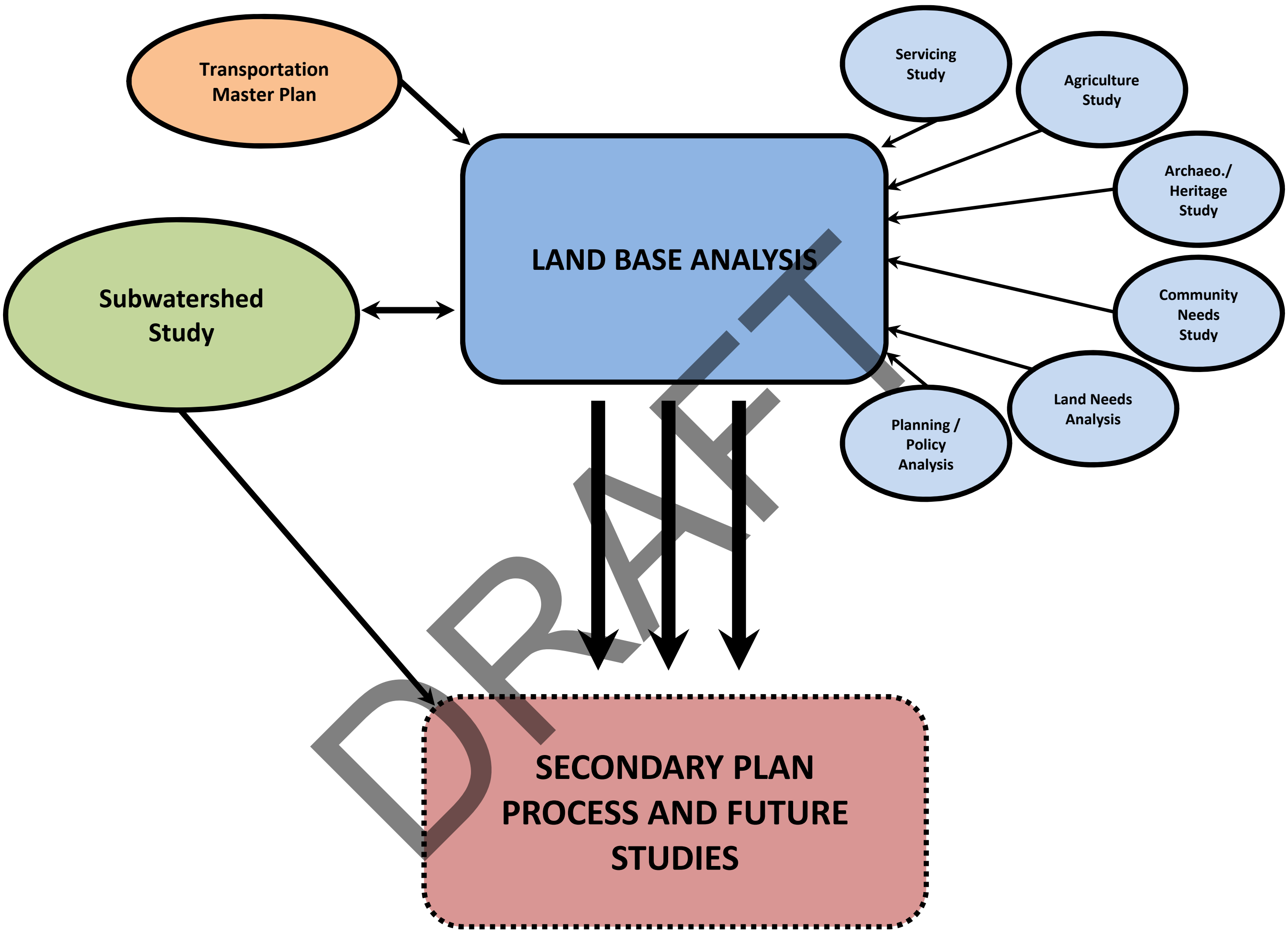

Figure 1.4 Land Base Analysis
(study components and relationship to the Secondary Plan process)

Ultimately the Secondary Plan(s) will establish a more detailed planning framework for the Sustainable Halton lands, building upon the general framework provided for in the Town and Region's Official Plan. It will also establish policies that will result in a complete, healthy, and sustainable community(ies). The Secondary Plan will implement the NHS and management framework established via this SWS.

Of note, other studies (e.g., transportation, servicing, land use) will also be initiated throughout the course of this SWS. These studies will be produced not only to inform the Secondary Plan but also so that they may be considered as part of the SWS analysis and in the development of management strategies for the study area, where appropriate.

1.4 Subwatershed Study Process

The SWS must ensure that all applicable Provincial, Regional and Town land use planning requirements, including conservation authority regulations, are achieved. More specifically, the SWS must demonstrate that it conforms to and/or meets the requirements of the Region, Town and Conservation Halton, as established in the following:

- Sections 116.1, 118(1.1) and 145(9) and all other relevant sections of the Halton Region Official Plan 2009 (ROPA #38);
- Section 5.4 and all other relevant sections, of the Town of Milton's Official Plan; and
- Policies and Guidelines for the Administration of Ontario Regulation 162/06 and Land Use Planning Policy Document, Conservation Halton, April 27, 2006, as revised August 11, 2011.

The SWS will also demonstrate that the goals and objectives established for this study and study area have been met (refer to Section 3.8).

In addition to the technical goals established for this study, the Town has made clear that its intention for this study SWS process is to ensure that it is collaborative and fostered in good working relationships among all parties. This SWS process is intended to be streamlined with clearly defined decision points.

As such, the SWS process has been structured to be carried out in four phases, which will result in four (4) documents/reports, including:

- Phase 1 – Background Review and Characterization;
- Phase 2 – Analysis;
- Phase 3 – Management Strategies; and
- Phase 4 – Implementation and Monitoring.

A brief overview of each of these phases and key outputs is described below.

One of the first steps in the South Milton Subwatershed Study (South Milton SWS) process involved the refinement of a work plan and preparation of a gap analysis/inventory of the available data (ref. Appendix A and J). The Work Plan builds off the Terms of Reference prepared by the Town as part of the RFP process and sets out the SWS Team's plan and specific tasks to achieve the requirements, goals and objectives for the study. The Work Plan has been refined over the course of 2016, in consultation with the SWS Steering Advisory Committee (SAC) and Technical Advisory Committees (TACs). With agreement from the SAC/TACs, the Work Plan was not finalized prior to the fieldwork commencing in an effort to ensure that fieldwork was undertaken during the critical field seasons of 2016.

The Gap Analysis lists the available data and provides an assessment of data gaps and the degree to which the available data can and/or should inform the SWS. This has been done in consultation with the SAC and TAC. The Gap Analysis report is a 'living document' which will be updated over the course of this study, based on new data that may become available or is collected throughout this study.

The purpose of Phase 1 (Background Review and Characterization) of the SWS is to gain a better understanding of the state, health and general character of the subwatershed. Reviews of existing studies and reports, fieldwork and, where appropriate, modelling has been undertaken in order to understand the baseline of conditions related to the following key components: Hydrology/Hydraulics, Hydrogeology, Water Quality, Stream Morphology and Aquatic and Terrestrial Resources. These components have been considered and assessed as part of this report.

Phase 2 (Analysis) and Phase 3 (Management Strategies) will involve undertaking an analysis of the study components in an integrated manner. Targets and management strategies to address potential impacts associated with future development, as it relates to the natural environment and stormwater, will be developed. Watercourses and natural heritage features will be assessed and given a constraint ranking, followed by an overall net rating. Any refinements to the Region's NHS will be identified and discussed during these phases.

Phase 4 (Implementation and Monitoring) will set the stage for the implementation and monitoring of the preferred management strategy for the subwatershed. A detailed subwatershed management implementation strategy will be developed for the preferred development scenario, based on the evaluation of subwatershed management options and using the subwatershed goals, objectives, targets. Additional studies that will be completed in support of future planning phases will also be identified. A preliminary monitoring program (pre, during and post-construction) to evaluate the effectiveness of the Study's recommendations, allowing for adaptive management, will also be recommended. Phase 4 will outline the agencies / organizations that are proposed to be responsible for carrying out the various recommendations and specify when in the development process the various recommendations need to be initiated.

At the conclusion of the SWS, the final reports are to be adopted by Council. The SWS must also be accepted by the Region, as per Section 116.1 a) of the Regional Official Plan.

1.5 Study Management

The SWS is being managed by Town of Milton staff and the Amec Foster Wheeler Team. Further, a number of committees have been formed in order to provide technical and strategic advice to the Town and its consulting team on the process and development of the SWS. Two key SWS-related committees have been established as part of this process and include the Steering Advisory Committee (SAC) and Technical Advisory Committee (TAC).

The SWS SAC is chaired by the Town and has representation from the following:

- Town of Milton
- Amec Foster Wheeler Team
- Conservation Halton
- Region of Halton
- Landowners' consultants
- Ministry of Natural Resources and Forestry (MNRF)

SAC members are responsible for coordinating and representing their agency's position and will serve as the liaison between their respective agency and the SAC. The SAC is responsible for confirming providing advice and direction on the key deliverables identified in the SWS Terms of Reference/Work Plan, as well as providing overall guidance, direction, technical and strategic advice to the Town and the Amec Foster Wheeler Team on the process and development of the SWS.

Small working groups (i.e., Sub-TACs) have been formed and have representation from each of the above listed groups. The TAC addresses specific components of the study (e.g., surface water, aquatic ecology, terrestrial ecology, fluvial geomorphology, planning/policy). The role of the TAC is to provide technical advice to the SAC throughout the SWS process. Advice will focus on the technical/scientific aspects of the SWS, including providing advice on available background resources, methodologies for fieldwork and analysis, as well as study results/conclusions. [Note: the make-up of the TACs may change as this study progresses and as there is more integration of disciplines]

A Charter was developed to guide the operation of all Committees involved in the Secondary Plan/SWS process. The purpose of the Charter is to establish parameters that will: 1) promote productive working relationships among all stakeholders; 2) lead to the most efficient and effective use of stakeholder time and resources; 3) ensure that the expertise and experience of each stakeholder is best utilized; and 4) ensure that the Secondary Plan/SWS process is as streamlined and seamless as possible. By agreeing to participate on the above-referenced committees, members have agreed to the principles outlined in the Charter.

2.0 CLASS ENVIRONMENTAL ASSESSMENT PROCESS

This Subwatershed Study (SWS) will ultimately constitute an environmental and stormwater master plan under the Class Environmental Assessment (EA) process as outlined in the Municipal Engineers Association (MEA) Municipal Class EA document (October 2000, as amended in 2007, 2011 and 2015). Master Plans are recognized to be a preferred planning and design process for infrastructure, as it considers a group or set of projects concurrently. At minimum, Master Plans address Phases 1 and 2 of the Class EA process. The overall EA process generally involves:

- Phase 1: Identification of Problems or Opportunities
- Phase 2: Identification of Alternative Solutions (to Problem or Opportunity)

- Phase 3: Identify Alternative Design Concepts for the Preferred Solution Implementation
- Phase 4: Document Environmental Assessment process (includes the design and consultation process in the main report)

Some of the distinguishing features of a Master Plan compared to project specific EA's include:

- That the scope is long-range, comprehensive analysis/assessment of a system 'as a whole';
- Outcomes typically reflect a set of works which are distributed across a broader system / area (like a subwatershed); and
- Works would be implemented over an extended period of time.

The Town of Milton has determined that Approach #1 of the Class EA Master Plan Process, more fully described in Appendix 4 of the Municipal Class EA, will be used for this study. Therefore, this Subwatershed Study/Master Plan will satisfy the Phase 1 and Phase 2 requirements for the Class EA process, unless otherwise noted. Any concurrent companion studies related to municipal infrastructure, in coordination with the LBA and/or future Secondary Plan(s), will also carry out and document the Class EA Master Plan process sufficient to address Phases 1 and 2 of the Class EA process. This will establish the documentation that will serve as the basis for specific future investigations and if Schedule B and/or C projects are identified. [Note: The MEA's Class EA document classifies projects as Schedules A, A+, B or C depending on the scope, potential for environmental impact or public concern. Any project identified in this Subwatershed Study/Master Plan and/or as part of the Secondary Plan process must be classified as to its level of complexity which will in turn decide which Schedule process needs to be followed.]

The Town of Milton has chosen to conduct the concurrent and fully collaborative land use, environmental and infrastructure studies to meet the provisions of the EA Act. The overall process, underpinned by the land use identified as part of the Secondary Plan process will highlight:

- Joint notifications and presentations to public, stakeholders and agencies;
- Concurrent assessment / analysis of land use, environmental and infrastructure issues;
- Concurrent decisions / recommendations;
- Collaborative approach to problem solving; and,
- Coordinated approach to documentation.

Phases 3-4 of the Municipal Class EA process will be addressed as part of future studies/projects, where required. Any required Notices of Study Completion for Schedule A+, B or C projects will be issued as part of subsequent planning processes following the completion of the LBA and/or Secondary Plan, as needed.

3.0 POLICY AND STUDY CONTEXT

3.1 Introduction

The protection of the natural environment and public health and safety are fundamental principles enshrined in the policies, guidelines and practices of provincial, municipal and local levels of government. This Subwatershed Study must ensure that all applicable Provincial, Regional and Town land use planning requirements, including conservation authority regulations, are achieved. The following sections summarize some of the key plans and policies that will influence the Sustainable Halton Lands in South Milton, specifically as it relates to subwatershed planning, the protection of the natural environment/public health and safety, and/or land use planning.

3.2 Province of Ontario

3.2.1 Provincial Policy Statement

The Provincial Policy Statement (PPS) (2014) is issued under Section 3 of the *Planning Act*. The PPS provides direction on matters of provincial interest related to land use planning and development. The PPS provides for appropriate development while protecting resources of provincial interest, public health and safety, and the quality of the natural environment. The PPS recognizes the complex inter-relationships among economic, environmental and social factors in planning and embodies principles of good planning for the creation of complete, healthy, and liveable communities. All land use decisions (provincial and municipal) must be consistent with the PPS.

The PPS provides guidance for the long-term, wise use and management of resources including the protection and management of natural heritage and water resources. The PPS provides specific policy direction on significant wetlands, endangered and threatened species, fish habitat, significant woodlands, significant valleylands, significant areas of natural and scientific interest (ANSI) and significant wildlife habitat. It also provides guidance for the protection, improvement and restoration of the quality and quantity of water resources. The PPS recognizes that the linkages and related functions among ground water features, hydrologic functions, natural heritage features and areas, and surface water features are to be maintained. It states that watersheds are the ecologically meaningful scale for integrated and long-term planning.

The PPS also provides direction relating to natural hazards, so as to ensure that development is directed away from areas of natural hazards where there is an unacceptable risk to public health or safety or of property damage. It is also to ensure that development does not create new or aggravate existing hazards.

3.2.2 Places to Grow Act and the Growth Plan for the Greater Golden Horseshoe

On June 13, 2005, the Provincial Government passed the *Places to Grow Act*, which was enacted to help the Province plan for growth in a coordinated and strategic way. It gives the Province the authority to, among other things, designate any geographic region of the province as a growth plan area and develop growth plans in any part of Ontario. The Places to Grow: Growth Plan for the Greater Golden Horseshoe (Office Consolidation, June 2013) outlines the Government of Ontario's vision and policies for how growth and development to the year 2041. The Growth Plan provides a framework for creating complete communities, providing a range of housing options, curbing sprawl and protecting farmland and green spaces, reducing traffic gridlock and improving access to a greater range of transportation options. [Note: The Growth Plan was amended twice since its release in 2006. The first amendment, released in January 2012, contains policies that apply in the Simcoe Sub-area. The second amendment, released in June 2013, updated and extended the Growth Plan's population and employment forecasts to 2041].

In February 2015, the Province announced the coordinated review of four Provincial land use plans: Growth Plan, Greenbelt Plan, Niagara Escarpment Plan and Oak Ridges Moraine Conservation Plan. In May 2016, the Government of Ontario released draft of the Growth Plan for public review. The Province introduced changes to the Growth Plan that included amended intensification and density targets, and policies related to prime employment areas and settlement area expansions. Changes were also proposed to policies related to natural heritage, water resources, and climate change.

The draft Growth Plan introduced new policies which would require municipalities to identify and protect a "water resource system", including key hydrologic features and key hydrologic areas. Watershed and subwatershed planning are to be the basis for identifying and protecting the water resource system and Greenbelt-level protections are proposed for natural heritage systems, key natural heritage features, key hydrologic features and key hydrologic areas outside existing settlement areas. The draft Growth Plan also proposed a new policy that would require the Province to identify a natural heritage system for the Greater Golden Horseshoe.

The Town already implements many of the principles related to identifying and protecting natural heritage and water-related features via its subwatershed study and secondary planning processes. However, consideration of the forthcoming/final Growth Plan will need to be considered as part of this process to determine how they apply to the Sustainable Halton Lands.

It is anticipated that a final version of the Growth Plan will be made public in Spring 2017.

3.2.3 Greenbelt Plan Act and Greenbelt Plan

The Greenbelt Act, 2005 provided the authority for the creation of the Greenbelt Area and the Greenbelt Plan. The Act sets out the main elements and objectives for the Greenbelt, which are addressed in the Plan and to permanently protect about 1.8 million acres of environmentally sensitive and agricultural land in the Greater Golden Horseshoe from urban development and sprawl. It includes and builds on about 800,000 acres of land within the Niagara Escarpment Plan and the Oak Ridges Moraine Conservation Plan. The Greenbelt Act, 2005 requires that decisions made under the Ontario Planning and Development Act, 1994, the Planning Act and the Condominium Act, 1998 conform to the Greenbelt Plan. The Greenbelt Plan identifies where urbanization should not occur and provides policy direction for permanently protecting the agricultural land base and the ecological features and functions on the landscape. [Note: The Greenbelt Plan has been amended once since its release in 2005. The amendment was released in 2013 and introduced a new Urban River Valley designation to the Plan. It also amended the

Plan to add the Glenorchy lands in Oakville, as the first expansion to the Greenbelt since it was created].

As noted in the preceding section, the Province initiated a coordinated review of four land use plans in February 2015 and released draft of the Greenbelt Plan for public review in May 2016. The Province introduced changes to the Greenbelt Plan including proposed policy changes related to agriculture/agricultural system, natural heritage and water, climate change and the urban river valley designation. The proposed changes are intended to maintain the interconnections and diversity of natural features and areas and to ensure that water quality and water quality is maintained across the Greater Golden Horseshoe. The proposed Greenbelt Plan places a greater emphasis on planning at a watershed and subwatershed scale, as well as highlights the role these features/areas can play in helping communities to mitigate the effects of greenhouse gas emissions and adapting to the effects of climate change.

Portions of the main branches of Sixteen Mile Creek, that traverse the study area, are within the Greenbelt Plan Area. The Town will need to consider the forthcoming/final Greenbelt Plan as part of this process to determine how they will apply to the Sustainable Halton Lands.

As stated above, it is anticipated that a final version of the Greenbelt Plan will be made public in Spring 2017.

3.3 Region of Halton

3.3.1 Official Plan / Regional Official Plan Amendment #38

The Regional Official Plan (ROP) is Halton's guiding document for land use planning. It contains Council's goals, objectives, and policies for managing growth and development and for directing physical change affecting the social, economic and natural environment of the Region.
The ROP provides policies related to a wide range of topics including, but not limited to the following:

- The setting of urban area boundaries to accommodate growth and to protect farmland;
- The protection of environmentally-sensitive areas and promotion of land stewardship;
- The promotion of economic development;
- The delivery of urban services such as water supply and wastewater treatment, transportation, energy and utilities; and
- The building of healthy, complete and sustainable communities.

The ROP is reviewed periodically to ensure that it remains responsive to Halton's needs and the vision of Regional Council. The last review, referred to as 'Sustainable Halton', was undertaken to update the Halton Region Official Plan [2006]. It culminated on December 16, 2009 with Regional Council unanimously adopting Regional Official Plan Amendment No. 38 (ROPA #38). In 2011, the Province modified and approved ROPA #38. This decision was subsequently appealed in its entirety to the Ontario Municipal Board (OMB). The OMB hearing process to address the appeals began in mid-2012 and is currently ongoing. However, certain policies of the ROP are now approved and in force as of the date set out in the OMB Order, subject to site specific or area specific matters. The new September 28, 2015 Interim Office Consolidation has been prepared to show those policies that are approved and in force, as well as those policies that remain under appeal. For those policies that remain under appeal, the concurrent policies of the ROP [2006] continue to apply.

ROPA #38 is Halton Region's growth management and land use response to the province's Places to Grow Plan, the Provincial Policy Statement and the Greenbelt Plan. ROPA #38, identified additional lands in the Town of Milton that are to accommodate population and employment growth from 2021 through to 2031 (referred to as the "Sustainable Halton Lands"). The lands identified for growth will serve as Milton's next urban expansion area and next major Secondary Plan Area(s). The Town is required to plan for the Sustainable Halton Lands comprehensively. The ROP (Section 77(5)) outlines the requirements for the preparation of Secondary Plans/Area Specific Plans for major growth areas, as well as requirements for the Secondary Planning process. Following the direction outlined in these Plans, the Town initiated the planning process for the Sustainable Halton Lands via two key studies, including this SWS and a Land Base Analysis (LBA).

The overarching vision articulated in ROPA #38 is, in large part, that of an "environment-first" philosophy. In line with the Provincial Policy Statement (2014), and building off of the Province's Greenbelt Plan (2005), ROPA #38 established a Natural Heritage System (NHS) with the goal of protecting and enhancing the Region's natural features, functions and areas for the long-term. ROPA #38 also establishes that local municipalities are required to carry out, prior to or as part of a Secondary Plan process, a SWS. The requirements for a SWS are set out in ROPA #38 and, in general, it is intended to provide a more detailed assessment of the existing natural heritage and water resource features, functions and areas that make up the Region's NHS in a given area, as well as identify potential impacts of future growth and development on the NHS. ROPA#38 allows for the refinements of the NHS but it can only be done in the context of a comprehensive environmental study, such a SWS. The ROP requires that the SWS be accepted by the Region. [Note: refer to Sections 116.1, 118(1.1) and 145(9) of the ROP for select subwatershed study related policies].

3.4 Town of Milton

3.4.1 Official Plan / Official Plan Amendment #31

The Official Plan describes Council's priorities and policies on how land in the Town should be used. The Official Plan establishes a framework for addressing how the Town will ensure that future planning and development will meet the specific needs of the community.

The Town's current Official Plan is based upon a planning horizon of 2021 and provides direction to manage growth within that timeframe. The Official Plan incorporated lands for urban expansion determined through the Halton Urban Structure Plan (HUSP) exercise, which was undertaken in the late 1990's. The Official Plan was last consolidated in August, 2008 and includes all amendments approved to that date. The Town is in the process of amending its Official Plan, via Official Plan Amendment (OPA) #31, to bring the Official Plan into conformity with upper tier planning documents, including the Growth Plan and ROPA #38, as discussed in the section below.

The Town's Official Plan establishes policies related to Secondary Plan process and it also outlines the detailed studies which are required in support of a Secondary Plan, which includes requirements for a SWS (refer to Sections 5.4 and 2.6.3.37). All Secondary Plans and detailed studies are to be prepared for newly developed/urban expansion areas and are to be carried out by the Town. Secondary Plans are policy plans which address, land use, urban form and design, transportation, servicing, and development guidelines, in more detail than the Official Plan. Secondary Plans are adopted as amendments to the Official Plan.

Since the Town's Official Plan was last updated, a number of policy changes have occurred at both the Provincial and Regional level (e.g., Provincial Policy Statement 2014, Growth Plan, Greenbelt Plan, ROPA #37 and #38). Given that the Town's Official Plan must conform to Provincial policy direction and the policies of the Region of Halton, the Town is required complete a review of its Official Plan and implement, by amendment, any required revisions.

OPA #31 was prepared based on a list of key policy directions required to bring the Town's Official Plan into conformity with the above-referenced upper tier documents. OPA #31 implements population (238,000) and employment (114,000) targets for Milton to 2031, and incorporates the applicable urban boundary expansions established through the Sustainable Halton Planning exercise to accommodate that projected population and employment growth.

OPA #31 is based on the August, 2008 Official Plan Consolidation and consists of a number of new and revised policies, as well as updated mapping. The document was adopted by Town Council in June 2010 and is currently with the Region for approval. Since OPA #31 is required to be in conformity with that of the Region, it was necessary for the ROPA #38 to first be adopted and in force and effect prior to the finalization of the Town's amendment.

Town and Regional staff is currently working to advance OPA #31 to ensure that the Town's Official Plan is in conformity with upper tier documents, as well as ensure the appropriate policy framework is in place to advance planning for the Sustainable Halton Lands.

3.5 Conservation Halton

3.5.1 Conservation Authorities Act / Ontario Regulation 162/06

Section 28 of the *Conservation Authorities Act* enables Conservation Authorities to develop and administer regulations relating to development and activities in or adjacent to river or stream valleys, Great Lakes and inland lakes shorelines, watercourses, hazardous lands and wetlands. In 2006, the Minister of Natural Resources and Forestry approved individual "Development, Interference and Alteration" Regulations for all Conservation Authorities consistent with Ontario Regulation 97/04 (i.e., Generic Regulation). It was at that time, that the Minister approved Conservation Halton's regulation, Ontario Regulation 162/06. Ontario Regulation 162/06 specifies that permission is required from Conservation Halton to:

- Develop in river or stream valleys, wetlands and adjacent lands (i.e., other areas where development could interfere with the hydrologic function of a wetland), shorelines or hazardous lands and associated allowances;
- Alter a river, creek, stream or watercourse; or
- Interfere with a wetland.

The administration of the regulation is guided by Conservation Halton's Board-approved policies ('Policies and Guidelines for the Administration of Ontario Regulation 162/06 and Land Use Planning (August 11, 2011)'). These policies complement the Natural Hazard policies of the PPS (Section 3.1 of the PPS).

If it can be demonstrated to the satisfaction of CH that the proposed work meets Board-approved policies and will not affect the control of flooding, erosion, dynamic beaches or pollution or the conservation of land, CH may grant permission for the proposed work.

Conservation Halton's Policy document (referenced above) also outlines the Authority's plan input and review role. Conservation Halton has a Memorandum of Understanding with the Region of Halton to provide technical input on a range natural heritage and water resource-related matters, including providing advice on subwatershed studies, that may be affected by planning and development proposals.

3.6 Other Governing Acts, Guidelines, and Policies

There is a broad framework of legislation that regulates land use and other activities within a watershed and along streams. The following is a summary of legislations not discussed above that will need to be considered as part of this Subwatershed Study.

Table 3.1.1 Summary of Acts, Guidelines, Policy

Level of Government	Name of Management Tool: Act/Regulation/ Policy/Guideline/ Program	Type of Tool	Purpose
Federal	Federal Fisheries Act (I)	Act	Purpose is to ensure the conservation and protection of fish and fish habitat.
	Migratory Birds Convention Act (1994)(I)	Act	Purpose is to protect listed migratory species during their nesting period.
	Species at Risk Act	Act	Protection of Wildlife species at risk; recovery plans regarding federally regulated resources.

Table 3.1.1 Summary of Acts, Guidelines, Policy

Level of Government	Name of Management Tool: Act/Regulation/ Policy/Guideline/ Program	Type of Tool	Purpose
Federal	Canadian Environmental Protection Act (CEPA)(1999)	Act	The goal of the Canadian Environmental Protection Act (CEPA) is to contribute to sustainable development through pollution prevention and to protect the environment, human life and health from the risks associated with toxic substances.
	Canadian Environmental Assessment Act	Act	The Act requires federal departments, including Environment Canada, agencies, and crown corporations to conduct environmental assessments for proposed projects where the federal government is the proponent
	Canada Water Act	Act	An Act to provide for the management of the water resources of Canada, including research and the planning and implementation of programs relating to the conservation, development and utilization of water resources
	Navigable Waters Protection Act	Act	It requires approval for any works that may affect navigation on navigable waters in Canada
Provincial	Nutrient Management Act (OMAF) (2002)	Act	As part of the Ontario government's Clean Water Strategy, the Nutrient Management Act provides for province-wide standards to address the effects of agricultural practices on the environment, especially as they relate to land-applied materials containing nutrients.
	Lakes and Rivers Improvement Act (1990)	Act	The Lakes and Rivers Improvement Act gives the Ministry of Natural Resources the mandate to manage water-related activities, particularly in the areas outside the jurisdiction of Conservation Authorities.
	Provincial Planning Act (D)	Act	The purposes of this Act is to promote sustainable economic development in a healthy natural environment
	Ontario Water Resources Act	Act	The Ontario Water Resource Act deals with the powers and obligations of the Ontario Clean Water Agency, as well as an assigned provincial officer, who monitors and investigates any potential problems with regards to water quality or supply. There are also extensive sections on Wells, Water Works, and Sewage works involving their operation, creation and other aspects.
	Environmental Protection Act	Act	The purpose of this Act is to provide for the protection and conservation of the natural environment. R.S.O.1990, c.E.19, s.3.

Table 3.1.1 Summary of Acts, Guidelines, Policy

Level of Government	Name of Management Tool: Act/Regulation/ Policy/Guideline/ Program	Type of Tool	Purpose
Provincial	Fish and Wildlife Conservation Act (1997)	Act	Fish and Wildlife Conservation Act enables the Ministry of Natural Resources and Forestry (MNRF) to provide sound management of the province's fish and wildlife.
	Municipal Act	Act	The Municipal Act sets forth regulations in regard to the structuring of municipalities in Ontario.
	Ontario Drinking Water Protection Regulation	Regulation	In August 2000, the Government of Ontario announced a new Drinking Water Protection Regulation (Ontario Regulation 459/00) to ensure the safety of Ontario's drinking water. The regulation issued under the Ontario Water Resources Act was a part of the comprehensive Operation Clean Water action plan. This regulation put the Ontario Drinking Water Standards into law, updating and strengthening the Ontario Drinking Water Objectives.
	Provincial Water Quality Objectives (MOE) (1994)	Guideline	To provide objectives for the protection of aquatic life.
	Significant Wildlife Habitat Technical Guide (2000, OMNR)	Guideline	Significant Wildlife Habitat has been identified as one of the natural heritage feature areas under the Provincial Policy Statement
	Ontario Drinking Water Standards (MOE) (2001)	Guideline	The purpose of the standards is to protect public health through the provision of safe drinking water.
	Technical Guideline for Private Wells: Water Supply Assessment (MOE) (1996)	Guideline	Guidance manual for the development of private wells.
	Provincial Policy Statement	Policy	Provincial Policy Statement was issued under Section 3 of the Planning Act (2014).
	Drainage Act	Act	Provides for the regulation of drainage practices in Ontario.
	Public Lands Act	Act	The Public Lands Act was implemented to grant the Ministry of Natural Resources charge of the management, sale and disposition of the public lands and forests

Table 3.1.1 Summary of Acts, Guidelines, Policy

Level of Government	Name of Management Tool: Act/Regulation/ Policy/Guideline/ Program	Type of Tool	Purpose
Provincial	Environmental Bill of Rights (EBR)	Bill of Rights	On February 15, 1994, the Environmental Bill of Rights (EBR) took effect and the people of Ontario received an important new tool to help them protect and restore the natural environment. While the Government of Ontario retains the primary responsibility for environmental protection, the EBR provides every resident with formal rights to play a more effective role.
	Endangered Species Act (2007)	Act	Updates species listed and regulated in Ontario
	Clean Water Act	Act	The Clean Water Act was implemented as a legislative measure to protect existing and future sources of drinking water.
	Greenbelt Act	Act	The Greenbelt Act was implemented in support of the Greenbelt Plan to direct land use planning to preserve existing agricultural lands and to provide protection to the land base needed to maintain, restore and improve the ecological and hydrological functions of the Greenbelt Area
	Places to Grow Act	Act	The Places to Grow Act was implemented to promote growth plans which reflect the needs, strengths and opportunities of the communities involved, and promotes growth that balances the needs of the economy with the environment
	Conservation Authorities Act	Act	Conservation Authorities, created in 1946 by an Act of the Provincial Legislature, are mandated to ensure the conservation, restoration and responsible management of Ontario's water, land and natural habitats through programs designed to further the conservation, restoration, development and management of natural resources other than gas, oil, coal, and minerals.
	Ontario Regulation 162/06	Regulation	This Regulation allows Conservation Halton to prohibit or regulate development in or adjacent to valleylands, floodplains, shorelines, wetlands and dynamic beaches, and other natural hazards; interference with wetlands; and alteration to watercourses.

Table 3.1.1 Summary of Acts, Guidelines, Policy

Level of Government	Name of Management Tool: Act/Regulation/ Policy/Guideline/ Program	Type of Tool	Purpose
Regional	ROPA 38 Sustainable Halton (2009)	Policy	Represents a major update to the Region of Halton Official Plan to bring it into conformity with other legislation and policies. Includes a Sustainable Halton Plan for future sustainable growth and environmental management.
	ROPA 25 (2004)	Policy	Provides direction re: Secondary Planning and Watershed studies; includes the new Significant Woodlands policy and criteria.
	Halton Tree Cutting By-Law	By-Law	The Tree Conservation By-Law is designed to support and encourage good forestry management and weed out those in the industry responsible for poor logging practices. The By-Law regulates tree cutting in woodlots. It does not prohibit it. Landowners are free to cut trees in their woodlots provided that they do not violate good forestry practice.
	EIS Guidelines	Guideline	Guidelines for the conduct of EIS projects in the Region. To standardize and put forward the requirements for EIS completion and review.
Municipal	Municipal Official Plans (D)	Policy	Municipal planning strategies, and associated land use bylaws, are the primary tools used by municipalities for land use planning. As a statement of Council's policies and priorities, a strategy establishes a framework for addressing how a community will respond to opportunities and challenges for orderly growth and development.
Conservation Authority	Policies, Procedures and Guidelines for the Administration of Ontario Regulation 162/06 and Land Use Planning Policy document	Policy	This document outlines the procedures and guiding policies of Conservation Halton in administering Ontario Regulation 162/06, as well as providing legislative background.
	Conservation Halton Landscaping and Tree Preservation Guidelines	Guideline	Guidelines specify the standards for plant material selection and use in landscape restoration and enhancement plantings.
	Conservation Halton EIS Guidelines	Guideline	Guidelines specify the required scope of studies and content for Environmental Impact Studies.

3.7 Study Goals and Objectives

The overall goal for the South Milton SWS is to identify and assess opportunities and constraints to development, as well as refine the Region of Halton's Natural Heritage System (NHS), within the study area. It is also to provide an overall strategic management framework for natural heritage and water resources within the respective study area.

This SWS is intended to provide sufficient detail on the natural systems (form and function) to support the completion of Secondary Plan(s) and any associated studies. It is expected that neighbourhood-level and site-specific stormwater and environmental management plans will be consistent with the recommended strategic direction of the South Milton SWS.

The specific goals and objectives for the South Milton SWS are as follows:

3.7.1 Natural Hazards

Goal:

To prevent, eliminate or minimize the risks to life and property caused by flooding and erosion hazards and not create new or aggravate existing hazards.

Objectives:

i. To ensure new development does not increase the frequency and intensity of flooding, the rate of natural stream erosion or increase slope instability;
ii. To establish development standards and land use controls that ensure future development is located outside of, and appropriately setback from, flooding and erosion hazards;
iii. To ensure that new development, including infrastructure, incorporates appropriate mitigation measures in order to avoid adverse impacts to natural features and areas as it relates to natural hazards; and
iv. To consider climate change adaptation measures as part of the development of flooding and erosion management strategies.

3.7.2 Natural Heritage

Goal:

To protect, restore or, where appropriate, enhance the biodiversity, connectivity and ecological functions of the natural heritage features and areas throughout the Study Area for the long term.

Objectives:

i. To ensure that natural heritage features and areas, associated with a refined NHS, including their ecological and hydrologic functions, are protected from potential adverse impacts of development;
ii. To ensure that buffers, corridors and linkages between natural features and areas, surface water features and groundwater features are maintained, restored or, where possible, improved through the establishment of the natural heritage system;

iii. To establish innovative development standards and land use controls that will ensure future development does not negatively impact the NHS;
iv. To consider climate change mitigation and adaptation measures as part of the development of natural heritage management strategies; and
v. To consider opportunities for maintaining and enhancing the aesthetic and recreational value of the NHS, as part the development of management strategies.

3.7.3 Water Resources

Goal:

To protect, improve or restore the quality and quantity of water resources within, adjacent to and downstream of the Study Area, including their associated ecological and hydrologic / hydrogeologic functions.

Objectives:

i. To ensure fluvial processes and stream morphology are maintained or improved to support important habitat attributes (pools, riffles, etc.), dynamic channel form and diversity which will contribute to maintaining a sustainable natural heritage system;
ii. To prevent nutrient enrichment and contamination of surface and groundwater resources from development and related activities;
iii. To ensure surface and groundwater features and their hydrologic functions are protected, improved or restored;
iv. To maintain linkages and related functions among groundwater features, surface water features, hydrologic functions, and natural heritage features and areas;
v. To consider climate change mitigation and adaptation measures as part of establishing management strategies; and
vi. To ensure that the riparian rights of downstream landowners is respected.

3.7.4 Stormwater Management

Goal:

To mitigate negative impacts related to the quality and quantity of stormwater within, adjacent to, and downstream of the Study Area.

Objectives:

i. To maintain/enhance baseflow to the receiving regulated watercourses;
ii. To ensure that post- to pre-development peak flow control (as a minimum) achieves flood control objectives for all storm events (2 year to 100 year) and including the Regional Storm event;
iii. To ensure that stormwater runoff controls maintain or enhance existing flow-duration exceedance characteristics and other erosion indicators in the receiving regulated watercourses;
iv. To ensure that the treatment of runoff mitigates surface water quality impacts due to development in accordance with Ministry of the Environment and Climate Change guidelines, to an *enhanced* standard;

v. To mitigate thermal impacts from stormwater runoff to the extent possible;
vi. To consider Low Impact Development (LID), Green Infrastructure and Best Management Practices (BMPs) to treat stormwater at its source; and
vii. To consider climate change mitigation and adaptation measures as part of establishing stormwater management strategies.

4.0 BASELINE INVENTORY

4.1 General

A baseline assessment has been compiled based upon a combination of desktop review of background information, field reconnaissance, and numerical analysis to characterize the existing conditions wihin the study area. The following sections summarize the key information sources as well as the findings for each study discipline.

4.1.1 Property Access

In an effort to gain the most complete understanding of the natural heritage and water resource features and functions in the study area, the Town of Milton committed to securing permission for its SWS Team to access as many properties with features/areas of interest, as possible. As such, in March 2016, Town staff sent a letter to all landowners in the broad study area to seek permission for the SWS to undertake fieldwork on their property(ies). The SWS team also identified priority properties for access, with a particular focus on locations within the primary study area, and Town staff attempted to contact these landowners by phone. As permissions were received, they were noted and tracked in a spreadsheet and associated mapping was updated. The Town and participating landowners of the Milton Phase 4 Landowners Group (MP4LG) entered into formal access agreements. Access was obtained for all lands participating as part of the MP4LG. The SWS Team was required to contact landowners in advance of visiting the site and was provided Town-issued identification badges.

4.1.2 LiDAR Mapping / Ortho Photos

LiDAR mapping has been obtained by the area landowners and provided for use in this study. The LiDAR mapping has been collected in 2016, and contours established at 1 m increments.

Orthophotos have been provided for the study area, for the years 1999, 2005, and 2015.

4.1.3 Information Tracking Chart

All background information provided for use in this study has been logged in an information tracking chart. A copy of the tracking chart is provided in Appendix ‘A’.

4.2 Climate

4.2.1 Importance / Purpose

Climate data are critical to developing the hydrologic and hydrogeologic/groundwater system modelling for characterization of the surface and subsurface water conditions, as well as the respective interactions for the Sixteen Mile Creek Watershed and its subwatersheds. Long-term and short-term meteorological data sets have been used as part of the assessment of water (surface and ground) modelling and specifically collected as part of this study within and proximate to the overall Sixteen Mile Creek Watershed for multi-seasonal characterization and for conducting multi-year assessments. These datasets, in conjunction with data collected from future studies, may also provide a means for assessing shifting trends in meteorological patterns associated with climate change.

Further, climate change influence on flood and erosion potential, as well as natural systems integrity long-term is being assessed both quantatively and qualitively through this study. General trends have shown increasing intensities and frequencies of heavy / intense rainfall, along with extended periods of drought. Major storm events including Peterborough 2004, Toronto/Hamilton 2005, Mississauga 2009 and Toronto 2013, all provide evidence towards ever increasing risk related to extreme storms.

4.2.2 Background Information

The Town of Milton has been collecting rainfall data within the Sixteen Mile Creek as part of its ongoing Holistic Monitoring Program for the developing land-base since 2004. Additional rainfall and precipitation data are available from monitoring stations maintained by Conservation Halton, as well as Environment Canada's Atmospheric Environmental Services (AES) stations. These datasets have been reviewed to characterize the meteorologic conditions (i.e. rainfall/precipitation and temperature) within the Primary and Supplemental Study Areas, as well as to assess the availability of meteorologic data for conducting long-term continuous simulations. The data source, type, timestep and period of record are summarized in Table 4.2.1.

Table 4.2.1 Precipitation Gauges and Sources

Gauge Location/Description	Source	Timestep	Period of Record
Fourteen Mile Creek at Oakville	CH	15 Minute	Jan 2007 – March 2016
Kelso Dam	CH	Hourly	Jan 1993 – March 2016
Scotch Block Dam	CH	Hourly	Jan 1993 – March 2016
Milton Flying Club	Town of Milton	15 Minute	April 2016 – Dec 2016
Royal Botanical Gardens	AES	1 Hour	Jan 1962 – Dec 1995
Pearson Airport	AES	Hourly	Jan 1960 – Dec 2007

The information in Table 4.2.1 indicates that the Pearson Airport gauge and the Royal Botanical Gardens Gauges provide the longest period of record of all stations. Recognizing that continuous simulation and frequency analysis requires a minimum of 20 years of rainfall for the hydrologic modelling, these gauges represent the only stations with a sufficient period of record for use in continuous simulation. The information in Table 4.2.1 also indicates that the data collected at the Royal Botanical Gardens station only extends to 1995, after which time the gauge became inoperable and was eventually discontinued. Similarly, the Pearson Airport Gauge collected precipitation until 2003; after that time, gaps in the dataset occurred for the period from 2004 to 2005, and the gauge ultimately operated only from April until October to collect rainfall data.

4.2.3 Methods / Analysis

The hydrologic analyses for the Sixteen Mile Creek Watershed currently apply the meteorological dataset from the Royal Botanical Gardens gauge for the period from 1962 to 1995, and meteorological data from the Pearson Gauge for the period from 1996 to 2003. The data from the various precipitation gauges thus have been reviewed to determine opportunities to extend the current meteorological dataset for continuous simulation beyond 2003. The hydrologic analyses currently simulate the influence of snow accumulation and melt, hence require precipitation data in order to fully execute the continuous simulation. As noted previously, neither the Pearson nor the Royal Botanical Gardens stations collected precipitation data following 2003, hence would not provide suitable data for the full continuous simulation.

The information provided by Conservation Halton for the Scotch Block Dam, Kelso Dam, and Fourteen Mile Creek stations suggests that the stations have collected precipitation data. However, a comparison of the data among the three gauges indicates significant differences in the seasonal and total annual precipitation recorded at the stations (i.e. some stations recording annual totals 50% less than the other two stations), although this trend is not consistent for all years, nor is it attributable to any single station. This would suggest that gauges at the subject stations may have been rotated over time (i.e. precipitation stations and rainfall only stations), or else malfunctions may have occurred at the gauges. While it may be possible to extend the meteorological dataset beyond 2003 using data from the Conservation Halton stations, the inconsistent results among the stations would suggest that no single station would be suitable for extending the continuous simulation period, hence a composite dataset developed from each of the three gauges would be required.

4.2.4 Interpretation / Key Findings

The South Milton Urban Expansion Area lies within Subwatersheds 2 and 7 toward the lower reaches of the Sixteen Mile Creek Watershed. The climatic conditions within the area are characteristic of the conditions elsewhere in southern Ontario, exhibiting mild winters and hot summers, with precipitation patterns exhibiting a seasonal variation.

Rainfall data proximate to the South Milton SWS Primary Study Area are available from various sources, including AES stations, Conservation Halton stations, and Town of Milton stations. The AES stations at the Royal Botanical Gardens and Pearson Airport have historically been used for continuous simulation and hydrologic analyses, however the datasets beyond 2003 are limited and do not represent total precipitation amounts including snowfall (i.e. rainfall only). The data available at the Conservation Halton stations may be used to extend the continuous simulation time series; however, a further review of the datasets indicates that the gauges either do not consistently record precipitation (i.e. some instances of rainfall only) or else have been subject to frequent malfunction. Consequently, it is anticipated that extending the current continuous simulation dataset beyond 2003 would require incorporating data from multiple stations in order to yield a full continuous precipitation dataset. The additional datasets are currently under review to develop an extended meteorological timeseries for continuous simulation.

4.3 Hydrogeology (Groundwater)

4.3.1 Importance / Purpose

It is important to understand the interrelationship between the hydrogeologic conditions, the ecosystem and the use of groundwater for anthropogenic needs, in order to assess and manage potential impacts from future land use changes on the groundwater flow system.

The primary objectives of the Phase 1 hydrogeological characterization component of this study are to:

- Define the geological and hydrogeological setting within, and adjacent to, the primary and Supplemental Study Area.
- Identify and evaluate the functional relationship and interactions groundwater may have with the existing surface watercourses and terrestrial resources.
- Assess shallow depth to groundwater, seepage areas and areas of potentially strong upward hydraulic gradient.
- Assess groundwater characterization and groundwater uses in the Primary Study Area as they relate to hydrogeological designations presented in the “Assessment Report - Halton Region - Source Protection Area” (Halton-Hamilton Source Protect Committee, July 2015).

4.3.2 Background Information

A significant amount of detailed groundwater information exists within, and adjacent to, the Primary Study Area. Based on the groundwater team’s local knowledge base and the preliminary background review, the following conceptual understanding and potential hydrogeologic characteristics were considered for further work:

- A bedrock valley is known to exist within the Primary Study Area. The continuity of the bedrock valley, the extent of the deposits of coarse grained material within the bedrock valley and the groundwater levels associated with the valley are important characteristics for refining the groundwater flow system.
- A potential connection may exist to the bedrock valley groundwater flow system northwest of the study area, where flowing wells and upward gradients have been documented.
- Significant groundwater recharge and discharge areas are considered to be limited in this area, due to the predominance of Halton Till (i.e. low permeability) and glaciolacustrine silt and clay, but any existing discharge areas may be important in supporting local aquatic and terrestrial ecosystems in the study area.
- Hydraulic characteristics associated with discrete sand lenses within the Halton Till or contact zone aquifer sediments may be significant for providing groundwater discharge to the local drainage features. Further, areas of proportionally higher recharge within the study area, potentially in the eastern portion of the study area, may be critically important for the local surface water features.

These hydrogeological considerations were discussed with the TAC leading into the gap analysis and were considered the primary focus for finalizing the scope of the current groundwater field program, which was prepared to confirm and refine the existing hydrogeological characterization. A review of the extent and quality of background groundwater information was carried out and is provided in the Gap Analysis Report (ref. Appendix A).

R.J. Burnside & Associates Ltd. (Burnside) commenced a field program within the Primary Study Area in July, 2015. Based on the 2015 field data a hydrogeological assessment was carried out and presented in the report “2015 Hydrogeological Assessment Milton Phase 4 Lands, Milton, Ontario – Milton Phase 4 Landowners Group” (Burnside, February 2016). This report provides a field investigation of the soil, groundwater and surface water (baseflow) conditions within a substantial portion of the Primary Study Area. The field investigation included borehole drilling, monitoring well installation, drive-point piezometer (mini piezometer) installation, grain size analysis, borehole hydraulic conductivity tests, groundwater level monitoring, surface water flow measurements and groundwater quality sampling. An interpretation of the geological and hydrogeological setting was subsequently presented.

Ongoing field measurements were collected by Burnside staff through 2016 and were provided to the study team in January of 2017, as part of a coordinated groundwater field program in support the Milton SWS characterization.

The following is a description of the most relevant of these data sources in areas outside of the Primary and Supplemental Study Areas.

- A hydrogeological assessment was carried out in the north-west portion adjacent to the Primary Study Area by TMIG and included in the report “Subwatershed Impact Study – Study Area 5A, Derry Green Corporate Business Park”, (TMIG, February 2016). The field investigation included borehole drilling, monitoring well installation, mini piezometer installation, grain size analysis, borehole hydraulic conductivity tests, groundwater level monitoring, surface water flow measurements and groundwater quality sampling. A detailed interpretation of the geological and hydrogeological setting was subsequently presented.
- A detailed hydrogeological assessment was carried out by WSP Canada Ltd. adjacent to the west-central portion of the Primary Study Area (Boyne area) and is presented in the report “Hydrogeological Phase 3 Blocks 5A,5B and 6 Subwatershed Impact Study – Milton Ontario” (WSP Canada Ltd., August 2016). The field investigation included borehole drilling, monitoring well installation, infiltration testing, borehole hydraulic conductivity tests, groundwater level monitoring, and groundwater quality sampling. An interpretation of the geological and hydrogeological setting was subsequently presented.
- Other additional studies carried out in the Boyne area include the “Boyne Survey Block 1 Subwatershed Impact Study-Town of Milton (Municipal Infrastructure Group Ltd., April 2014) and “Boyne Survey Block 2 Subwatershed Impact Study” (MTE, March 2014).
- The “Hydrogeological Investigation for the Rural Community of Hornby – Town of Halton Hills”, (Hydrology Consultants, July 1983) was also reviewed. This report provides a characterization indicating a significant bedrock valley, which is likely connected into and through the Primary Study Area.

Borehole logs and groundwater levels for the above noted studies along with the MOECC water well data have been included in the groundwater database.

4.3.3 Methods / Results

As discussed, the scope of work for the groundwater field program was based on reviewing existing historical data available and the ongoing landowner field data.

The groundwater field program by the Town's SWS team (Matrix) supports refinements to the existing hydrogeological characterization and establishes baseline conditions within the Primary Study Area. Groundwater field work was coordinated with the work being completed by the other disciplines in recognition of the inter-relationship between the hydrogeological, ecological and hydrologic systems to allow for insights gained from one discipline to be integrated with the wider team.

The following section provides the methods used by Matrix Solutions Inc. (Matrix) to obtain the additional data required to complete the hydrogeological assessment of the subwatershed study area to refine the spatial characterization and address the specific considerations, particularly the extent and infilling of the bedrock valley and the potential ecological connections. The scope of work included the following major field work tasks:

- Borehole Drilling and Monitoring Well Installations
- Drive Point Mini-Piezometer Installations
- Groundwater Level Monitoring
- Groundwater Quality Sampling
- Hydraulic Response Testing
- Surface Water Spot Flow Measurements

Similar hydrogeological field data was collected by Burnside in 2015 and 2016 within the Primary Study Area.

4.3.3.1 Borehole Drilling and Monitoring Well Installation

A drilling program and well installation program was supervised by Matrix staff between May 19 and June 17, 2016. Drilling was carried out using both a truck-mounted and a track-mounted auger drill rig operated by Aardvark Drilling Inc. of Guelph, ON. Ontario One Call was contacted before the start of any drilling and registered utility owners in the area were notified of the upcoming work. Matrix personnel completed a pre-drilling site visit at all proposed drilling locations to meet with landowners (where available) and to look for visual onsite indications of non-registered buried infrastructure.

Boreholes were drilled using 203 mm hollow stem augers with concurrent split spoon samples collected continuously to 3.66 metres below ground surface (mbgs) and then once every 1.52 m to the end of the borehole. Matrix personnel were onsite to record observations on the geologic logs including lithology, colour, texture, structure, moisture, and consistency and monitoring well completion details. Geologic logs indicating borehole lithology and monitoring well installation details are provided in Appendix C1.

Aardvark completed each monitoring well using 52 mm diameter slotted (010) and solid Schedule 40 PVC pipe. Each monitoring well was completed with a 1.52 m section of screened interval. The annular space between the PVC pipe and the wall of the borehole was backfilled with a sand filter pack to approximately 0.10 to 0.30 m above the top of the screened section and a bentonite based granular and/or grout seal was installed in the remaining annulus to ground surface to prevent downward surface water migration. The monitoring wells were installed with riser pipes extending approximately 0.7 m above the ground surface and were covered with a protective steel surface casing, well cap and lock. Matrix personnel developed each well by purging at least three well volumes or, in most cases, until the well went dry using a dedicated Waterra inertial pumping system. The wells were purged dry a second time, at a later date, where turbidity remained high following initial development. The stick up height at each well was measured from ground surface to the top of the PVC riser pipe. Ground elevations at each monitoring well were determined using a 1 m LiDAR dataset.

In total, 13 boreholes at 11 locations were advanced and all boreholes were completed as monitoring wells. The borehole locations were chosen to provide further data in areas where data gaps were identified related to bedrock topography and hydrostratigraphy. At two locations (MW1a/b, MW2a/b), one shallow (a) and one deep (b) borehole were completed as overburden monitoring well nests. An additional nine boreholes were drilled and monitoring wells installed (MW3-MW11). Matrix well locations are illustrated on Figure 4.3.1. Matrix monitoring well completion data is summarized in Table 1 (ref. Appendix C).

Matrix monitoring wells were installed in the following stratigraphic layers:

- MW1b, MW2b, MW3, MW5, MW7, MW8 were completed in sand/gravel to sandy silt
- MW1a, MW2a, MW6, MW10 were completed in till.
- MW4, MW9, MW11were completed in the shale bedrock.

Burnside completed a total of 18 monitoring wells at 14 locations including four nested wells in 2015 within the Primary Study Area. Burnside monitoring well (RJB) locations are shown on Figure 4.3.1 and borehole logs can also be found in Appendix C1. Monitoring wells were installed in each of the stratigraphic layers as follows:

- RJB1, RJB2, RJB4, RJB5d, RJB6, RJB8s, RJB9s, RJB10 and RJB13 were completed in sand.
- RJB3, RJB5s, RJB7, RJB12 and RJB14 were completed in till.
- RJB8d, RJB9d, RJB11s and RJB11d were completed in the shale bedrock.

4.3.3.2 Drive Point Mini Piezometer Installations

In July 2016, a total of 11 drive point mini piezometers were installed by Matrix personnel in locations identified as areas of potential groundwater – surface water interaction (Figure 4.3.1.).

Monitoring locations were determined in consultation with Dougan & Associates staff based on observations of potential groundwater surface water interactions as indicated by terrestrial characteristics.

Seven mini piezometers were installed along surface water courses throughout the study area (MP-01, MP-03, MP-05, MP-07, MP-09, MP-10, and MP-11). MP-02 was installed in a wetland area surrounded by cattails along Sixth Line; MP-04 was installed in a suspected frog pond at the back of the property at 6692 Eighth Line; and, MP-08 was installed in a suspected vernal pool within a forested area at 6252 Eighth Line. MW-05b was installed in an area of suspected groundwater discharge along the perimeter of an agricultural field at 6343 Fifth Line. Mini piezometers were built using 0.3 m x 20 mm stainless steel drive point tips with steel pipe extensions up to approximately 1.0 m above ground surface. The depth of each mini piezometer ranged from 0.78 to 1.42 mbgs. Installation details and observed vertical hydraulic gradients are presented in Table 2 (Appendix C). Matrix personnel measured the stick up height of the top of each mini piezometer above ground surface. The ground elevations of the mini piezometers were determined using a 1 m LiDAR dataset.

Burnside installed mini (drive-point) piezometers at nine locations including 4 nested locations at various sites adjacent to water courses and wetlands. The locations for the Burnside mini piezometers can be found in Appendix C2.

4.3.3.3 Groundwater Level Monitoring

Groundwater levels were monitored at all 2016 installed monitoring wells and mini piezometers, as well as one additional, pre-existing well (RJB12) located at 6119 Trafalgar Road with the landowner's permission. Mini piezometers were monitored with monthly manual measurements. Monitoring wells were manually monitored once every three months and all wells (except of RJB12) are equipped with a Solinst™ Levelogger Model 3001 non-vented pressure transducer automatically recording every 60 minutes. Data from a Solinst™ Barologger recording atmospheric pressure at MW08 was used to correct the water level pressure recordings to gauge pressure. The manual water level was measured at each well and mini piezometer relative to the top of the PVC/steel pipe using a Solinst™ electronic water level tape. Groundwater elevations at each station were calculated by subtracting measured depths to water from the top of casing/pipe elevations. Groundwater levels obtained from the Matrix monitoring wells and mini piezometers are presented in Table 1 (Appendix C) and Table 2 (Appendix C), respectively. Hydrographs for Matrix monitoring wells are presented in Appendix C2.

Burnside staff carried out monthly water levels in the monitoring wells and mini piezometers from July 2015 through December 2016. Hydrographs can be found in Appendix C2 along with a figure presenting associated Burnside locations.

4.3.3.4 Groundwater Quality Sampling

Matrix personnel conducted groundwater quality sampling events in June 21, 2016 and October 19, 2016 at MW1b, MW2a/2b, MW4, MW5, MW6, MW8, MW9, MW10, and MW11. Monitoring wells were purged prior to groundwater sampling in order to obtain samples that represent the water quality in the formation. Matrix personnel purged three casing volumes as per the CCME (1994) method or until dry before collecting groundwater samples using dedicated inertial lift Waterra™ sampling pumps or dedicated Waterra™ bailers.

Field-measured parameters including pH, EC, temperature and dissolved oxygen were conducted on groundwater samples collected from the wells once purging is complete. The instruments were checked for calibration and corrected where necessary prior to measuring the field parameters.

Groundwater samples from ten monitoring wells (all 2016 wells excepts MW1a, MW3, and MW7) were collected by pouring water directly from the Waterra™ tubing or bailer into the appropriate, laboratory supplied, pre labeled sample bottles. Each groundwater sample collected for dissolved metals analysis was field filtered using disposable 0.45 micron filters.

Samples collected in 2016 were analyzed for the following parameters:

- general and inorganic parameters, including pH, EC, turbidity, calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), iron (Fe), manganese (Mn), chloride (Cl), bicarbonate (HCO_3), sulphate (SO_4), nitrite-nitrogen (NO_2-N), nitrate-nitrogen (NO_3-N), total Kjeldahl nitrogen (TKN) and total dissolved solids (TDS)
- dissolved metals including silver (Ag), aluminum (Al), arsenic (As), boron (B), barium (Ba), beryllium (Be), bismuth (Bi), cadmium (Cd), cesium (Cs), cobalt (Co), chromium (Cr), copper (Cu), lithium (Li), molybdenum (Mo), nickel (Ni), phosphorus (P), lead (Pb), rubidium (Rb), sulfur (S), antimony (Sb), selenium (Se), silicon (Si), tin (Sn), strontium (Sr), tellurium (Te), thorium (Th), titanium (Ti), thallium (Tl), uranium (U), vanadium (V), tungsten (W), zinc (Zn), and zirconium (Zr)

Samples were placed in laboratory-supplied containers, stored in coolers with ice, and transported to ALS Laboratory Group in Waterloo, Ontario for analysis. An appropriate chain-of-custody form indicating sample numbers was submitted to and signed at the laboratory. Copies of the signed forms were placed in the project files and are available upon request. Results of laboratory analyses were downloaded into Matrix's database management system from data provided by the analytical laboratory.

The results of the groundwater quality testing completed to date are presented in Table 3 (ref. Appendix C) and Table 4 (ref. Appendix C). Copies of the laboratory Certificates of Analysis are provided in Appendix C3.

All samples meet the criteria outlined in the Ontario Drinking Water Quality Standards (ODWQS) (MOE, 2006) with the exception of the following:

- samples collected from monitoring wells MW9, MW10 and MW11 exceed the OWDS aesthetic objective for sodium. Sodium levels were reported to range between 31 mg/L and 1,500 mg/L as compared to the ODWS aesthetic objective of 200 mg/L.

- samples collected from monitoring wells MW6, MW9, and MW10 exceed the OWDS aesthetic objective for chloride. Chloride levels were reported to range between 17 mg/L and 3,890 mg/L as compared to the ODWS aesthetic objective of 250 mg/L.
- samples collected from monitoring wells MW9 and MW11 exceed the OWDS aesthetic objective for sulphate. Sulphate levels were reported to range between 9 mg/L and 1,020 mg/L as compared to the ODWS aesthetic objective of 500 mg/L.
- samples collected from monitoring wells MW6, MW8, and MW10 exceed the OWDS aesthetic objective for Iron. Iron levels were reported as high as 0.77 mg/L as compared to the ODWS aesthetic objective of 0.3 mg/L.
- samples collected from monitoring wells MW1b. MW2a, MW2b, MW5, MW6, MW9, MW10, and MW11 exceed the OWDS aesthetic objective for manganese. Manganese levels were reported to range between 0.018 mg/L and 0.980 mg/L as compared to the ODWS aesthetic objective of 0.05 mg/L.
- The October 2016 sample collected from MW10 exceeds the OWDS maximum allowable concentration for barium. The barium level was reported as 1.07 mg/L as compared to the ODWS criteria of 1.0 mg/L.

Matrix personnel collected samples for enriched tritium analysis on June 21, 2016 from the monitoring well nest MW2a/MW2b. The samples were placed in laboratory-supplied containers and transported to Isotope Tracer Technologies in Waterloo, Ontario for analysis. An appropriate chain-of-custody form indicating sample numbers was submitted to and signed at the laboratory. The results are provided in Table 5 (ref. Appendix C).

4.3.3.5 Hydraulic Conductivity Tests

Hydraulic response tests were completed on June 29 and 30, 2016 on Matrix wells to estimate the horizontal hydraulic conductivity of the hydrostratigraphic units. All the monitoring wells drilled in 2016 were tested except MW1a where the water level was within the well screen interval. Tests consisted of displacing a known volume of groundwater in the well by rapidly inserting a plastic slug or a known volume of deionized water and then monitoring the rate at which the water level returned to equilibrium. The water level recoveries were measured using the dedicated Solinst Leveloggers that were calibrated to manual water level readings collected at regular timed intervals until the water level returned to at least 80% of the initial static level.

The hydraulic response test data were interpreted using AQTESOLV™ software (HydroSOLVE 2007). The Bouwer-Rice (1976), and Hyder et al. (KGS; 1994) methods for partially penetrating wells were selected to estimate the hydraulic conductivity values. The results are summarized in Table 1 (ref. Appendix C) and the analytical solution curves are provided in Appendix C4.

4.3.3.6 Surface Water Spot Flow Measurements

Surface water spot flow measurements were collected by Matrix staff during three monitoring periods in 2016 (May 10,11,12,18, September 6, 7 and October 25, 26) at the 61 locations shown in Figure 4.3.2 within both the Primary and Supplemental Study Areas. The spot flow measurements represent seasonal base flow conditions in the streams throughout the subwatershed study area. Total cumulative precipitation did not exceed 5 mm in the three days preceding the monitoring event to ensure baseflow conditions.

Spot flow measurements were completed by securing a measuring tape across the banks of the stream and dividing the cross section of the stream into approximately 10 panels of equal width. A Son-Tek FlowTracker Acoustic Doppler Velocimeter (ADV) was used to record the width, water depth and flow velocity in each panel to produce a final discharge value for the stream at each monitoring location. Discharge was calculated at several locations where perched culverts or weirs allowed stream flow to be collected in a bucket and timed with a stop watch. At some locations, discharge was too low (<1 L/s) to measure using the FlowTracker and was consequently estimated using visual inspection.

The Matrix surface water spot flow measurement results to date are presented in Table 6 (ref. Appendix C) and Figure 4.3.3. The following subsections summarize the spot flow measurements as they relate to each subcatchment water course within the study area.

Burnside also collected spot flow measurements from July 2105 through December 2016 at 32 locations within the primary study area. The measurements and a figure showing the locations are provided in Appendix C5. Burnside spot flow locations will be referenced for example as (Burnside B1) in the following discussion.

In general, the majority of the study area tributaries were not flowing during the spotflow surveys. Reaches that exhibited flow experienced the greatest discharge rates in the spring and late fall and the least in the summer months. These spot flow observations are consistent with historical studies within and adjacent to the study area. Sections 4.7.4 (Aquatic Resources), provides additional observation details on branch and reach specific characteristics.

4.3.3.7 West Branch

The headwaters of the West Branch of Sixteen Mile Creek are found north of the Primary Study Area at the base of the Escarpment, including Kelso Lake, then flows south, through the Town of Milton where the waste water treatment plant discharges into West Branch, and continues south where it flows into the Main Branch near Highway 407. The tributaries flowing into the West Branch are typically a network of swales and ditches that appear have been modified by historical agricultural practices.

The majority of the minor tributaries were dry during all events. Flow was observed at B2 and B3 and downstream at RR25-1 and BLW-4 in May 2016 and October 2016, but not in September 2016. It is expected that the catchment areas upstream within the urban setting are providing flow through stormwater management ponds in May and October 2016. No flow was observed by Burnside at Britannia Road and Thompson Road (Burnside B1, B2) and downstream through 2015 and 2016 except for October and November 2015 at the furthest downstream reach (Burnside F3).

4.3.3.8 East Branch

The headwaters of the East Branch of Sixteen Mile Creek originate north of the Primary Study Area near Georgetown. The East Branch flows into Lower Middle Branch near the intersection of Trafalgar and Britannia roads. Aerial imagery along with field observations indicates that the main East Branch is dammed just south of the Derry Road crossing (D4).

The highest discharge on the East Branch occurred in the May 2016 with very little or no discharge on the East Branch and all tributaries in September 2016. Discharge both increased and decreased in the lower part of the catchment between stations T3 and T4 in May and October of 2016. The summer data from both Matrix and Burnside show no flow within the upper area of the East Branch and minimal flow (0.5 l/s or less) in the downstream reach T3, T4). Online ponds downstream of Derry Road may provide some flow during summer low flow periods. It is noted in the Section 4.7.4 that in August of 2016 flow appeared to have ceased in the East Branch, but there was standing water in all of the places where it was examined.

4.3.3.9 Lower Middle Tributary

Lower Middle Tributary is entirely contained within the Primary and Supplemental Study Area. It is largely agricultural land use. The Matrix spot flow measurements showed no or minor flow during the May, September and October 2016 measuring period. Burnside spot flow measurements at the Trafalgar Road culvert indicate no or minor flow as well from May through December 2016 but show relatively significant flows at various periods related to the spring melt or high rainfall events prior to May 2016.

4.3.3.10 Middle Branch – Mid East Branch – Lower Middle Branch

The Middle Branch and Middle East Branch headwaters originate north of the study area. The Middle Branch originates along the base of the Niagara Escarpment and includes the Scotch Block reservoir. The Middle East Branch originates north of Hornby. Both branches flow into Lower Middle Branch in the study area. Lower Middle Branch flows through the study area and into the Main Branch south of the study area near Highway 407 and the West Branch confluence.

4.3.3.11 Lower Middle Branch

The May and October 2016 Matrix monitoring results show that the Lower Middle Branch generally had relatively consistent flows with the exception of the reach above Lower Baseline Road. The September 2016 results showed a general decrease in flows from the top end of the catchment through to Britannia Road with a small increase in the lower reach. The Matrix 2016 monitoring results show basically no flow in all the tributaries to the Lower Middle Branch with the exception of the tributary with locations F3 and S10, also known as the Center Tributary. This tributary and its minor branches have headwaters within the Town of Milton which are associated with stormwater management ponds. The Burnside spot flow program shows similar results for the tributaries including the Center tributary.

4.3.4 Interpretation / Key Findings

A number of the following characterization sections rely on mapping and interpretations from a geological/hydrogeological database created for this study. This database includes MOECC water well records, borehole logs and water levels from studies described in Section 4.3.2.

4.3.4.1 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 very closely related that, for the purposes of this study, the physical setting overview is a synthesis of both.

The majority of the study area is situated within the Peel Plain physiographic region and is characterized by a glacial till plain that generally slopes from northwest to southeast and has local areas of incised slopes adjacent to more major water courses. A small portion of the southern part of the Supplemental Study Area includes the South Slope physiographic region including the Trafalgar Moraine. The shape of the bedrock surface, as well as the stratigraphy of the overburden, 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 Wisconsinan 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 sediments.

4.3.4.2 Surficial Geology

The regional surficial geology mapping and data is provided by the Ontario Geological Survey (OGS 2010). The surficial geology consist primarily of fine grained sediments characterized by the glaciolacustrine silt and clay and glaciolacustrine derived silty to clayey till (Halton Till). Areas of glaciolacustrine sand and gravel (foreshore basinal deposits) occur in the eastern portion of the Primary and Supplemental Study Areas between 6th Line and 8th Line north of Britannia Road and along 8th Line south of Britannia Road. Modern alluvial deposits (sand/gravel and organic material) occur along the Sixteen Mile Creek tributaries. The surficial geology is presented in Figure 4.3.3.

This characterization is consistent with the borehole logs related to the Matrix and Burnside drilling programs. Exceptions include finer grained silt and clay found at MW4 (till), MW8 (till), RJB5s and RJB11s where sand was originally mapped.

The overburden thickness within the study area is on the order of 25 m in the northeastern and southeastern boundaries of the study area and is 0 m where the West Branch and Lower Middle Branch are incised in the bedrock south of Britannia Road. Generally the overburden thickness is between 10 m and 15 m (Figure 4.3.4).

4.3.4.3 Bedrock Geology

The underlying bedrock within the study area is comprised of the Upper Ordovician Queenston Formation characterized by red shale. The shale is comprised of red mudstone with green siltstone bands as well as thinly bedded layers of grey limestone/dolostone. The shale is generally extensively weathered at the surface (bedrock/overburden contact) and is more competent with depth except in areas where glacial scouring may have selectively removed previously weathered shale.

A component of the current study's field work was to assess the bedrock topography and confirm and refine the extent and depth of an existing buried valley through the drilling program. Bedrock was encountered in ten Matrix borehole locations and five Burnside borehole locations within the primary study area. In addition, the overall borehole database was used to assess the bedrock topography. The bedrock topography is presented in Figure 4.3.5.

Bedrock topography ranges from 190 masl in the northeast corner of the study area to 155 masl in the southwest corner of the study area where the Main Branch of Sixteen Mile Creek cuts into the Queenston Shale.

A bedrock valley in and to the northwest of the primary study area has been recognized through mapping in previous studies including the Halton Aquifer Management Plan (Region of Halton February 1995). The "Hydrogeological Investigation for the Rural Community of Hornby – Town of Halton Hills" (Hydrology Consultants, July 1983) provides a characterization of this valley northwest of the study area. Two minor bedrock valley systems exist north of Steeles Avenue, enter from the northwest and north of the study area and extend southeast across Steeles Avenue and Highway 401. The current bedrock topography mapping (Figure 4.3.5) shows this northerly connection to the main bedrock valley in the Primary Study Area. Monitoring well MW1b, located in the northeast corner and which was 26 m deep, did not encounter bedrock. This indicates that the bedrock at this location is deeper than 178 masl. This area may reflect the east branch of the bedrock valley north of Highway 401.

The bedrock valley tends to follow the Lower Middle Branch to the Main Branch of Sixteen Mile Creek, as well as a subtle bedrock valley slope to the southeast. The topography within the valley ranges from 190 masl to less than 170 masl. Lower bedrock levels on Figure 4.3.5 south of Lower Baseline Road reflect Sixteen Mile Creek cutting into the bedrock.

4.3.4.4 Stratigraphy

A detailed stratigraphic setting was previously presented in the Burnside report "2015 Hydrogeological Assessment Milton Phase 4 Lands, Milton, Ontario – Milton Phase 4 Landowners Group" (February 2016). The Matrix drilling program built upon the Burnside characterization to confirm or refine the bedrock topography and the potential extent of the permeable sand and gravel unit within the valley and at the bedrock contact.

A review of the Matrix borehole logs located along previously interpreted Burnside Cross-Sections A-A' (MW7, MW8), B-B' (MW2b, MW4, MW10, MW11) and D-D' (MW5) confirm the interpolated bedrock topography and stratigraphy and continuity of the valley. As such we have re-presented the original Burnside cross-sections. Seven cross-sections are presented for review. The four original Burnside cross-sections are provided on Figure 4.3.6 and Figure 4.3.7 with edits based on the additional Matrix boreholes. Three additional Matrix cross-sections have been created and are presented on Figures 4.3.8, 4.3.9 and 4.3.10. The cross-section locations are illustrated on Figure 4.3.1. Cross-section locations include:

- Britannia Road (A-A')
- 6th Line (B-B')
- James Snow Parkway (C-C')
- Trafalgar Road (D-D')
- Main Street (E-E')
- Derry Road (F-F')
- 8th Line (G-G')

Major observations related to specific cross-sections include the following:

- The bedrock valley is evident on the three cross-sections (A-A', E-E' and F-F') crossing 6th Line and Trafalgar Road (A-A', B-B', C-C', D-D'). Matrix boreholes confirmed the continuity of the bedrock valley at locations MW2b, MW4, MW5, MW8, MW7 and MW10. As outlined above, MW1b did not encounter bedrock at 178 masl, which may suggest that the valley spreads out slightly to the north – northeast.
- The 6th Line (B-B') and Trafalgar Road (D-D') cross section generally bound the flanks of the valley north of Britannia Road and indicate significant basal deposits of sand and gravel The Main Street, Derry Road and Britannia cross-sections also confirm these deposits varying in thickness from 5-10 m.
- Basal sand and gravel deposits also exist on the 8th Line cross-section southeast of Britannia Road.
- The surficial sand unit shown on Figure 4.3.3 is relatively thin and is underlain by thicker sequences of fine grained material as shown on the 8th Line cross-section.
- There is no apparent continuous stratigraphic connection between the more prevalent basal sand and gravel and ground surface through the till and glaciolacustrine silt and clay.

The overall stratigraphic characteristics were confirmed and include the following:

- The thickness of the overburden in the study area ranges from about 5 m to more than 30 m in bedrock valleys, but is most often in the 10 m to 15 m range.
- The overburden materials generally consist of low permeable glacial till, silt and clay deposits.
- The majority of the basal sand and gravel within the valley exists north of Britannia Road.
- Discontinuous sand and gravel deposits exist at the bedrock contact at various locations within the study area.

- Thin, discontinuous deposits of sand and gravel are evident at various depths within the till.
- The surficial sand and gravel deposits are relatively thin and in some cases not as prevalent as shown on Figure 4.3.3.

4.3.4.5 Groundwater Use

A detailed groundwater use review was carried out by Burnside and reported in "2015 Hydrogeological Assessment Milton Phase 4 Lands, Milton, Ontario – Milton Phase 4 Landowners Group". Burnside assessed domestic wells within the Primary Study Area and the Supplemental Study Area. Burnside noted the following characteristics:

- Discrete sand/gravel lenses within the overburden and sand and gravel deposits at the bedrock contact provide adequate water supplies.
- The record review for water supply wells in the vicinity of the study area found that only about 35% of the wells were completed in overburden deposits and the remainder were completed in the shale bedrock.
- The Queenston shale is generally not considered a good aquifer (for water quality or quantity), but serves as the most significant local aquifer, due to the lack of other aquifers in much of the study area. In particular, the upper portions of the shale, where it is fractured and weathered, can be an important zone of groundwater movement.

For the overburden wells:

- The well depths are reported between 3 m and 23 m (only one well was reported at a greater depth of 59 m in a presumed bedrock valley).
- 83% are dug wells, i.e., larger diameter boreholes typically used in areas where groundwater supplies are limited.
- 17% are drilled wells, but only about one third of these are screened in sand zones. In most cases the wells are completed in till.
- The reported well yields are low with only about 5% of the wells reporting yields greater than 1 L/s.

For the bedrock wells:

- The majority of wells are less than 50 m deep with only four wells reported at greater depths.
- 39% are dug wells showing bedrock may be encountered at relatively shallow depths.
- 61% are drilled wells.
- The reported well yields are low with only about 3% of the wells reporting yield greater than 1 L/s.
- The well records suggest that the water quality is relatively poor, with mineralized, salty and sulphurous water noted in some of the shale records.

Matrix staff reviewed the current Permit to Take Water (PTTW) database within and immediately adjacent to the Primary Study Area. There are 17 active permits; however, 16 of these are for construction dewatering and one permit for golf course irrigation. The permit information and locations are provided in Appendix C6. Construction dewatering is usually temporary and golf course dewatering for irrigation is seasonal. The amount of dewatering for construction will depend on the depth and size of the excavation and whether it has intercepted the more permeable sand and gravel deposits or shallow fracture bedrock.

The Highly Vulnerable Aquifer (HVA) mapping presented in the "Assessment Report - Halton Region - Source Protection Area" (Halton-Hamilton Source Protection Committee, July 2015) indicates a very small HVA just south of Highway 401 within the study area in the vicinity of MW2a/b. This may be related to the basal sand and gravel at the surface of the bedrock valley.

4.3.4.6 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. This usually occurs within several metres of the bedrock surface.

The Matrix results of the analyses are presented in Table 1 (ref. Appendix C). The results for the clayey silt till indicate a hydraulic conductivity of approximately 1×10^{-8} m/s. The results for the coarser grained silt, sandy silt and sand indicate a hydraulic conductivity of 3×10^{8} m/s to 6×10^{6} m/s. The weathered shale ranged from 2×10^{-7} m/s to 6×10^{-6} m/s.

The highest hydraulic conductivity result was 4×10^{-4} m/s and was observed at MW6. The borehole location was drilled twice. During the first drilling attempt, flowing sand was encountered just above the bedrock contact during well installation, which resulted in difficulty installing the monitoring well. As a result, the borehole was re-drilled 6.1 metre adjacent to the first site and a well screen installed within unit of medium to coarse sand and gravel.

Burnside carried out borehole test for hydraulic conductivity as well as grain size analysis (Hazen method) for hydraulic conductivity for their monitoring wells and reported the following results:

- The borehole results for the silt and silty clay till indicate a low hydraulic conductivity ranging from 1.9×10^{-8} m/s to 7.6×10^{-8} m/s.
- The results of the analyses of the sandy silt, sand and gravel indicate a higher hydraulic conductivity ranging from 1.6×10^{-8} m/s to 2.3×10^{-6} m/s.
- Tests completed in the shale bedrock provided results ranging from 6.7×10^{-9} m/s to 1.4×10^{-6} m/s.
- The results of the grain-size analysis of three samples collected from the silt and clay till suggest a relatively low hydraulic conductivity of less than 1×10^{-8} m/s.
- Four samples comprised of silt and sand provides a slightly higher hydraulic conductivity value ranging from 5.8×10^{-8} m/s to 7.2×10^{-7} m/s.

- Two samples collected from sand deposits provide a higher hydraulic conductivity value ranging from 2.6×10^{-5} m/s to 7.6×10^{-4} m/s.
- Hydraulic conductivity tests carried out adjacent to the study area for the Boyne lands indicate ranges in the till of 5.2×10^{-7} m/s to 3.3×10^{-9} m/s, ranges in the silty sand of 1.1×10^{-6} m/s to 1.1×10^{-8} m/s and 1.2×10^{-5} m/s for the fractured shale.

In general, the hydraulic conductivity related to the sand and gravel within the till have a moderate hydraulic conductivity, whereas, the sand and gravel deposits at the bedrock contact and the fractured shale have a relatively higher hydraulic conductivity.

4.3.4.7 Groundwater Levels

Monitoring Wells

Groundwater level monitoring data for the Matrix monitoring wells are provided in Table 1 (ref. Appendix C). Hydrographs for the Matrix and Burnside monitoring wells are presented in Appendix C2. The groundwater level data indicates the following:

- The depth to groundwater varies across the Primary Study Area with a majority of the wells within the upper 2.5 m.
- Groundwater tends to be closer to ground surface in topographic lows and slightly deeper in topographic highs. Groundwater levels tend to be lower (>4 m) in deeper wells within the till.
- Groundwater levels in wells screened in the shale (RJB8d, RJB9d, RJB11d, MW9, MW4) tend to be close to ground surface, with the exception of MW11 where groundwater was up to 6 m deep. Bedrock wells demonstrate the same seasonal trends.
- Seasonal trends in the monitoring wells tend to vary in the 1-2 m range. The Burnside wells, which have been monitored through 2015 and 2016, show a greater seasonal water level decline in a larger number of wells in all stratigraphic units through the summer and fall of 2016, likely reflective of the drier conditions through 2016.
- The water level trend in MW1a believed to have been recovering from well development for up to six months.
- MW7 shows of close to 3 m drop at beginning in September 2016. MW7 was paired with RJB12, a shallower well that also demonstrates a water level drop. RJB1 shows a significant drop of up to 4 m from March 2016 through to November 2016. This may partially reflect a seasonal trend but may also relate to nearby seasonal dewatering for road construction projects.
- Multilevel wells RJB5s/d, RJB8s/d, RJB11s/d, show minor vertical gradients downward, MW1a/b, MW2a/b and MW7/RJB12 show stronger downward gradients, and RJB9s/d shows a slight upward gradient.

Mini (Drive-Point) Piezometers

Groundwater level monitoring data for the Matrix mini piezometers are provided in Table 2 (ref. Appendix C). The locations, hydrographs and data for the Burnside mini piezometers are provided in Appendix C5.

Matrix carried out groundwater level monitoring on August 15, 2016, September 28, 2016, October 20, 2016, November 21, 2016 and January 4, 2017.

- Seven mini piezometers were installed along surface water courses throughout the study area (MP-01, MP-03, MP-05, MP-07, MP-09, MP-10, and MP-11). MP-01 (Sept.), MP-03 (Sept., Oct., Nov.), MP-05 (Oct., Nov.), MP-10 (Sept., Oct.) and MP-11(Jan.) showed upward vertical hydraulic gradients on various dates shown. MP-07 and MP-09 showed downward gradients on all dates. MP-10 was destroyed by ice flows during December 2016.
- MP-02 was installed in a wetland area surrounded by cattails along Sixth Line and demonstrated downward gradients on all dates.
- MP-04 was installed in a suspected frog pond, MP-08 was installed in a suspected vernal pool and MW-05b was installed in an area of suspected groundwater discharge area along the perimeter of an agricultural field. All three mini piezometers were dry on all dates.

Burnside carried out monthly water levels from July 2015 through December 2016 at nine locations including four nested locations at various sites adjacent to water courses and wetlands.

- PZ1s/d is located adjacent to a wetland. Downward gradients were observed June 2015 and March, April, May and June of 2016. The mini piezometers were observed to be dry through the remainder of 2015 and 2016 indicating that the water table is below the wetland area.
- PZ2s/d and PZ5s/d are also located within wetlands/vernal pools. Hydrographs for both locations show seasonal variations with downward gradients through June of 2016. Upward gradients begin in June, 2016 until the mini piezometers become dry in the late summer.
- PZ6s/d is located adjacent to a watercourse and the monitoring results show that neutral or downward gradients occur at this location.
- The single mini piezometers (PZ3, PZ4, PZ7, PZ8 and PZ9) reflect seasonal variations in water levels with no significant indications for groundwater discharge potential.

Provincial Groundwater Monitoring Network (PGMN) Wells

Two PGMN wells exist within or adjacent to the study area (Figure 4.3.1). Well 124-1 south of Lower Baseline Road is 13.5 m deep and screened in a 2 m layer of fine sand below till. Well W125-1 is located in the vicinity of Coates Park in Milton and is 13 m deep and screened in the upper shale underlying till. Water levels were provided by Conservation Halton for the periods September 2002 through December 2015. Both wells show long term fluctuations (1-2 years) of 2-3 metres leading up to 2011. Fluctuations are more subdued from 2011 – 2015, with seasonal trends noticeable in both wells. Hydrographs can be found in Appendix C2.

4.3.4.8 Conceptual Groundwater Flow

General Considerations

Water from precipitation percolates or infiltrates into the ground. Water which reaches the water table may provide recharge to the overall groundwater flow system. Areas where water moves downward to the water table are known as recharge areas. These areas are commonly in areas of topographically higher relief. Areas where groundwater moves upward to the water table are known as discharge areas and these generally occur in areas of topographically low relief, such as stream valleys. Groundwater that discharges to streams maintains the baseflow of the stream. Wetlands may also 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 locally or regionally significant quantities of water are known as aquifers. Aquifers are "water bearing" formations meaning that water can be relatively 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 much of the study area, 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.

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.

Overburden Groundwater Flow

A groundwater flow map was prepared that utilized groundwater levels from monitoring wells within the Primary and Supplemental Study Area, water levels from monitoring wells adjacent to the study area, and domestic water wells within and beyond the study area. Estimates of shallow groundwater flow directions utilizing water well records are considered appropriate for larger scale studies but may, in part, reflect a groundwater flow trend that is averaged over many years and at a slightly greater depth.

A map reflecting directions of shallow groundwater flow within the overburden is presented on Figure 4.3.11. The map shows horizontal groundwater flow from the west northwest and converging within the West Branch of Sixteen Mile Creek and the Middle Branch of Sixteen Mile Creek. Steeper gradients can be seen at the confluence of the Main Branch where Sixteen Mile Creek cuts more deeply into the Queenston shale. The groundwater divides for the overburden within the study area tend to follow the surface water divides. Horizontal gradients vary from approximately 0.0025-0.0035 within the majority of the Primary Study Area. Gradients are steeper within the major valley systems.

Water table depths within the Halton Till and glaciolacustrine silt and clay in this study area and similar surficial geology settings 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 typically follow the local variations in topography.

The horizontal component of groundwater flow, particularly within the overburden through most of the study area, will be weak due to the prevalence low permeability Halton Till and glaciolacustrine silt and clay sediments. Areas mapped as more permeable sand deposits (Figure 4.3.3) will have a much greater potential for horizontal flow. The lateral extent of this shallow flow will depend on the more site specific continuity of surficial sand layer.

The surficial Halton till and glaciolacustrine silt and clay is expected to transmit relatively higher quantities of water through areas that are potentially fractured but on a more local scale. An understanding of the hydrogeologic characteristics of this shallow unit is important to the understanding of potential infiltration, recharge and localized shallow flow. A significant amount of research has focused on the hydrogeology of fractured glacial tills 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 the Halton Till and glaciolacustrine silt/clay:

- Frequency and depth of fractures can depend on the clay/silt/sand content, average precipitation and temperature.
- Fractures can occur up to 6 m but they are likely more prevalent within the upper 2 to 3 m of fractured overburden.
- The lateral connection within the upper fractured overburden can be relatively significant but are localized laterally (10’s of metres).
- Horizontal flow patterns in the upper fractured overburden will be controlled by local depressional topography and restricted by underlying more massive and less permeable till.
- Vertical groundwater flow below the upper fractured overburden is generally low unless more permeable, interconnected lenses exist
- Evapotranspiration will significantly reduce water levels in the upper fractured overburden.
- Lateral flow in the fractured network 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 drop in the upper fractured unit as a result of seasonal variations in precipitation and evapotranspiration (ET).

Fractures and iron staining are observed in boreholes adjacent to the study area as well as other similar stratigraphic settings in Brampton and Smithville.

Where the deeper till is massive both vertical and horizontal groundwater flow is restricted. The vertical hydraulic gradients are generally quite higher than the horizontal gradients. Some level of fracturing may occur in the more massive till. In areas where the overburden thickness is on the order of 6 m, it is expected there is an increased potential for groundwater flux to the bedrock but where the overburden thickness is on the order of 2 to 3 m it is expected there is a much more direct connection from ground surface to the upper bedrock.

Vertical flow through the overburden is driven by the vertical hydraulic gradients. There is generally a stronger vertical gradient through an aquitard that is underlain by a permeable unit. Within the Primary and Supplemental Study Areas the bedrock and associated permeable sand and gravel at the bedrock surface can act as an aquifer and the prevalence of overlying till and fine grained material act as an aquitard. Vertical gradients within the overburden range from slightly upward at RJB9s/d to 0.57 downward at MW7/RJB12. At monitoring well nest MW2a/b the vertical downward gradient is 0.12. The hydraulic conductivity was measured in the till to be 1.4 x 10^{-8} m/s. Assuming a matrix porosity of 0.4 the vertical groundwater velocity is estimated to be 0.13 m/year. The travel time through 7 metres of till at this location is estimated to be approximately 54 years which coincides with the enriched tritium result of <0.8 Tritium Unit (TU) which corresponds to an age prior to 1956.

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 be a more direct connection from the lower basal sand and gravel and shallow bedrock unit through the overburden aquitard. Hydrogeological studies in the Hornby area indicated significant upward gradients and flowing domestic wells. In addition a dewatering exercise north of Highway 401 at Steeles Avenue demonstrated connections between the bedrock valley basal aquifer and sand lenses within the till and some surface water features.

As discussed in Section 4.3.4.4, this stratigraphic connection does not appear to exist within the study area and downward hydraulic gradients exist in all the multilevel monitoring wells except RJB9s/d which demonstrates a slight upward gradient. Two flowing domestic wells are noted north of MW1a/b but MW1a/b demonstrates a downward gradient (after initial recovery).

Bedrock Groundwater Flow

It is expected that the groundwater flow directions within the upper fractured bedrock will generally follow the bedrock topography. The lateral connection within the upper fractured bedrock and basal sand and gravel depends on the continuity of both units. The basal sand and gravel does not appear to be continuous through the Primary Study Area but the overall fractured nature of the upper shale bedrock is expected to be relatively continuous and likely provides a larger-scale connection through the Primary Study Area and beyond. The upper shale bedrock may therefore be connected to recharge areas further north and northwest where hydraulic connection through the overburden may be more prevalent. The analysis of the enriched tritium sample collected in MW2b provided a result of 3.78 TU. This result can correspond to possible ages ranging from 1954 -2004. This range may reflect local recharge through the tight till or recharge through a more permeable overburden connection locally or further north in the regional groundwater system.

4.3.4.9 Recharge and Discharge Conditions

The amount of recharge within the Primary and Supplemental Study Areas is limited to a greater extent by the lower permeability of the surficial sediments. The recharge values may be higher or lower depending the overall clay, silt and sand content within surficial unit. Where the surficial sand exists, higher recharge values will exist. Higher depressional focused recharge can also occur in topographic lows. Recharge is expected to provide a local component of the flow, as described above. The local recharge that does not discharge locally will eventually recharge the deeper sand lenses, and potentially the basal aquifer and upper bedrock where downward hydraulic gradients persist.

The Significant Groundwater Recharge Mapping presented the "Assessment Report - Halton Region - Source Protection Area" (Halton-Hamilton Source Protect Committee, July 2015) indicates areas of medium vulnerability that are related to the surficial sands mapped on Figure 4.3.3. As discussed in Section 4.3.4.4 the surficial sand unit is underlain by the less permeable till unit.

Quantification of recharge is to be carried out in Phase 2. A more detailed discussion on the relationship between infiltration and recharge as it relates to the overburden stratigraphy and flow system within the study area will be presented during Phase 2.

Groundwater discharge to stream reaches is very limited throughout the study area. Spot flow measurements described in Section 4.3.3.6 indicate that all the tributaries feeding the Lower Middle Branch and the West Branch are dry in the summer months except for the East Branch (<0.5 L/s) and tributaries (S10, B2) that are fed by stormwater management ponds within Milton. Summer flow in the Middle Branch and East Middle Branch within the study area enters north in the upstream area and is likely derived from groundwater discharge in the upper portions of those subwatersheds. Seepage areas were noted along lower slopes in both West Sixteen Mile Creek and lower East Sixteen Mile Creek where deeper cuts have occurred and valley walls are steep (Section 4.8.4). These seepage faces are more common where the water table meets a steep valley wall and groundwater discharge is quite diffuse. Relatively more seepage is usually seen where the valley face cuts into the bedrock or intercepts a local sand lens. The groundwater discharge observations for the tributaries within the study area are consistent with historical observations from the previous subwatershed studies and the studies noted in Section 4.3.2.

All of the mini piezometers within wetlands or vernal pools are dry or show downward gradients except the mini piezometers PZ2s/d (adjacent to RJB14) and PZ5s/d on the 5th Line north of RJB3. These piezometers go from downward to upward gradients in June and then become dry. The seasonal reversal of hydraulic gradient is likely a result of increased ET and a reduction in the water table as opposed to a larger scale groundwater flow system discharge.

4.4 Hydrology and Hydraulics (Surface Water)

4.4.1 Importance / Purpose

Hydrologic and hydraulic models are developed for urbanizing subwatersheds to provide a better understanding of the amount and movement of water in the system both under existing land use and proposed future land use conditions, based upon the physical conditions in the watershed under both land use scenarios. By developing representative models, which reasonably predict seasonal and storm-based runoff response, the impacts of proposed future urbanization can be better quantified and thereby appropriate management strategies can be established in the future, as part of integrated management plans.

4.4.2 Background Information

4.4.2.1 Reports

Numerous reports have been provided for reference in characterizing the hydrology within the watershed as well as the overall study area. The following summarizes the key sources of information:

- Sixteen Mile Creek Watershed Plan (Gore & Storrie Limited, 1995)
- Sixteen Mile Creek Areas 2&7 Subwatershed Study (Philips Planning and Engineering Limited, January 2000)
- Sixteen Mile Creek Areas 2&7 Subwatershed Update Study (AMEC et. al., November 2015)
- 2014 Municipal Structure Inventory and Inspection / Bridge Needs Study Summary Report (Chisholm, Flemming and Associates Consulting Engineers, January 2015)

In addition to the foregoing information which provides an overview of the hydrologic and hydraulic conditions within the Sixteen Mile Creek Watershed at the subwatershed and/or watershed scale, various stormwater management reports have been provided specifically for reference and use in this study, as well as through Amec Foster Wheeler's ongoing peer review support for the Town of Milton (ref. Appendix A).

4.4.2.2 Mapping

The following mapping has been provided and used for the baseline characterization and assessment of the surface water hydrology and hydraulics in the South Milton Phase 4 Area:

- 2016 LiDAR Mapping
- 2014 MNRF and Conservation Halton approved mapping for open watercourse systems.
- 2013 Contour Mapping provided by Conservation Halton
- Bridge Projects and Hydraulic Structure Locations

- Hydraulic Structure Inventory provided by Urbantech Consulting on behalf of the area landowners
- 2015 Air Photos
- Surficial Soils and Surficial Geology Mapping (Conservation Halton)
- Conservation Halton Regulated Limit
- Floodline Mapping

4.4.2.3 Hydrologic and Hydraulic Models

Hydrologic modelling of the Sixteen Mile Creek Watershed has been completed most recently using the USEPA HSP-F methodology. The HSP-F hydrologic model for the Sixteen Mile Creek Watershed was originally developed and calibrated as part of the Sixteen Mile Creek Areas 2&7 Subwatershed Study (Philips Planning and Engineering Limited, January 2000). More recently, the HSP-F hydrologic model has been updated as part of the Sixteen Mile Creek Subwatershed Update Study (AMEC et. al., November 2015), which included refinement and calibration within the limits of the Boyne Survey Secondary Plan Area and the Derry Green Secondary Plan Area. Prior to that study, hydrologic modelling for the Sixteen Mile Creek Watershed had been completed using the HYMO model as part of the Floodplain Mapping Study (Proctor & Redfern, 1988) and later using the QUALHYMO model as part of the Sixteen Mile Creek Watershed Plan (Gore & Storrie Ltd. and Ecoplans Ltd., February 1996).

Hydraulic modelling within the Sixteen Mile Creek Watershed has been completed most recently for the area watercourses using the HEC-RAS methodology. These models have been applied by Conservation Halton for determining Regulatory Floodline Mapping and establishing Conservation Halton's Regulatory Limit. The quality and format of the datasets used to develop the various HEC-RAS models vary throughout the watershed (i.e. imported HEC-2 hydraulic models developed as part of the FDRP, local HEC-RAS hydraulic models developed for specific studies and/or infrastructure projects and based upon approved design and/or as-built information, HEC-RAS hydraulic models developed based upon 2002 MNR mapping and estimated dimensions for hydraulic structures).

4.4.3 Methods / Analysis

4.4.3.1 Baseline Characterization

A baseline characterization of the hydrologic conditions within the South Milton SWS study area has been developed based upon a desktop review of the background information provided for this study. This review has characterized the existing drainage systems, soils, slopes, and land use conditions within the Primary and Supplemental Study Areas, as well as the surrounding lands.

Drainage Systems

The South Milton SWS extends across the lower reaches of Subwatersheds 2 and 7 within the Sixteen Mile Creek. Portions of the study area also lie within Subwatershed 4 toward the northeast limit of the area.

Runoff within the study area is generally conveyed by defined watercourses toward well-defined riverine systems. The watercourses are typically agricultural drainage systems, and have been subject to past alteration as part of agricultural practices.

The lands within Subwatershed 7 include an existing golf course with its own defined drainage system. The locations and connections of subsurface drainage infrastructure within the golf course is currently unknown.

Soils

Soils within the study area have been characterized based upon a review and comparison of the information provided in the surficial soils and surficial geology mapping. Surficial soils mapping and surficial geology mapping are provided in Appendix D. The information in Appendix D indicate that soils within the majority of the study area consist of clay loam soils which exhibit low infiltration and high runoff potential. Within isolated areas toward the northeast of the study area, higher permeability sands are noted to be found, although the limits of the higher permeability material is noted to vary slightly between the two sources.

Slopes

The ground slopes at surface within the South Milton Subwatershed Study Area have been characterized based upon the detailed 2016 LiDAR mapping provided for this study by the MPA Landowners. The information in the LiDAR mapping indicates that the surficial slopes within the area are relatively low, and are generally less than 1 %. Along the watercourses, slopes can increase to approximately 10 % however this tends to be isolated to areas where the tributaries confluence with the riverine systems.

Land Use

Land use conditions within the South Milton Subwatershed Study Area have been characterized based upon a review of aerial photography. The existing land use conditions within the South Milton Subwatershed Study Area are primarily agricultural with some forests along and adjacent to the open watercourses. As noted, a portion of the South Milton Subwatershed Study Area in Subwatershed 7 also includes an existing golf course.

The lands toward the north and northwest of the South Milton Subwatershed Study Area are primarily residential, with some institutional and recreational land uses. It is further noted that the Boyne Survey Area and the Derry Green Area are proposed to be developed to provide primarily residential land use and employment land use respectively. The Bristol Survey Area which lies toward the north and west is noted to be sully developed as primarily residential land uses, as well as stormwater management facilities to provide stormwater quality, erosion, and quantity (flood) control.

The lands toward the north and east, which are external and upstream of the South Milton Subwatershed Study Area are primarily agricultural, with some forests and natural areas, and some isolated commercial, recreational, and estate residential land uses, as well as the Highway 401 corridor.

4.4.3.2 Field Monitoring

A field monitoring program has been implemented as part of the Subwatershed Study to collect streamflow data and rainfall data to support the calibration and validation the hydrologic models, as well as to characterize the local runoff response within the subwatersheds, in accordance with the Work Plan for the Subwatershed Study (ref. Appendix J). Continuous streamflow monitoring has been completed by the Amec Foster Wheeler Team at six locations established in consultation with the TAC, and a temporary rainfall gauge has been installed within the study area, in consultation with the TAC. The locations of the surface water monitoring stations are provided on Figure 4.4.1.

The monitoring program was initiated by the Amec Foster Wheeler Team in the spring of 2016. Water level probes were installed at the Trafalgar North, Trafalgar South, Fifth Line South, and Thompson stations on April 20, 2016, and a water level probe was installed at the Fifth Line North station on April 24, 2016. A sixth water level probe was installed at the Sixth Line station on July 9, 2016, following comments provided by Conservation Halton on the original Work Plan. In addition, a tipping bucket rain gauge was installed at the Milton Flying Club on April 20, 2016. All equipment was removed on December 8, 2016, at the completion of the monitoring program.

The Amec Foster Wheeler Team has collected data to establish stage-discharge relationships at each streamflow monitoring locations, and to determine flow rates based on recorded flow depths at each monitoring location. Velocity metering has been conducted within the channel at each 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 locations 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. Furthermore, local HEC-RAS hydraulic models have been developed for each monitoring location to develop stage-discharge relationships at each site, and the roughness coefficients adjusted to best reproduce the observed depth at the corresponding discharge values. The rating curves for each monitoring location are presented in Figures 4.4.2 to 4.4.5, and a summary of the field flow monitoring is provided in Table 4.4.1.

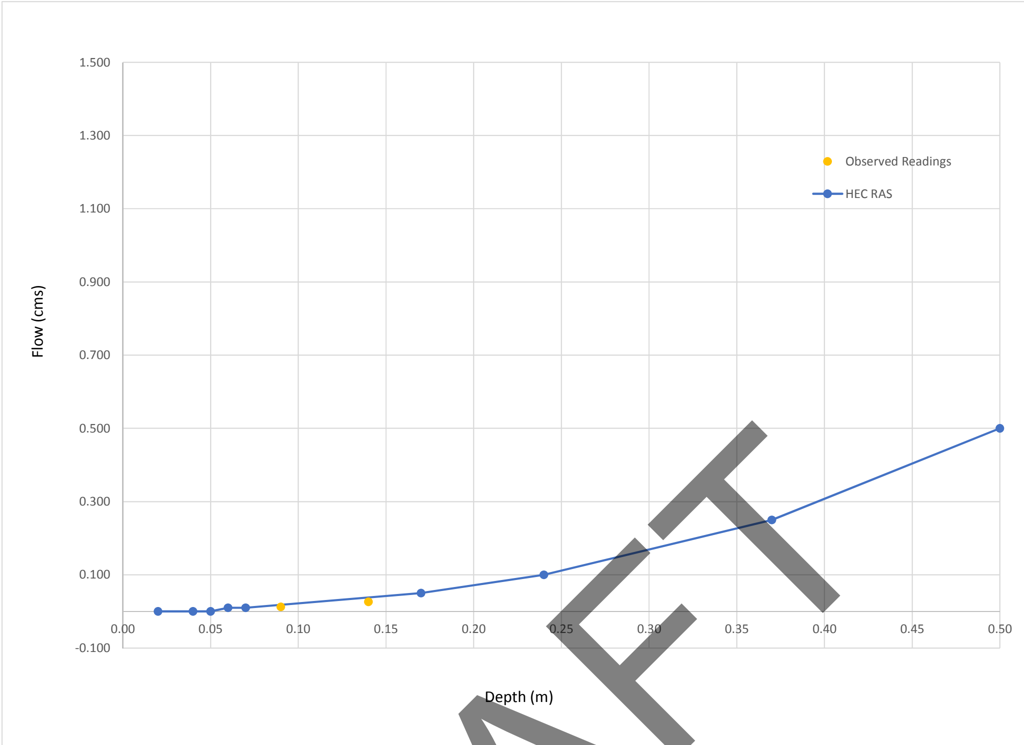

Figure 4.4.2: Rating Curve for Fifth Line South Monitoring Station

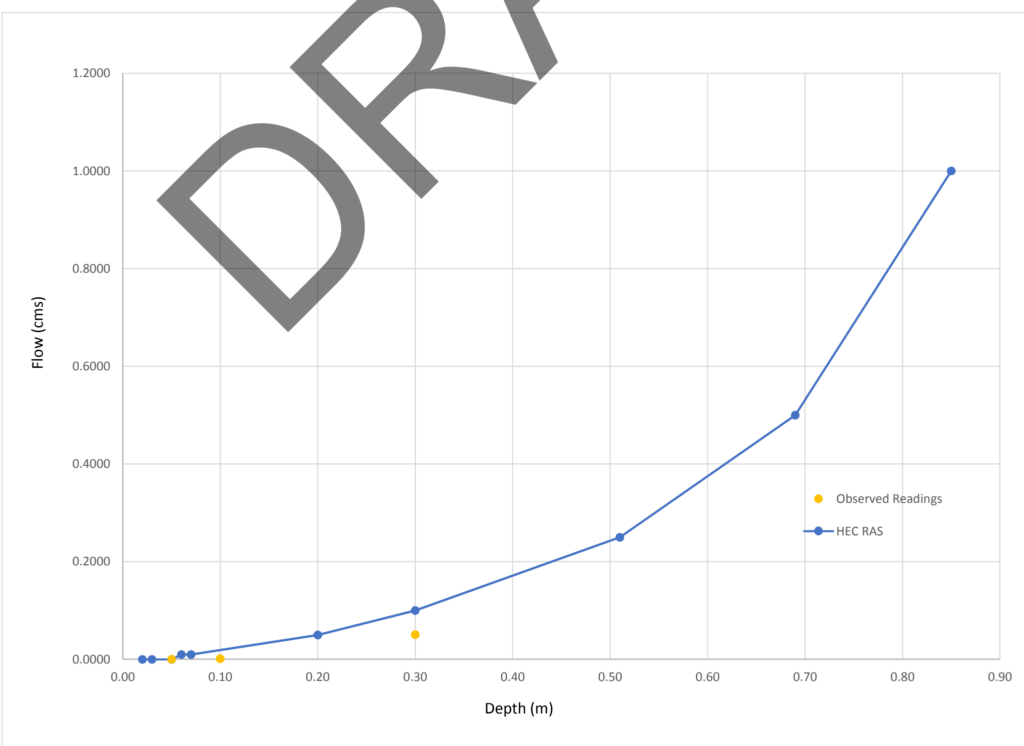

Figure 4.4.3: Rating Curve for Trafalgar South Monitoring Station

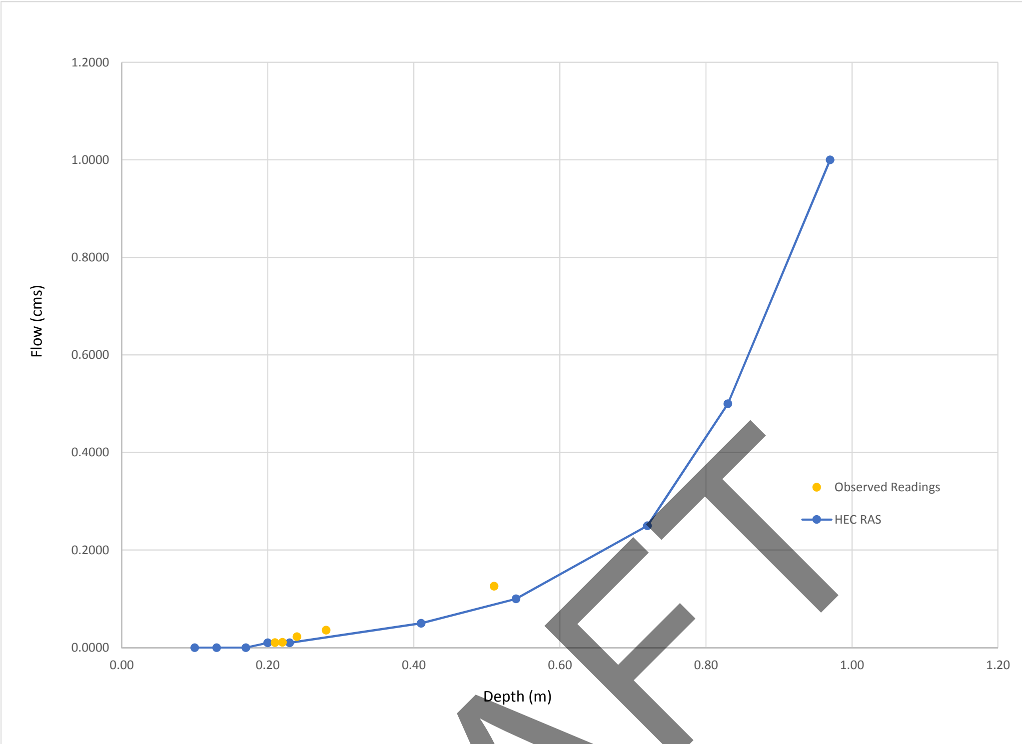

Figure 4.4.4: Rating Curve for Trafalgar North Monitoring Station

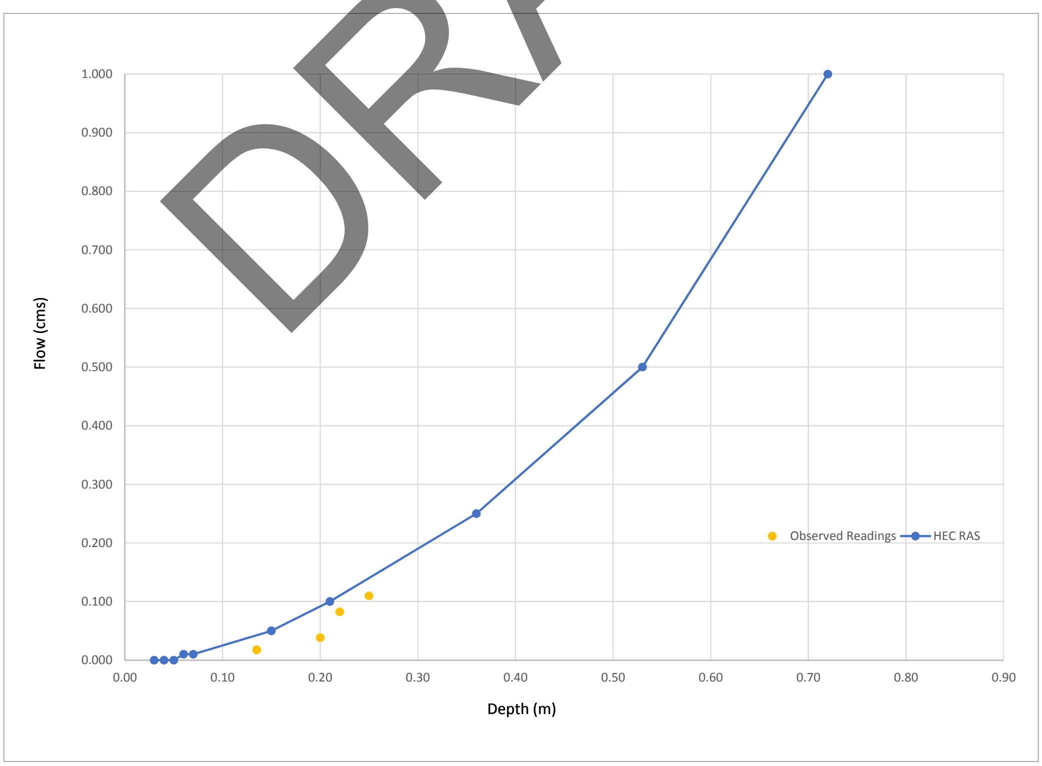

Figure 4.4.5: Rating Curve for Sixth Line Monitoring Station

Table 4.4.1 Summary of Field Measurement Events at Temporary Flow Monitoring Stations

Date	Temporary Flow Monitoring Station					
	Sixth Line	Trafalgar North	Trafalgar South	Fifth Line South	Fifth Line North[1.]	Thompson[1.]
June 6, 2016		✓	✓	✓		
July 25, 2016	✓					
August 17, 2016	✓	✓				
October 2, 2016	✓	✓				
November 3, 2016	✓	✓	✓	✓		
January 25, 2017		✓				

NOTE: 1. Velocity measurements were attempted during all six (6) events; no velocity measurements were obtained due to absence of flow at the time of measurement.

The information in Table 4.4.1 indicates that velocity measurements were obtained for rating curve development at four (4) of the six (6) temporary monitoring stations, however no measurements were obtained at two (2) of the temporary flow monitoring stations due to the absence of flow at the two stations during the site visits. The information also indicates that limited information was collected at the Trafalgar South and the Fifth Line South stations; this is attributable in part to the restriction on access at these locations, which prohibited access after 6 pm.

The information in Figures 4.4.2 to 4.4.5 indicate that the rating curves generated using HEC-RAS correspond to the measured flow data for the lower flows, however the rating curves tend to separate from the observed data for the higher flow conditions.

The recorded water levels have been compared to the rainfall data in order to identify coincident storm events between the rainfall dataset and the temporary streamflow responses, and to thereby screen the rainfall and flow data to determine the number of potential events for use in model calibration. The findings of this assessment are presented in Table 4.4.2.

Table 4.4.2 Summary of Observed Storm Responses at Rainfall Gauge and Temporary Flow Gauges

Event Date	Total Rainfall (mm)	Duration (hours)	Peak Intensity (mm/hr)	Flow Response Recorded At Gauge					
				Sixth Line	Trafalgar North	Trafalgar South	Fifth Line North	Fifth Line South	Thompson
May 13, 2016	23.8	3.45	40.8	N/A	Yes	Yes	Yes	Yes	Yes
May 26, 2016	14.0	2	25.6	N/A	Yes	Yes	Yes	Yes	Yes
July 14, 2016	30.2	3.5	21.6	N/A	Yes	No	No	No	No
August 16, 2016	14.6	10	9.6	Yes	No	No	No	No	No
August 25, 2016	23.8	2	25.6	No	Yes	No	No	No	No
September 29, 2016	19.0	14.5	6.4	No	No	No	No	No	No
November 3, 2016	19.8	5	14.4	Yes	Yes	Yes	Yes	Yes	Yes

The information in Table 4.4.2 indicates that a total of seven (7) storm events have been identified over the course of the monitoring program, for which only three (3) events generated runoff at all of the monitoring stations. For the remaining four (4) events, limited runoff responses were recorded at the flow monitoring stations (i.e. no runoff responses recorded at the stations, or one station recorded runoff response). The lack of response at the flow monitoring stations is considered attributable to the dry conditions which prevailed over the course of 2016. Due to the atypically dry conditions, as well as the limited number of events available, the information collected from the monitoring program is considered of limited utility for the purpose of calibrating and validating the HSP-F hydrologic model. Recognizing the legacy of development, calibration, and validation of the HSP-F hydrologic model over the past twenty (20) years, it is anticipated that the information collected by one year of monitoring would be of limited utility to inform model parametrization. On that basis, it is recommended that the surface water monitoring program be conducted solely to inform the baseline condition for future holistic monitoring programs, and that the hydrologic analyses apply the hydrologic model with the current paramertization.

4.4.3.3 Hydrologic Model Development

Hydrologic analyses for the South Milton SWS have been completed using the HSP-F methodology, which is fully supported and maintained by the USGS. As noted previously, the HSP-F hydrologic model has been applied for the hydrologic analyses within the Sixteen Mile Creek Watershed for nearly 20 years, and has been refined and calibrated over that time for five secondary plans (i.e. Bristol Survey, Sherwood Survey, Highway 401 Business Park, Boyne Survey, and Derry Green Secondary Play Area) since the development of the hydrologic model. Furthermore, the HSP-F hydrologic model has been updated to incorporate approved stormwater management plans and designs prepared in support of Tertiary Planning Studies and detailed designs within each of the Secondary Planning Areas as well as other areas in the Town of Milton. Given the legacy of continued use within the Sixteen Mile Creek Watershed, the HSP-F hydrologic model represents the currently approved hydrologic model for the Watershed and has been applied for use in this study.

Subcatchment Discretization

The HSP-F hydrologic model has been refined within the limits of the South Milton SWS based upon the watercourse information and LiDAR mapping provided for use in this study. The refinements have been completed to generate simulated peak flows at key locations of interest (i.e. reach outlets, reach confluences, roadway crossings) at the limits of and within the South Milton SWS study area. The subcatchment boundary plan is presented in Figure 4.4.6, and the model schematic is presented in Figure 4.4.7. The refinements to the HSP-F model have resulted in the following:

- Number of subcatchments increase from 202 in the original model to 306 in the refined model
- Average catchment size decreased from 192 ha to 125 ha
- Number of channel rating elements increased from 82 to 113

Model Parameterization

A tabular summary of the subcatchment parameters within the HSP-F hydrologic model is summarized in Table 4.4.3.

Table 4.4.3 HSP-F Hydrologic Model Parameters

Study Area/ Subcatchment ID	Area (ha)	Imperviousness (%)	Pervious Parameters								Impervious Parameters		
			INFILT	IRC	UZNS	LZNS	LSUR	SLOPE	NSUR	AGWRC	LSUR	SLOPE	NSUR
Boyne Survey Area													
2402	16.93	3.0	0.50	0.05	7.50	75.00	193.3	0.0060	0.4	0.97	96.6	0.0060	0.2
2507	21.26	3.0	0.50	0.05	7.50	75.00	93.2	0.0089	0.4	0.97	46.6	0.0089	0.2
2528	16.4	3.0	0.50	0.05	7.50	75.00	182.2	0.0062	0.4	0.97	91.1	0.0063	0.2
2509	50.55	3.0	0.50	0.05	7.50	75.00	234.0	0.0071	0.4	0.97	117.0	0.0071	0.2
2510	15.45	3.0	0.50	0.05	7.50	75.00	124.6	0.0097	0.4	0.97	62.3	0.0097	0.2
2511	12.95	3.0	0.50	0.05	7.50	75.00	107.9	0.0089	0.4	0.97	54.0	0.0089	0.2
2512	9.09	3.0	0.50	0.05	7.50	75.00	162.3	0.0071	0.4	0.97	81.2	0.0071	0.2
2513	16.15	3.0	0.50	0.05	7.50	75.00	299.1	0.0097	0.4	0.97	149.5	0.0097	0.2
2514	30.6	3.0	0.50	0.05	7.50	75.00	126.4	0.0069	0.4	0.97	63.2	0.0069	0.2
2575	15.02	3.0	0.50	0.05	7.50	75.00	203.0	0.0031	0.4	0.97	101.5	0.0031	0.2
2516	15.81	3.0	0.50	0.05	7.50	75.00	213.6	0.0112	0.4	0.97	106.8	0.0112	0.2
2101	9.08	3.0	0.46	0.05	7.50	75.00	197.4	0.0094	0.4	0.97	98.7	0.0094	0.2
2102	11.04	3.0	0.46	0.05	7.50	75.00	90.5	0.0110	0.4	0.97	45.2	0.0110	0.2
2009	35.31	3.0	0.46	0.05	7.50	75.00	145.9	0.0062	0.4	0.97	73.0	0.0062	0.2
2010	88.01	3.0	0.46	0.05	7.50	75.00	184.9	0.0069	0.4	0.97	92.4	0.0069	0.2
2012	50.41	40.0	0.50	0.05	7.50	75.00	100.0	0.0083	0.4	0.97	50.0	0.0083	0.2
213	25.09	40.0	0.50	0.05	7.50	75.00	102.9	0.0083	0.4	0.97	51.4	0.0083	0.2
2801	41.53	3.0	0.46	0.05	7.50	75.00	171.6	0.0051	0.4	0.97	85.8	0.0051	0.2
2802	61.29	3.0	0.46	0.05	7.50	75.00	136.2	0.0071	0.4	0.97	68.1	0.0071	0.2
7301	55.57	3.0	0.58	0.05	7.50	75.00	224.1	0.0013	0.4	0.97	112.0	0.0013	0.2
7302	83.24	3.0	0.58	0.05	7.50	75.00	215.6	0.0030	0.4	0.97	107.8	0.0030	0.2
7303	12.56	3.0	0.58	0.05	7.50	75.00	483.1	0.0040	0.4	0.97	241.5	0.0040	0.2
7304	84.72	3.0	0.58	0.05	7.50	75.00	190.8	0.0034	0.4	0.97	95.4	0.0034	0.2
Derry Green Secondary Plan Area													
8101	51.75	3.0	0.50	0.05	7.50	75.00	468.8	0.0020	0.4	0.97	234.4	0.0020	0.2
8102	21.35	3.0	0.50	0.05	7.50	75.00	1034.0	0.0040	0.4	0.97	517.0	0.0040	0.2
8103	28.41	3.0	0.50	0.05	7.50	75.00	263.9	0.0060	0.4	0.97	132.0	0.0060	0.2
8104	20.28	3.0	0.50	0.05	7.50	75.00	287.7	0.0060	0.4	0.97	143.9	0.0060	0.2
8105	6.12	2.9	0.50	0.05	7.50	75.00	494.0	0.0060	0.4	0.97	245.0	0.0060	0.2
8106	10.20	3.0	0.50	0.05	7.50	75.00	402.7	0.0040	0.4	0.97	201.4	0.0040	0.2
8107	10.02	3.0	0.50	0.05	7.50	75.00	478.9	0.0070	0.4	0.97	239.4	0.0070	0.2
8108	15.01	3.0	0.50	0.05	7.50	75.00	470.0	0.0040	0.4	0.97	235.0	0.0040	0.2
8109	21.40	3.0	0.50	0.05	7.50	75.00	732.9	0.0082	0.4	0.97	366.5	0.0082	0.2
8110	7.02	3.0	0.50	0.05	7.50	75.00	462.2	0.0079	0.4	0.97	231.1	0.0079	0.2
8111	10.85	3.0	0.50	0.05	7.50	75.00	577.2	0.0043	0.4	0.97	288.6	0.0043	0.2
8112	0.80	2.5	0.50	0.05	7.50	75.00	102.6	0.0051	0.4	0.97	51.3	0.0051	0.2
8113	2.60	3.1	0.50	0.05	7.50	75.00	144.5	0.0100	0.4	0.97	72.2	0.0100	0.2
8114	9.40	3.0	0.50	0.05	7.50	75.00	258.3	0.0044	0.4	0.97	129.1	0.0044	0.2
8115	14.45	3.0	0.50	0.05	7.50	75.00	752.6	0.0104	0.4	0.97	376.3	0.0104	0.2
8116	2.10	2.9	0.50	0.05	7.50	75.00	291.7	0.0083	0.4	0.97	145.8	0.0083	0.2
8117	5.20	3.1	0.50	0.05	7.50	75.00	85.3	0.0091	0.4	0.97	42.6	0.0091	0.2
8118	5.23	3.1	0.50	0.05	7.50	75.00	373.2	0.0057	0.4	0.97	186.6	0.0057	0.2
8119	4.72	3.0	0.50	0.05	7.50	75.00	381.1	0.0097	0.4	0.97	190.5	0.0097	0.2
8120	3.02	3.0	0.50	0.05	7.50	75.00	210.1	0.0083	0.4	0.97	105.0	0.0083	0.2
8121	10.28	3.0	0.50	0.05	7.50	75.00	282.3	0.0066	0.4	0.97	141.2	0.0066	0.2
8122	0.81	43.2	0.50	0.05	7.50	75.00	87.5	0.0200	0.4	0.97	43.8	0.0200	0.2
8123	8.15	2.9	0.50	0.05	7.50	75.00	295.3	0.0080	0.4	0.97	147.7	0.0080	0.2
8124	8.65	3.0	0.50	0.05	7.50	75.00	1201.4	0.0083	0.4	0.97	600.7	0.0083	0.2
8125	11.85	3.0	0.50	0.05	7.50	75.00	265.7	0.0022	0.4	0.97	132.9	0.0022	0.2
8126	23.85	3.0	0.50	0.05	7.50	75.00	890.0	0.0060	0.4	0.97	445.0	0.0060	0.2
8127	15.40	3.0	0.50	0.05	7.50	75.00	1375.0	0.0018	0.4	0.97	687.5	0.0018	0.2
8128	33.62	3.0	0.50	0.05	7.50	75.00	2711.3	0.0032	0.4	0.97	1355.7	0.0032	0.2
8129	20.77	3.0	0.50	0.05	7.50	75.00	1731.3	0.0183	0.4	0.97	865.6	0.0183	0.2
8130	12.42	3.0	0.50	0.05	7.50	75.00	310.7	0.0040	0.4	0.97	155.3	0.0040	0.2
8131	12.90	3.0	0.50	0.05	7.50	75.00	285.4	0.0035	0.4	0.97	142.7	0.0035	0.2
8132	7.25	3.0	0.50	0.05	7.50	75.00	329.6	0.0064	0.4	0.97	164.8	0.0064	0.2
8133	4.13	15.0	0.50	0.05	7.50	75.00	736.6	0.0071	0.4	0.97	368.3	0.0071	0.2
8134	45.85	20.0	0.50	0.05	7.50	75.00	587.8	0.0026	0.4	0.97	293.9	0.0026	0.2
8135	3.07	2.9	0.50	0.05	7.50	75.00	334.3	0.0109	0.4	0.97	167.1	0.0109	0.2
8136	5.78	15.1	0.50	0.05	7.50	75.00	465.8	0.0129	0.4	0.97	232.9	0.0129	0.2
8137	23.35	3.0	0.50	0.05	7.50	75.00	748.4	0.0032	0.4	0.97	374.2	0.0032	0.2
8138	7.60	3.0	0.50	0.05	7.50	75.00	380.0	0.0060	0.4	0.97	190.0	0.0060	0.2
8139	4.07	2.9	0.50	0.05	7.50	75.00	175.7	0.0034	0.4	0.97	87.8	0.0034	0.2
8140	26.40	3.0	0.50	0.05	7.50	75.00	1157.9	0.0105	0.4	0.97	579.0	0.0105	0.2
8141	4.05	3.0	0.50	0.05	7.50	75.00	326.6	0.0048	0.4	0.97	163.3	0.0048	0.2
8142	22.15	3.0	0.50	0.05	7.50	75.00	954.8	0.0069	0.4	0.97	477.4	0.0069	0.2
8143	12.47	3.0	0.50	0.05	7.50	75.00	95.2	0.0046	0.4	0.97	47.6	0.0046	0.2

Table 4.4.3 HSP-F Hydrologic Model Parameters

Study Area/ Subcatchment ID	Area (ha)	Imperviousness (%)	Pervious Parameters								Impervious Parameters		
			INFILT	IRC	UZNS	LZNS	LSUR	SLOPE	NSUR	AGWRC	LSUR	SLOPE	NSUR
8144	6.75	3.0	0.50	0.05	7.50	75.00	767.1	0.0091	0.4	0.97	383.5	0.0091	0.2
8145	23.37	3.0	0.50	0.05	7.50	75.00	927.6	0.0071	0.4	0.97	463.8	0.0071	0.2
8146	2.07	43.0	0.50	0.05	7.50	75.00	87.5	0.0200	0.4	0.97	43.8	0.0200	0.2
8147	3.75	42.9	0.50	0.05	7.50	75.00	87.5	0.0200	0.4	0.97	43.8	0.0200	0.2
8148	6.80	2.9	0.50	0.05	7.50	75.00	354.2	0.0010	0.4	0.97	177.1	0.0010	0.2
8149	6.90	3.0	0.50	0.05	7.50	75.00	288.1	0.0030	0.4	0.97	144.0	0.0030	0.2
8005	28.80	47.2	0.50	0.05	7.50	75.00	1000.0	0.0025	0.4	0.97	1000.0	0.0025	0.2
8006	73.90	53.0	0.50	0.05	7.50	75.00	1000.0	0.0025	0.4	0.97	1000.0	0.0025	0.2
Primary Study Area													
4201	37.64	3.0	0.50	0.05	7.50	75.00	54.6	0.0155	0.3	0.97	27.3	0.0155	0.1
4202	61.96	3.0	0.50	0.05	7.50	75.00	96.4	0.0191	0.3	0.97	48.2	0.0191	0.1
4203	14.96	3.0	0.50	0.05	7.50	75.00	68.2	0.0154	0.3	0.97	34.1	0.0154	0.1
4204	23.58	3.0	0.50	0.05	7.50	75.00	67.6	0.0105	0.3	0.97	33.8	0.0105	0.1
5501	79.56	3.0	1.30	0.06	7.95	77.50	141.4	0.0176	0.3	0.97	70.7	0.0176	0.1
7210	32.43	3.0	0.58	0.05	7.50	75.00	44.3	0.0094	0.4	0.97	72.2	0.0094	0.2
7211	20.14	3.0	0.58	0.05	7.50	75.00	148.6	0.0086	0.4	0.97	24.3	0.0086	0.2
7212	46.31	3.0	0.58	0.05	7.50	75.00	250.0	0.0080	0.4	0.97	125.0	0.0080	0.2
7213	13.53	3.0	0.58	0.05	7.50	75.00	157.2	0.0072	0.4	0.97	78.6	0.0072	0.2
7201	71.14	3.0	0.58	0.05	7.50	75.00	185.2	0.0117	0.4	0.97	92.6	0.0117	0.2
7202	96.42	3.0	0.58	0.05	7.50	75.00	190.4	0.0058	0.4	0.97	95.2	0.0058	0.2
7203	14.36	3.0	0.58	0.05	7.50	75.00	86.3	0.0062	0.4	0.97	43.2	0.0062	0.2
7204	20.30	3.0	0.58	0.05	7.50	75.00	72.3	0.0076	0.4	0.97	36.2	0.0076	0.2
7205	33.49	3.0	0.58	0.05	7.50	75.00	139.1	0.0053	0.4	0.97	69.5	0.0053	0.2
7206	21.23	3.0	0.58	0.05	7.50	75.00	184.0	0.0039	0.4	0.97	92.0	0.0039	0.2
7207	53.55	3.0	0.58	0.05	7.50	75.00	334.9	0.0061	0.4	0.97	167.4	0.0061	0.2
7208	70.95	3.0	0.58	0.05	7.50	75.00	108.5	0.0128	0.4	0.97	54.3	0.0128	0.2
7209	117.84	3.0	0.58	0.05	7.50	75.00	205.1	0.0091	0.4	0.97	102.5	0.0091	0.2
7510	14.83	3.0	0.60	0.05	7.50	75.00	144.0	0.0087	0.4	0.97	72.0	0.0087	0.2
7511	25.42	3.0	0.60	0.05	7.50	75.00	135.9	0.0071	0.4	0.97	68.0	0.0071	0.2
7512	82.56	3.0	0.60	0.05	7.50	75.00	86.6	0.0080	0.4	0.97	43.3	0.0080	0.2
7513	31.91	3.0	0.60	0.05	7.50	75.00	115.0	0.0052	0.4	0.97	57.5	0.0052	0.2
7502	81.84	3.0	0.60	0.05	7.50	75.00	137.0	0.0137	0.4	0.97	68.5	0.0137	0.2
7503	29.42	3.0	1.30	0.06	7.95	77.50	80.3	0.0103	0.4	0.97	40.2	0.0103	0.2
7504	12.51	3.0	0.60	0.05	7.50	75.00	103.1	0.0184	0.4	0.97	51.6	0.0184	0.2
7505	39.12	3.0	1.30	0.06	7.95	77.50	93.4	0.0103	0.4	0.97	46.7	0.0103	0.2
7506	23.74	3.0	0.60	0.05	7.50	75.00	120.3	0.0086	0.4	0.97	60.2	0.0086	0.2
7507	14.65	3.0	0.60	0.05	7.50	75.00	47.8	0.0073	0.4	0.97	23.9	0.0073	0.2
7508	59.23	3.0	0.60	0.05	7.50	75.00	308.7	0.0072	0.4	0.97	154.4	0.0072	0.2
7509	30.23	3.0	0.60	0.05	7.50	75.00	173.2	0.0054	0.4	0.97	86.6	0.0054	0.2
7601	15.26	3.0	0.76	0.05	7.50	75.00	102.4	0.0116	0.4	0.97	51.2	0.0116	0.2
7602	83.63	3.0	0.76	0.05	7.50	75.00	97.9	0.0156	0.4	0.97	49.0	0.0156	0.2
7603	34.72	3.0	3.70	0.07	9.30	85.00	172.4	0.0143	0.4	0.97	86.2	0.0143	0.2
7604	32.09	3.0	3.70	0.07	9.30	85.00	230.0	0.0078	0.4	0.97	115.0	0.0078	0.2
7605	53.92	3.0	4.50	0.08	9.75	87.50	152.4	0.0092	0.4	0.97	76.2	0.0092	0.2
7606	24.16	3.0	2.90	0.07	8.85	82.50	110.0	0.0055	0.4	0.97	55.0	0.0055	0.2
7607	14.01	3.0	0.76	0.05	7.50	75.00	150.0	0.0058	0.4	0.97	75.0	0.0058	0.2
7701	45.74	3.0	5.30	0.08	10.20	90.00	57.1	0.0110	0.4	0.97	28.6	0.0110	0.2
7801	15.47	3.0	0.62	0.05	7.50	75.00	154.6	0.0182	0.4	0.97	77.3	0.0182	0.2
7802	29.43	3.0	4.50	0.08	9.75	87.50	128.6	0.0135	0.4	0.97	64.3	0.0135	0.2
7803	67.20	3.0	2.50	0.06	8.63	81.25	153.7	0.0189	0.4	0.97	76.8	0.0189	0.2
7804	19.08	3.0	3.70	0.07	9.30	85.00	124.9	0.0070	0.4	0.97	62.4	0.0070	0.2
7805	6.60	3.0	0.50	0.05	7.50	75.00	82.2	0.0052	0.4	0.97	41.1	0.0052	0.2
7806	22.37	3.0	8.50	0.10	12.00	100.00	192.2	0.0047	0.4	0.97	96.1	0.0047	0.2
2601	56.33	3.0	0.30	0.05	7.50	75.00	97.2	0.0170	0.4	0.97	48.6	0.0170	0.2
2701	92.25	3.0	0.46	0.05	7.50	75.00	196.6	0.0190	0.4	0.97	98.3	0.0190	0.2
2702	46.09	3.0	0.46	0.05	7.50	75.00	184.2	0.0181	0.4	0.97	92.1	0.0181	0.2
2703	8.65	3.0	0.46	0.05	7.50	75.00	130.8	0.0237	0.4	0.97	65.4	0.0237	0.2
2704	64.24	3.0	0.46	0.05	7.50	75.00	199.6	0.0117	0.4	0.97	99.8	0.0117	0.2
2705	25.11	3.0	0.46	0.05	7.50	75.00	150.6	0.0127	0.4	0.97	75.3	0.0127	0.2
2706	96.24	3.0	0.46	0.05	7.50	75.00	263.8	0.0099	0.4	0.97	131.9	0.0099	0.2
2707	10.65	3.0	0.46	0.05	7.50	75.00	163.5	0.0097	0.4	0.97	31.7	0.0097	0.2
2708	18.93	3.0	0.46	0.05	7.50	75.00	159.7	0.0099	0.4	0.97	79.9	0.0099	0.2
2709	76.04	3.0	0.46	0.05	7.50	75.00	206.5	0.0106	0.4	0.97	103.2	0.0106	0.2
2109	39.89	3.0	0.50	0.05	7.50	75.00	94.1	0.0165	0.4	0.97	47.0	0.0165	0.2
2905	98.01	3.0	0.50	0.05	7.50	75.00	271.6	0.0167	0.4	0.97	135.8	0.0167	0.2
3110	122.05	3.0	2.90	0.07	8.85	82.50	101.8	0.0076	0.3	0.97	50.9	0.0076	0.1
3101	23.90	3.0	0.50	0.05	7.50	75.00	174.6	0.0184	0.3	0.97	87.3	0.0184	0.1
3102	43.10	3.0	0.50	0.05	7.50	75.00	153.9	0.0147	0.3	0.97	76.9	0.0147	0.1

Table 4.4.3 HSP-F Hydrologic Model Parameters

Study Area/ Subcatchment ID	Area (ha)	Imperviousness (%)	Pervious Parameters								Impervious Parameters		
			INFILT	IRC	UZNS	LZNS	LSUR	SLOPE	NSUR	AGWRC	LSUR	SLOPE	NSUR
3103	135.01	3.0	2.50	0.06	8.63	81.25	285.6	0.0120	0.3	0.97	142.8	0.0120	0.1
3104	18.82	3.0	5.30	0.08	10.20	90.00	220.3	0.0119	0.3	0.97	110.1	0.0119	0.1
3105	84.42	3.0	1.30	0.06	7.95	77.50	172.7	0.0121	0.3	0.97	136.4	0.0121	0.1
3106	186.69	3.0	0.50	0.05	7.50	75.00	208.7	0.0167	0.3	0.97	104.3	0.0167	0.1
3107	27.87	3.0	0.50	0.05	7.50	75.00	115.6	0.0088	0.3	0.97	57.8	0.0088	0.1
3108	96.81	3.0	0.50	0.05	7.50	75.00	393.2	0.0079	0.3	0.97	196.6	0.0079	0.1
3109	114.24	3.0	0.50	0.05	7.50	75.00	334.7	0.0090	0.3	0.97	167.4	0.0090	0.1
3201	53.29	3.0	0.50	0.05	7.50	75.00	195.2	0.0116	0.3	0.97	97.6	0.0116	0.1
3203	65.93	3.0	4.50	0.08	9.75	87.50	165.0	0.0073	0.3	0.97	82.5	0.0073	0.1
3204	83.81	3.0	0.50	0.05	7.50	75.00	122.0	0.0056	0.3	0.97	61.0	0.0056	0.1
3207	55.72	3.0	0.50	0.05	7.50	75.00	227.2	0.0087	0.3	0.97	113.6	0.0087	0.1
3208	36.83	3.0	0.50	0.05	7.50	75.00	177.8	0.0044	0.3	0.97	88.9	0.0044	0.1
3210	49.53	3.0	0.50	0.05	7.50	75.00	276.3	0.0145	0.3	0.97	138.1	0.0145	0.1
3212	59.88	3.0	0.50	0.05	7.50	75.00	134.6	0.0075	0.3	0.97	67.3	0.0075	0.1
Supplemental Study Area													
2901	140.43	3.0	0.50	0.05	7.50	75.00	133.0	0.0234	0.4	0.97	66.5	0.0234	0.2
2110	8.30	3.0	0.50	0.05	7.50	75.00	129.1	0.0117	0.4	0.97	64.5	0.0117	0.2
2902	34.66	3.0	0.50	0.05	7.50	75.00	125.7	0.0191	0.4	0.97	62.9	0.0191	0.2
2103	22.80	3.0	0.50	0.05	7.50	75.00	230.0	0.0175	0.4	0.97	115.0	0.0175	0.2
2104	45.73	3.0	0.50	0.05	7.50	75.00	128.0	0.0107	0.4	0.97	64.0	0.0107	0.2
2105	61.99	3.0	0.50	0.05	7.50	75.00	231.9	0.0120	0.4	0.97	115.9	0.0120	0.2
2106	51.77	3.0	0.50	0.05	7.50	75.00	400.0	0.0066	0.4	0.97	200.0	0.0066	0.2
2107	80.44	3.0	0.50	0.05	7.50	75.00	192.5	0.0111	0.4	0.97	96.2	0.0111	0.2
2108	23.90	3.0	0.50	0.05	7.50	75.00	175.0	0.0193	0.4	0.97	87.5	0.0193	0.2
2301	14.92	3.0	0.50	0.05	7.50	75.00	240.1	0.0160	0.4	0.97	120.0	0.0160	0.2
2302	14.21	3.0	0.50	0.05	7.50	75.00	253.5	0.0161	0.4	0.97	126.8	0.0161	0.2
2303	28.15	3.0	0.50	0.05	7.50	75.00	108.5	0.0128	0.4	0.97	54.2	0.0128	0.2
2304	29.64	3.0	0.50	0.05	7.50	75.00	151.1	0.0120	0.4	0.97	75.6	0.0120	0.2
2305	48.69	3.0	0.50	0.05	7.50	75.00	115.1	0.0100	0.4	0.97	57.6	0.0100	0.2
2306	44.43	3.0	0.50	0.05	7.50	75.00	300.0	0.0193	0.4	0.97	150.0	0.0193	0.2
2307	34.59	3.0	0.50	0.05	7.50	75.00	300.0	0.0127	0.4	0.97	150.0	0.0127	0.2
2903	12.73	3.0	0.50	0.05	7.50	75.00	140.0	0.0264	0.4	0.97	70.0	0.0264	0.2
2904	69.72	3.0	0.50	0.05	7.50	75.00	114.5	0.0224	0.4	0.97	57.2	0.0224	0.2
7101	76.77	3.0	0.46	0.05	7.50	75.00	246.5	0.0230	0.4	0.97	123.2	0.0230	0.2
7102	358.15	3.0	0.46	0.05	7.50	75.00	113.2	0.0184	0.4	0.97	56.6	0.0184	0.2
7103	34.69	3.0	0.46	0.05	7.50	75.00	179.9	0.0089	0.4	0.97	90.0	0.0089	0.2
7104	32.39	3.0	0.46	0.05	7.50	75.00	189.6	0.0123	0.4	0.97	94.8	0.0123	0.2
7105	12.28	3.0	0.46	0.05	7.50	75.00	149.2	0.0110	0.4	0.97	74.6	0.0110	0.2
7501	252.10	3.0	0.60	0.05	7.50	75.00	207.9	0.0127	0.4	0.97	104.0	0.0127	0.2
3202	51.38	3.0	2.50	0.06	8.63	81.25	105.1	0.0105	0.3	0.97	52.5	0.0105	0.1
3205	27.86	3.0	0.50	0.05	7.50	75.00	245.9	0.0104	0.3	0.97	123.0	0.0104	0.1
3206	87.40	3.0	0.50	0.05	7.50	75.00	259.7	0.0100	0.3	0.97	129.9	0.0100	0.1
3209	34.42	3.0	1.30	0.06	7.95	77.50	274.0	0.0112	0.3	0.97	137.0	0.0112	0.1
3211	74.70	3.0	0.50	0.05	7.50	75.00	263.8	0.0087	0.3	0.97	181.9	0.0087	0.1

Soils

Soils parameterization have been developed for the refined HSP-F hydrologic model based upon the soil parameterization within the parent HSP-F model. As noted previously, the soils within the South Milton SWS area are primarily low permeability clay loams, similar to the soils within the Derry Green and Boyne Survey Areas. The soil parameterization within the Derry Green and Boyne Survey Areas were calibrated as part of the November 2015 Subwatershed Update Study, based upon locally collected flow and rainfall data, hence are considered representative of the physiological conditions which prevail throughout the study area. The parameterization for the higher permeability materials within portions of the watershed were developed and calibrated as part of the original Subwatershed Study. The soil parameterization for the respective subcatchments have been determined by areally weighting the parameters for the respective soil types within the subcatchments.

Imperviousness

The impervious coverage for the subcatchments within the HSP-F hydrologic model have been determined based upon a review of the background information. The impervious coverages within the areas external to and within the South Milton SWS study area have been established based upon the coverage within the detailed design reports where applicable, and the values within the currently approved hydrologic model where no other information is available. As noted previously, the land use conditions within the South Milton SWS study area are primarily agricultural and open land use conditions, hence a nominal impervious coverage of 5% has been applied to these areas to account for the presence of rural roads, homes, and small structures.

Subcatchment Slope

Subcatchment slope in the HSP-F hydrologic model has been determined based upon the average subcatchment grade. For the subcatchments which include defined riverine systems, the grades associated with the valley walls have been excluded from the calculation, as the slopes associated with these features has been noted to skew the calculated grade for the subcatchment, resulting in unreasonably high values. This parameter has been calculated using a slope grid created using the LiDAR DEM and the Surface Analysis function of ArcGIS 3D Analyst™, which has then been combined with the subcatchment boundary layer.

Overland Roughness

Overland roughness coefficients for the HSP-F model subcatchments have been retained from the parameterization within the parent model.

Overland Flow Length

The overland flow length in the HSP-F hydrologic model represents the average overland distance which runoff travels before reaching a drainage feature. The overland flow length has been calculated in accordance with the HSP-F methodology, using the following relationship:

Drainage Density = Total Length of Drainage Features/Subcatchment Area

Overland Flow Length = 1/(2*Drainage Density)

Hydrologic Analysis and Model Validation

The updated and refined HSP-F hydrologic model has been used to establish simulated peak frequency and Regional Storm peak flows at key locations within the study area. The hydrologic model has been executed for a 42 year continuous simulation using the current meteorological dataset developed for the watershed. Simulated instantaneous peak flows have been extracted from the continuous simulation dataset, and frequency analyses have been completed using the Log Pearson Type III Distribution, which is represents the applicable distribution for the watershed; the applicability of the Log Pearson Type III Distribution has been confirmed based upon the review of the coefficient of skew, as well as visual inspection of the correlation between the best fit trendline and the sample population. In addition the Regional Storm event has been simulated as a discrete storm event, and the simulated peak flows have been obtained from the simulated results; the applicable reduction factors have been applied to the rainfall datasets for the Regional Storm event simulation, in accordance with current Provincial standards. The simulated peak frequency flows and Regional Storm peak flows for the existing land use conditions are summarized in Table 4.4.4.

Table 4.4.4 Simulated Peak Frequency Flows and Regional Storm Event Flows for Existing Land Use Conditions (m^3)

Reference Node	Frequency (Years)							
	1.25	2	5	10	20	50	100	Regional
2.010	24.4	35.1	51.7	64.0	76.8	94.8	109.6	439.0
2.020	3.4	5.0	7.9	10.2	12.7	16.7	20.2	65.6
2.030	2.6	3.8	6.0	7.9	10.0	13.3	16.2	53.8
2.040	0.5	0.8	1.3	1.7	2.2	2.9	3.6	12.4
2.050	0.8	1.2	2.0	2.6	3.3	4.4	5.4	21.4
2.060	18.8	27.5	40.5	49.7	59.1	71.9	82.1	358.0
2.070	18.7	27.3	40.2	49.4	58.7	71.4	81.4	358.0
2.080	0.7	1.0	1.7	2.3	3.1	4.2	5.2	11.7
2.090	0.2	0.4	0.6	0.8	1.1	1.5	1.8	4.0
2.100	16.4	24.1	35.4	43.4	51.4	62.1	70.4	334.0
4.011	52.2	80.4	122.9	153.1	183.2	224.0	255.9	833.0
7.010	32.5	52.4	82.5	103.5	124.4	152.1	173.4	521.0
7.011	31.1	50.6	80.3	101.2	121.8	149.2	170.3	521.0
7.030	1.2	1.7	2.6	3.4	4.2	5.4	6.4	20.5
7.090	10.7	9.2	7.5	6.2	5.0	3.5	2.5	1.9
7.100	1.9	1.6	1.2	0.9	0.7	0.5	0.3	0.2

The simulated peak flows from the updated HSP-F hydrologic model have been compared with the results presented in previous Subwatershed Studies, in order to validate the results generated by the updated HSP-F hydrologic model. The percent difference between the results generated by the updated HSP-F hydrologic model and the results generated in previous studies, at comparable locations, are summarized in Table 4.4.5.

Table 4.4.5 Percent Difference in Simulated Peak Frequency Flows and Regional Storm Event Flows Between Updated HSP-F Hydrologic Model and Previous Studies (%)

Reference Node	Frequency (Years)							
	1.25	2	5	10	20	50	100	Regional
2.010	57	38	29	27	28	30	33	-20
2.020	130	64	45	46	51	65	80	6
2.030	105	49	34	37	45	60	75	4
2.040	19	-4	-12	-12	-7	-1	8	-28
2.050	54	21	18	19	25	38	50	8
2.060	37	29	26	26	27	29	31	-23
2.070	35	28	25	25	26	28	30	-22
2.080	169	96	87	95	115	136	157	8
2.090	335	308	216	220	255	295	319	72
2.100	19	20	22	23	24	26	27	-22
4.011	61	24	2	-5	-10	-13	-15	-20
7.010	63	17	-7	-14	-18	-21	-22	-15
7.011	59	16	-7	-14	-18	-21	-22	-14
7.030	74	17	-4	-6	-6	-3	1	-30
7.090	187	70	17	4	-3	-8	-9	33
7.100	43	11	-20	-26	-23	-22	-21	-33

The information in Table 4.4.5 indicates that the simulated peak flows generated by the updated and refined hydrologic model are generally higher than previously reported results, with Regional Storm event peak flows generally lower than previously reported values. The higher peak flows for the frequency flows are considered primarily attributable to refinements within the HSP-F hydrologic model (i.e. increases in subcatchment parameters). The generally lower peak flows for the Regional Storm event are considered attributable to the separation in the timing of peak flows for the Regional Storm event, resulting from the more refined routing through the study area.

The results also indicate that the greatest relative (i.e. percent) difference in peak flows are associated with locations with relatively smalle drainage areas and hence smaller peak flows. At these locations, the absolute difference in the simulated peak flows tend to be low (i.e. less 2.5 m^3/s +/-), however the relative difference tend to be high due to the lower peak flows representing the basis of comparison. For the locations with higher Regional Storm peak flows, the results from the refined hydrologic model are generally within 20% of the results generated from the parent HSP-F model.

4.4.3.4 Hydraulic Analysis

Hydraulic analytic characterization of the regulated watercourses within the South Milton SWS has been completed using the HEC-RAS hydraulic model. The HEC-RAS tool has been developed based on the U.S. Army Corp of Engineers HEC-2 hydraulic model, and uses energy and momentum equations to determine water surface elevations for given channel geometric cross-sections, crossings and boundary conditions

Previous Hydraulic Modelling

As noted previously, hydraulic models for the reaches of the Sixteen Mile Creek and its tributaries through the study area have been completed using various tools and base information. Hydraulic modelling was initially completed as part of the FDRP using the HEC-2 hydraulic model to establish Regulatory Floodlines for the watershed (ref. Proctor & Redfern, 1986). Subsequent to that time, the HEC-2 hydraulic model has been imported into HEC-RAS, and various local hydraulic models have been developed to evaluate water surface elevations and establish floodlines along specific reaches in support of various infrastructure and channel realignment projects within the watershed. In various locations, HEC-RAS models have been developed by Conservation Halton to establish the Regulatory Floodplain as part of the conformity exercise; the openings of hydraulic structures incorporated into the hydraulic models developed for this purpose were frequently estimated based upon a review of air photos, and thus generally do not reflect as-built or field conditions.

Hydraulic Structure Inventory

Field reconnaissance has been conducted in order to obtain the geometry and dimensions of the hydraulic structures spanning the regulated watercourses within the South Milton SWS. A photographic inventory of the culverts has been obtained, and Total Station Survey completed at the structures in order to establish the structure inverts and dimensions, as well as to obtain cross-sections of the open watercourses upstream and downstream of the structure. The hydraulic structure inventory has been supplemented by information provided by the Town of Milton and the area landowners for various structures in the area. The hydraulic structure location plan is presented in Figure 4.4.8, and the hydraulic structure inventory is presented in Table 4.4.6.

Table 4.4.6 Hydraulic Structure Inventory

Culvert Location		Culvert Type			Culvert Dimensions						Invert		Additional Notes
ID#	Location	Material	Shape	O/C	Rise (m)	Span (m)	Cover (m) US	Cover (m) DS	Skew	Wall Thickness (m)	Upstream (m)	Downstream (m)	
BR1	Britannia Road	CSP	Ellipse	C	1.20	2.20	0.4	0.55	-	-			Rise from sediment – approx. 0.1m of sediment in culvert.
BR2	Britannia Road	Concrete	Bridge	O	4.50	24.40	1.0 centre 1.80 sides		-	-			Top of opening is arched, centre deck = 1m, sides of deck = 1.8m.
BR3	Britannia Road	PVC	Circle	C	0.65 d		0.6	0.75	-	-			Concrete cover, D/S channel running through residential lots.
BR4	Britannia Road	CSP	Circle	C	0.90 d 0.60	 0.90	0.6	1.0	-	-			DS opening filled with 0.3m sediment, available rise = 0.6m.
DER1	Derry Road	Concrete Metal Top	Bridge	O	2.65	40.0	1.20 conc. 1.55 metal		-	-			Bridge deck is concrete, culvert top is metal, total deck width 2.75m.
DER2	Derry Road	Concrete	Bridge	O	3.25	18.0	1.15 deck		-	-			Concrete bridge deck with small metal railing is 1.4m.
DER3	Derry Road	Concrete	Box	O	1.20 1.40	4.0 4.5	0.4	0.50	- 45°	0.30			Culvert changes direction (skew) and widens on D/S extent into pond.
EIG1	Eighth Line	CSP	Circle	C	0.60 d		0.20	0.20	-	-			Ditch channel cross culvert.
EIG2	Eighth Line	Concrete	Box	O	0.90	3.20	0.25	0.20	-	0.20			Rise from sediment, D/S opening rise = 0.8m.
FIF1	Fifth Line	CSP	Ellipse	C	1.20	1.75	0.40	0.40	-	-			Fifth Line under road reconstruction, unsure if culverts will be replaced.
FIF2	Fifth Line	Concrete	Box	O	0.85	7.0	0.20	0.20	45°	0.35			Rise from sediment.
FIF3	Fifth Line	-	-	-	-	-	-	-	-	-			Culvert not found during inspection.
FIF4	Fifth Line	CSP	Ellipse	O	0.90 0.65	1.85 1.85	1.0	1.0	-	-			Rise from sediment, D/S opening filled with 0.25m sediment.
FIF5	Fifth Line	Concrete	Bridge	O	2.50	6.20	0.60 centre 0.90 sides		-	-			Top of opening is arched, centre deck = 0.6m, sides of deck = 0.9m, wing walls on both sides, 1.5m high, metal railing = 1.1m.
FOU1	Fourth Line	CSP	Circle	C	0.40 d		0.40	0.40	-	-			D/S opening slightly damaged.
FOU2	Fourth Line	CSP	Circle	C	0.90 d		0.70	1.10	20°	-			0.5m scour below D/S opening causing pooling.
FOU3	Fourth Line	CSP	Circle	C	0.30 0.20	0.60 0.45	1.30	1.10	-	-			Circle culvert very filled with sediment and vegetation, believe it is 0.60 d, D/S extent damaged.
JS1	James Snow Pkwy	Concrete	Bridge	O	1.85	20.0	2.50 deck		-	-			Deck width includes concrete road barrier – with small metal railing deck = 2.75m.
LB1	Lower Base Line	Concrete	Box	C	0.75	1.80	0.15	0.15	45°	0.30			Rise from sediment, approx. 0.15m of sediment in culvert.
LB2	Lower Base Line	Concrete	Box	C	1.20	1.85	0.25	0.25	45°	0.20			Rise from culvert bottom - minimal sediment in culvert.
LB3	Lower Base Line	Concrete	Box	C	2.15	1.50	N/A	N/A	-	0.20			Long exposure of culvert on D/S side, very deep pool.
LB4	Lower Base Line	CSP	Circle	C	0.60 d		0.60	0.60	-	-			U/S culvert extent slightly damaged.
LB5	Lower Base Line	Concrete	Bridge	O	4.0	26.50	1.65 deck		-	-			Bank treatment under bridge, alters opening dimensions. Concrete bridge deck with metal railing is 2.75m.

Table 4.4.6 Hydraulic Structure Inventory

Culvert Location		Culvert Type			Culvert Dimensions						Invert		Additional Notes
ID#	Location	Material	Shape	O/C	Rise (m)	Span (m)	Cover (m) US	Cover (m) DS	Skew	Wall Thickness (m)	Upstream (m)	Downstream (m)	
LB6	Lower Base Line	CSP	Circle	C	0.90 d		1.0	1.20	45°	-			D/S channel is entrenched with bedrock/shale bed material.
LB7	Lower Base Line	CSP	Circle	C	0.50 d		0.8	0.8	-	-			Channel is fed by golf course pond, small PVC culvert from pond leads to U/S CSP culvert.
LB8	Lower Base Line	Concrete	Box	N/A	1.30	2.50	0.20	0.20	-	0.25			Rise from sediment.
LB9	Lower Base Line	CSP	Circle	C	0.40 d		0.35	0.35	-	-			Primarily a ditch channel.
LB10	Lower Base Line	Concrete	Circle	C	1.40 d		N/A	-	-	-			Concrete inlet structure with wing and headwall, flow is piped under road, multiple grated inlets and cross connections along Lower Base (South of Fifth line), could not find outlet into main branch. Recommend requesting storm sewer layer for details.
LB11	Lower Base Line	Concrete	Bridge	O	3.10	40.0	1.35 deck		-	-			Concrete bridge deck with metal railing is 2.45m. 4 Pillars in-line in channel, concrete box width = 1.50m, pillar diameter = 1.0m.
LB12	Lower Base Line	CSP	Circle	C	1.0 d 0.60	1.0	N/A	N/A	-	-			D/S extent filled with approx. 0.4m of sediment.
RR1	Regional Road 25	Concrete	Arch	O	1.90	6.20	1.10	1.10	45°	0.20			Con Span Canada culvert, rise from sediment.
RR2	Regional Road 25	Concrete	Arch	O	2.0	7.30	N/A	N/A	-	0.30			Con Span Canada culvert, rise from sediment.
SIX1	Sixth Line	Concrete	Bridge	O	4.0	18.35	1.0 centre 1.55 sides		-	-			Top of opening is arched, centre deck = 1.0m, sides of deck = 1.55m, metal railing = 1.20m high.
SIX2	Sixth Line	Concrete	Box	N/A	1.15	1.50	0.10	0.10	45°	0.20			Rise from sediment, unsure if open or closed. D/S extent has 2 PVC culverts, and an inlet grate, piping flow through residential lot.
SIX3	Sixth Line	Concrete	Box	N/A	1.80	2.15	0.10	0.10	45°	0.25			Rise from sediment, unsure if open or closed.
SIX4	Sixth Line	Concrete	Bridge	O	2.65	14.50	1.0 centre 1.55 sides		-	-			Top of opening is arched, centre deck = 1.0m, sides of deck = 1.55m, metal railing = 1.20m high.
SIX5	Sixth Line	Concrete	Bridge	O	3.10	20.30	1.0 centre 1.55 sides		-	-			Top of opening is arched, centre deck = 1.0m, sides of deck = 1.55m, metal railing = 1.20m high.
SIX6	Sixth Line	PVC	Circle	C	0.45 d		0.65	0.65	-	-			Channel might be fed by pond in private residence.
SIX7	Sixth Line	Concrete	Box	O	2.30	4.80	1.0	1.0	-	0.30			Rise from sediment, on LB of D/S extent - sediment build-up of approx. 0.20m.
SIX8	Sixth Line	CSP	Circle	C	0.60 d 0.40	0.60	0.90	1.0	-	-			D/S extent filled with approx. 0.20m of sediment, leads to a second CSP culvert (Rise = 0.30, Span 0.60) – could be filled 0.60m circle, flow is then piped.
SIX9	Sixth Line	Concrete	Box	N/A	1.10 0.95	3.10 3.10	0.30	0.20	-	0.20			Rise from sediment, unsure if open or closed. Approx. 0.15m more sediment at D/S extent.
SIX10	Sixth Line	CSP	Circle	C	0.40 d		0.40	0.50	-	-			Culvert slightly damaged on D/S side, starting to bend on US side due to asphalt cover.
SIX11	Sixth Line	Concrete	Bridge	O	3.50	29.0	4.0 deck		-	-			Concrete bridge deck with small metal railing is 4.25m.

Table 4.4.6 Hydraulic Structure Inventory

Culvert Location		Culvert Type			Culvert Dimensions						Invert		Additional Notes
ID#	Location	Material	Shape	O/C	Rise (m)	Span (m)	Cover (m) US	Cover (m) DS	Skew	Wall Thickness (m)	Upstream (m)	Downstream (m)	
SIX12	Sixth Line	CSP	Circle	C	1.20 d		N/A	N/A	45°	-			D/S extent very scoured around culvert opening, approx. 0.60m drop.
SIX13	Sixth Line	CSP	Circle	C	1.40 d 0.90	 1.40	N/A	N/A	30°	-			D/S extent approx. filled with 0.50m of sediment.
TH1	Thompson Road	CSP	Circle	C	0.60 d		0.05	0.10	30°	-			Ponded channel running through agricultural crop fields.
TRA1	Trafalgar Road	Concrete	Box	C	1.17 0.90	2.40 2.40	0.20	0.50	45°	0.20			U/S and D/S extent have approx. 0.03m and 0.30m of sediment respectively.
TRA2	Trafalgar Road	Concrete	Bridge	O	2.20	14.80	1.75 deck		-	-			Concrete bridge deck with small metal railing is 2.0m.
TRA3	Trafalgar Road	Concrete	Bridge	O	2.75	18.40	1.75 deck		-	-			Concrete bridge deck with small metal railing is 2.0m.
TRA4	Trafalgar Road	Concrete	Box	N/A	1.90	3.60	N/A	N/A	-	0.30			Could be closed box culvert, saw small bottom lip similar to the top, couldn't be sure due to rock and sediment coverage.

NOTES:

- ID# – Chosen by field inspector, includes abbreviation of road crossing and numbering based on NSEW (North-South running roads start 1 at North, West-East running roads start 1 at West)
- Culvert Type – O = Open, C = Closed, N/A = Could not tell from inspection – sediment coverage
- Culvert Dimensions – Rise and Span are of culvert opening (Rise from sediment if applicable), Cover est. from culvert top to road, or deck of bridge, N/A if unable to estimate
- " – " indicates measurement or data is not applicable to the culvert in question
- Dimensions of Culvert are generalized by U/S and D/S conditions to make one measurement – Averaged measurement, unless significant difference between U/S and D/S openings due to sediment deposition

Table 4.4.7

Culvert Location			Culvert Type			Culvert Dimensions						Invert		Additional Notes
Amec Foster Wheeler ID#	Urbantech ID#	Location	Material	Shape	Open /Closed	Rise (m)	Span (m)	Cover (m) US	Cover (m) DS	Skew	Wall Thickness (m)	Upstream (m)	Downstream (m)	
BR1	TESMC9 – BR7	Britannia Road – 160m West of 6th Line	CSP	Ellipse	Closed	1.20	2.20	0.4	0.55	-	-	188.54 (centre line of creek)	188.56 (centre line of creek)	Rise from sediment – approx. 0.1 m of sediment in culvert.
BR2		Britannia Road – 180m West of Trafalgar Rd.	Concrete	Bridge	Open	4.50	24.40	1.0 centre 1.80 sides		-	-	175.75	175.89	Top of opening is arched, centre deck = 1 m, sides of deck = 1.8 m.
BR3	MSMCX-BR9	Britannia Road – 300m East of Trafalgar Rd.	PVC	Circle	Closed	0.65 d		0.6	0.75	-	-	185.02	184.93	Concrete cover, D/S channel running through residential lots.
BR4	MSMCX-BR10	Britannia Road – 500m West of 8th Line	CSP	Circle	Closed	0.90 d 0.60	0.90	0.6	1.0	-	-	185.68	185.67	DS opening filled with 0.3 m sediment, available rise = 0.6 m.
DER1		Derry Road – 130m East of Sixth Line	Concrete Metal Top	Bridge	Open	2.65	40.0	1.20 conc. 1.55 metal		-	-	183.24	182.85	Bridge deck is concrete, culvert top is metal, total deck width 2.75 m.
DER2		Derry Road – 700m West of Trafalgar Rd.	Concrete	Bridge	Open	3.25	18.0	1.15 deck		-	-	186.00	186.04	Concrete bridge deck with small metal railing is 1.4 m.
DER3		Derry Road – 300m West of Trafalgar Rd.	Concrete	Box	Open	1.20 1.40	4.0 4.5	0.4	0.50	- 45°	0.30	188.00	187.66	Culvert changes direction (skew) and widens on D/S extent into pond.
EIG1		Eighth Line – 920m South of Derry Rd.	CSP	Circle	Closed	0.60 d		0.20	0.20	-	-	192.64	192.63	Ditch channel cross culvert.
EIG2		Eighth Line – 1570m North of Britannia Rd.	Concrete	Box	Open	0.90	3.20	0.25	0.20	-	0.20	190.18	190.46	Rise from sediment, D/S opening rise = 0.8 m.
FIF1		Fifth Line – 1140m South of Derry Rd.	CSP	Ellipse	Closed	1.20	1.75	0.40	0.40	-	-	189.02	188.90	Fifth Line under road reconstruction, unsure if culverts will be replaced.
FIF2		Fifth Line – 1190m North of Britannia Rd.	Concrete	Box	Open	0.85	7.0	0.20	0.20	45°	0.35	189.43	189.36	Rise from sediment.
FIF3		Fifth Line – 650m North of Britannia Rd.	-	-	-	-	-	-	-	-	-	N/A	N/A	Culvert not found during inspection.
FIF4		Fifth Line – 1120m South of Britannia Rd.	CSP	Ellipse	Open	0.90 0.65	1.85 1.85	1.0	1.0	-	-	186.68	186.60	Rise from sediment, D/S opening filled with 0.25 m sediment.
FIF5	TESMC9-FL6	Fifth Line – 570 m North of Lower Baseline	Concrete	Bridge	Open	2.50	6.20	0.60 centre 0.90 sides		-	-	178.78	178.67	Top of opening is arched, centre deck = 0.6 m, sides of deck = 0.9 m, wing walls on both sides, 1.5 m high, metal railing = 1.1 m.

Table 4.4.7

Culvert Location			Culvert Type			Culvert Dimensions						Invert		Additional Notes
Amec Foster Wheeler ID#	Urbantech ID#	Location	Material	Shape	Open /Closed	Rise (m)	Span (m)	Cover (m) US	Cover (m) DS	Skew	Wall Thickness (m)	Upstream (m)	Downstream (m)	
FOU1	TESMC4-FL3	Fourth Line – 700m South of Britannia Rd.	CSP	Circle	Closed	0.40 d		0.40	0.40	-	-	N/A	N/A	D/S opening slightly damaged. AMEC-FW crew surveyed crossing that was 1200m South of Britannia Road – no inverts available.
FOU1	TESMC4-FL3	Fourth Line – 700m South of Britannia Rd.	CSP	Circle	Closed	0.45 d		0.45	0.48	-	-	189.48	189.46	RPE survey data – June 16, 2016.
FOU2		Fourth Line – 930m South of Lower Baseline	CSP	Circle	Closed	0.90 d		0.70	1.10	20°	-	180.74	180.23	0.5m scour below D/S opening causing pooling.
FOU3		Fourth Line – Southern part of Fourth Line and HWY 407	CSP	Circle	Closed	0.30 0.20	0.60 0.45	1.30	1.10	-	-	N/A	N/A	Circle culvert very filled with sediment and vegetation, believe it is 0.60 d, D/S extent damaged.
JS1		James Snow Pkwy – 1030m North of Britannia Rd.	Concrete	Bridge	Open	1.85	20.0	2.50 deck		-	-	N/A	N/A	Deck width includes concrete road barrier – with small metal railing deck = 2.75 m.
LB1		Lower Base Line – 60m West of Henderson Rd.	Concrete	Box	Closed	0.75	1.80	0.15	0.15	45°	0.30	178.99	178.99	Rise from sediment, approx. 0.15 m of sediment in culvert.
LB2		Lower Base Line – 140m East of Henderson Rd.	Concrete	Box	Closed	1.20	1.85	0.25	0.25	45°	0.20	178.02	177.94	Rise from culvert bottom - minimal sediment in culvert.
LB3		Lower Base Line – 360m East of RR25	Concrete	Box	Closed	2.15	1.50	N/A	N/A	-	0.20	167.50	167.04	Long exposure of culvert on D/S side, very deep pool.
LB4		Lower Base Line – 610m East of RR25	CSP	Circle	Closed	0.60 d		0.60	0.60	-	-	162.89	162.43	U/S culvert extent slightly damaged.
LB5		Lower Base Line – 1150m East of RR25	Concrete	Bridge	Open	4.0	26.50	1.65 deck		-	-	149.21 (Lowest Elevation)	N/A	Bank treatment under bridge, alters opening dimensions. Concrete bridge deck with metal railing is 2.75m.
LB6		Lower Base Line – 1240m West of 4th Line	CSP	Circle	Closed	0.90 d		1.0	1.20	45°	-	166.87	166.52	D/S channel is entrenched with bedrock/shale bed material.
LB7	TSMC2 LBL W7	Lower Base Line – 350m West of 4th Line	CSP	Circle	Closed	0.50 d		0.8	0.8	-	-	182.58	182.50	Channel is fed by golf course pond, small PVC culvert from pond leads to U/S CSP culvert.
LB8	TESMC4 LBL W8	Lower Base Line – 530m East of 4th Line	Concrete	Box	N/A	1.30	2.50	0.20	0.20	-	0.25	184.19	183.71	Rise from sediment.
LB9	LBLEA Culv 5-1	Lower Base Line – 830m East of 4th Line	CSP	Circle	Closed	0.40 d		0.35	0.35	-	-	184.15	184.08	Primarily a ditch channel.

Table 4.4.7

Culvert Location			Culvert Type			Culvert Dimensions						Invert		Additional Notes
Amec Foster Wheeler ID#	Urbantech ID#	Location	Material	Shape	Open /Closed	Rise (m)	Span (m)	Cover (m) US	Cover (m) DS	Skew	Wall Thickness (m)	Upstream (m)	Downstream (m)	
LB10	TESMC4 LBLW-9	Lower Base Line – At 5th Line	Concrete	Circle	Closed	1.40 d		N/A	-	-	-	181.52	N/A	Concrete inlet structure with wing and headwall, flow is piped under road, multiple grated inlets and cross connections along Lower Base (South of Fifth line), could not find outlet into main branch. Recommend requesting storm sewer layer for details.
LB11		Lower Base Line – On Fifth Line 380m South of Lower Baseline Rd.	Concrete	Bridge	Open	3.10	40.0	1.35 deck		-	-	163.22	163.10	Concrete bridge deck with metal railing is 2.45m. 4 Pillars in-line in channel, concrete box width = 1.50m, pillar diameter = 1.0m.
LB12		Lower Base Line – 450m West of 6th Line	CSP	Circle	Closed	1.0 d 0.60	1.0	N/A	N/A	-	-	182.72	182.22	D/S extent filled with approx. 0.4m of sediment.
RR1		Regional Road 25 – 1230m South of Britannia Rd.	Concrete	Arch	Open	1.90	6.20	1.10	1.10	45°	0.20	N/A	N/A	Con Span Canada culvert, rise from sediment.
RR2		Regional Road 25 – 200m North of Lower Baseline Rd.	Concrete	Arch	Open	2.0	7.30	N/A	N/A	-	0.30	173.41	172.94	Con Span Canada culvert, rise from sediment.
SIX1		Sixth Line – 1260m South of HWY 401	Concrete	Bridge	Open	4.0	18.35	1.0 centre 1.55 sides		-	-	185.70	185.77	Top of opening is arched, centre deck = 1.0m, sides of deck = 1.55m, metal railing = 1.20m high.
SIX2		Sixth Line - 1820m South of HWY 401	Concrete	Box	N/A	1.15	1.50	0.10	0.10	45°	0.20	188.74	188.78	Rise from sediment, unsure if open or closed. D/S extent has 2 PVC culverts, and an inlet grate, piping flow through residential lot.
SIX3		Sixth Line – 640m North of Derry Rd.	Concrete	Box	N/A	1.80	2.15	0.10	0.10	45°	0.25	187.49	187.35	Rise from sediment, unsure if open or closed.
SIX4		Sixth Line – 640m South of Derry Rd.	Concrete	Bridge	Open	2.65	14.50	1.0 centre 1.55 sides		-	-	181.63	181.65	Top of opening is arched, centre deck = 1.0m, sides of deck = 1.55m, metal railing = 1.20m high.
SIX5		Sixth Line - 930m South of Derry Rd.	Concrete	Bridge	Open	3.10	20.30	1.0 centre 1.55 sides		-	-	180.60	180.63	Top of opening is arched, centre deck = 1.0m, sides of deck = 1.55m, metal railing = 1.20m high.
SIX6		Sixth Line -1110m South of Derry Rd.	PVC	Circle	Closed	0.45 d		0.65	0.65	-	-	180.73	180.74	Channel might be fed by pond in private residence.
SIX7		Sixth Line - 1270m South of Derry Rd.	Concrete	Box	Open	2.30	4.80	1.0	1.0	-	0.30	N/A	N/A	Rise from sediment, on LB of D/S extent - sediment build-up of approx. 0.20m.
SIX8			CSP	Circle	Closed	0.60 d		0.90	1.0	-	-	187.67	187.57	

Table 4.4.7

Culvert Location			Culvert Type			Culvert Dimensions						Invert		Additional Notes
Amec Foster Wheeler ID#	Urbantech ID#	Location	Material	Shape	Open /Closed	Rise (m)	Span (m)	Cover (m) US	Cover (m) DS	Skew	Wall Thickness (m)	Upstream (m)	Downstream (m)	
		Sixth Line - 1700m South of Derry Rd.				0.40	0.60							D/S extent filled with approx. 0.20m of sediment, leads to a second CSP culvert (Rise = 0.30, Span 0.60) – could be filled 0.60m circle, flow is then piped.
SIX9	TESMC9- SL8	Sixth Line – 300m South of Britannia Rd.	Concrete	Box	N/A	1.10 0.95	3.10 3.10	0.30	0.20	-	0.20	187.12	187.30	Rise from sediment, unsure if open or closed. Approx. 0.15m more sediment at D/S extent.
SIX10		Sixth Line – 750m South of Britannia Rd.	CSP	Circle	Closed	0.40 d		0.40	0.50	-	-	188.05	187.94	Culvert slightly damaged on D/S side, starting to bend on US side due to asphalt cover.
SIX11		Sixth Line	Concrete	Bridge	Open	3.50	29.0	4.0 deck		-	-	170.70	N/A	Concrete bridge deck with small metal railing is 4.25m.
SIX12		Sixth Line – 1km North of Lower Baseline	CSP	Circle	Closed	1.20 d		N/A	N/A	45°	-	182.06	181.11	D/S extent very scoured around culvert opening, approx. 0.60m drop.
SIX13		Sixth Line – 60m North of HWY 407	CSP	Circle	Closed	1.40 d 0.90	 1.40	N/A	N/A	30°	-	N/A	N/A	D/S extent approx. filled with 0.50m of sediment.
TH1		Thompson Road – 300m South of Britannia Rd.	CSP	Circle	Closed	0.60 d		0.05	0.10	30°	-	187.25	187.11	Ponded channel running through agricultural crop fields.
TRA1		Trafalgar Road – 680m North of Derry Rd.	Concrete	Box	Closed	1.17 0.90	2.40 2.40	0.20	0.50	45°	0.20	193.16	193.28	U/S and D/S extent have approx. 0.03m and 0.30m of sediment respectively.
TRA2	XSMCX TR7	Trafalgar Road – 1.3km North of Britannia Rd.	Concrete	Bridge	Open	2.20	14.80	1.75 deck		-	-	181.40	N/A	Concrete bridge deck with small metal railing is 2.0m.
TRA3	XSMCX TR8	Trafalgar Road – 450m north of Britannia Rd.	Concrete	Bridge	Open	2.75	18.40	1.75 deck		-	-	N/A	178.05	Concrete bridge deck with small metal railing is 2.0m.
TRA4	XSMCX TR9	Trafalgar Road – 550m South of Britannia Rd.	Concrete	Box	N/A	1.90	3.60	N/A	N/A	-	0.30	177.52	177.30	Could be closed box culvert, saw small bottom lip similar to the top, couldn't be sure due to rock and sediment coverage.

Hydraulic Model Development

HEC-RAS hydraulic models have been developed to conduct hydraulic analyses along the regulated watercourses through the South Milton SWS area. The initial cross-section locations and alignments have been established based upon the cross-section locations provided by Conservation Halton for the current HEC-RAS hydraulic models; the alignments and locations have been revised as appropriate in order to correspond to the contours within the LiDAR mapping provided for use in this study, as well as to extend the limits of the model to encompass all regulated watercourses (i.e. watercourses with contributing drainage areas greater than 50 ha) not included within the current hydraulic modelling.

The low flow channel has been incorporated into the model cross-sections based upon the Total Station Survey information at the hydraulic structures. Manning's roughness coefficients have been established at the cross-sections as 0.035 for the main channel. Manning's roughness coefficients have been determined based upon a review of available air photos provided for use in the study; a minimum roughness coefficient of 0.08 has been applied for the overbanks, consistent with the current practice at Conservation Halton. The HEC-RAS hydraulic model has been used to generate regulatory floodplain mapping based upon the Regional Storm peak flows generated by the refined HSP-F hydrologic model. The cross-section location plan is provided on Figure 4.4.9 and the corresponding floodplain mapping is provided on Drawing 4.4.10.

4.4.4 Interpretation / Key Findings

The soils within the South Milton SWS area generally exhibit low infiltration and high runoff potential. Some higher permeability material is localized toward the northeast limit of the study area, although the extents of this material are limited therefore should be assessed as part of th next stages of planning and design.

The currently approved HSP-F hydrologic model for the Sixteen Mile Creek Watershed has been refined within the limits of the South Milton SWS area to generate instantaneous peak flows at hydraulic structure crossings and watercourse confluences. Subcatchment parameterization has initially been established based upon the soil parameterization within the parent subcatchments, and validated based upon the calibrated parameters established for the Boyne Survey and Derry Green Secondary Plan Areas as part of the November 2015 Subwatershed Update Study.

An atypically low amount of precipitation fell over the course of the 2016 monitoring program. This resulted in little to no runoff at the flow monitoring stations, and limited the potential for developing reliable rating curves at the flow monitoring stations. Consequently, the hydrometeorological data which was collected over the course of 2016 is considered inadequate for calibrating the HSP-F hydrologic model. As per the Terms of Reference and Work Plan, the monitoring program is proposed to continue into 2017, hence adequate information may be collected for calibrating the hydrologic model. Alternatively, it is suggested that the hydrologic analyses be completed using the base parameterization within the refined HSP-F hydrologic model, on the basis that the parameterization has been validated as part of the November 2015 Subwatershed Update Study and the January 2000 Subwatershed Planning Study. Discussion with Conservation Halton and the Town of Milton is required to confirm acceptance of this approach.

The watercourses and tributaries which extend through the South Milton SWS include features regulated by Conservation Halton. HEC-RAS hydraulic models have been developed based upon the LiDAR mapping provided for use in this study, and the hydraulic structure inventory conducted as part of the field monitoring program. Manning's roughness coefficients have been established based upon a review of air photos provided for use in this study, and a minimum roughness coefficient of 0.08 has been applied for the overbank areas, in accordance with current practice by Conservation Halton. The floodline mapping through the study area is generally consistent with the current regulatory floodline mapping generated by Conservation Halton. The floodlines for the watercouirses toward the east limit of the study area are noted to be more extensive than the previous floodline mapping for the area, due primarilyi to the limited grades as presented in the LiDAR mapping.

4.5 Fluvial Geomorphology

4.5.1 Importance / Purpose

The primary purpose of the fluvial geomorphology component is the characterization of the form and function of the watercourses within the Primary and Supplemental Study Areas. The role of channel processes needs to be quantified such that guidance can be given to any proposed land use changes, thereby ensuring continued channel dynamics as well as ensuring any potential impact to downstream channels is minimized. This information will provide guidance to channel management and enhancements within the Primary Study Area in relation to future development and infrastructure.

The stream morphology component characterizes the existing and historic form and function of the watercourses within the Primary and Supplemental Study Areas. This includes 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 any potential impact to downstream channels is avoided and/or minimized. To achieve this objective, the assessment includes 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 with-in the Primary and Supplemental Study Areas
- Complete field reconnaissance to confirm existing geomorphic conditions, document evidence of active erosion and confirm desktop results

The Primary and Supplemental Study Areas are located within Sixteen Mile Creek watershed. Subwatersheds 2 (West Branch) and Subwatershed 7 (Lower Middle Branch) form the majority of the overall drainage systems. However, Subwatersheds 3, 4 and 5 (Middle Branch, Middle East Branch and East Branch respectively) contribute to the northern and eastern boarders to the Primary and Supplemental Study Areas.

4.5.2 Background Information

Background Information Review

A background review was undertaken to gather information on the watercourses contained within the Primary and Supplemental Study Areas. Reviewed data included previous reports, historic aerial photos, and mapping resources, including information regarding physiography and surficial geology. This information formed the foundation of the characterization work which then informed the field program, ensuring proper focus on pertinent characteristics.

In addition to the background information provided prior to the initiation of the study, a number of studies were initiated by landowner consultants to support the characterization South Milton Urban Expansion Area. These studies cover the majority of the Primary Study Area with the exception of a few areas where landowners are non-participants of the Milton Phase 4 Landowners Group (MP4LG). Extensive coverage by landowner consultants for the stream morphology component provides baseline characterizations for 'West' and 'Trafalgar' area corridors. The Town's consultant's characterization work was scoped to perform field verification of the consultants' data. Phase 1 characterization by the Amec Foster Wheeler Team was two-fold and consisted of:

a. Desktop review and field verification of landowner reporting,
b. Supplementary characterization to address information gaps.

4.5.3 Methods / Analysis

4.5.3.1 Desktop Assessment

Reach Delineations

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 4.5.3.1 displays large scale mapping of reach breaks for watercourses and headwater drainage features within the Primary and Supplemental Study Areas. Appendix F displays more detailed reach breaks for the Primary and Supplemental Study Areas.

The delineated watercourse reaches have been further identified as being 'unconfined' or 'confined' systems based on their overall valley form. This type of classification will further assist during the delineation of meander belt widths and erosion hazard limits. Unconfined watercourse systems have no discernable valley slope that can be detected from the surrounding landscape either by field investigation aerial photography and/or map interpretation. Typically, these types of systems are found in fairly flat or gently rolling landscapes and can be located within the headwater areas of drainage basins. Confined watercourses are ones in which the physical presence of a valley walls, with heights greater than or equal to 2 m, are visibly discernible. For this type of system the location of the watercourse may be located at the base of a valley slope or in close proximity to it (MNR, 2002).

Due to the overall size of the combined Primary and Supplemental Study Areas, a coded naming convention was developed to identify watercourse and headwater drainage features reaches. The naming convention allows the viewer to identify which primary watercourse the reach is associated with without the need for a visual map. The name will also indicate if the watercourse feature is a tributary and its general location within the subwatershed, from downstream to upstream. For example, the reach name "SMC(1)" stands for "Sixteen Mile Creek (reach 1)". This watercourse segment is the first upstream geomorphic reach identified for Sixteen Mile Creek. Additionally, the reach name "TMSMC(3)2-1" indicates that this watercourse segment is the first reach (x-1) of the second tributary (2-x) to Middle Sixteen Mile Creek (reach 3).

Historical 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 photo 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 photos are also analyzed to determine changes in surrounding land use which may have impacted channel migration. For the Primary and Supplemental Study Areas, historic photos from 1954, 1978 and 2016 were reviewed.

Meander Belt and Erosion Hazard Delineation

The meander belt width defines the area that a watercourse currently occupies or can be expected to occupy in the future. Meander belt delineation is commonly used as a planning tool in order to protect private property and structures from erosion due to fluvial action or geotechnical instability (Parish, 2001). Within a subwatershed study context, studies require the general identification of meander belt widths to facilitate the planning process. Therefore, for the purposes of this subwatershed study, meander belt widths are developed from a geomorphological perspective on a broad scale and should be considered subject to refinement as part of future, more detailed, studies. Future detailed studies would confirm whether the meander belt fully represents the constraining parameters for the watercourse relative to the Regulatory floodplain or ecological considerations. For this study, meander belt widths are only delineated for unconfined stream reaches that have defined bed and banks. For unconfined watercourses, limits of the meander belt are defined by parallel lines drawn tangential to the outside bends of the laterally extreme meanders of the planform for each reach. Due to the broad-scale nature of this study, in lieu of calculating the 100 year migration rate for each reach, a factor of safety was generally calculated as 20% of the meander belt width (10% applied on either side of the meander belt width).

In addition to meander belt delineations for unconfined watercourse reaches, an erosion hazard limit is determined for confined channel systems. For the confined systems within the Primary and Supplemental Study Areas, an erosion hazard limit will be delineated following Provincial Policy Statement (PPS) technical guidelines. Within the confined reaches of the Primary and Supplemental Study Areas, the watercourses typically meander back and forth between valley wall contacts. Following PPS guidelines, the erosion hazard limit is determined by applying a toe erosion allowance plus stable slope allowance. For the purposed of this study, a 5 m toe erosion allowance suitable for soft rock (shales, limestone) slopes was applied along with a 3:1 (horizontal to vertical; H:V) stable slope). The toe erosion allowance was projected horizontally outward from the valley toe, at the extent of the 5 m, the stable slope was then extended until it daylights along the tablelands at the top of the valley. Delineation of the toe erosion allowance and stable slope line would be refined as part of future detailed studies and geotechnical analysis.

Figure 4.5.3.1 and Appendix F display watercourse reach breaks and their associated valley classifications.

4.5.3.2 Field Reconnaissance

Headwater Drainage Feature Assessment

A number of smaller features within the Primary and Supplemental Study Areas are considered as Headwater Drainage Features (HDFs) as defined by the TRCA/CVC protocol (2014). HDFs are, in general, poorly defined in nature and have been modified to facilitate drainage of the adjacent lands. The importance of the headwater channels is well recognised (i.e. water infiltration, attenuation, sediment and biota supply) with respect to the multiple functions they provide to the downstream subwatershed. Headwater systems are considered important sources of food, sediment, water, nutrients, and organic matter for downstream reached. Therefore the quantitative analysis of their formative requirements, basin contributions and the impacts of channel loss through development and land use change has come to the forefront of research and policy direction within Ontario.

The HDFs within the Primary and Supplemental Study Areas 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 flagged as potential HDFs. Following HDF assessment protocol (TRCA/CVC, 2014) a detailed field study was undertaken to field verify potential features. The protocol requires three separate site visits; this is largely to characterize the hydrologic function under different seasonal conditions. The three separate visits also help determine the extent of fish habitat based on the amount of flow present. All features identified during the desktop phase were assessed during the "first visit" which takes place shortly after spring freshet (late March or early April). Recording flow condition and feature type as outlined in the OSAP protocol (Stanfield, 2010) are the main focus of this visit. Based on the results, features may be classified as 'limited function' and receive the management recommendation of 'no management required' (TRCA/CVC, 2014). These features 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 the "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 HDF assessment visits occurred on three separate rounds and were conducted within the Primary and Supplemental Study Areas where property access was granted. Each round falls within the recommended timing window, with the acceptation of Round 2 site visits that extended into June in order to accommodate property access permissions and requirements. Round 1 site visits occurred on March 14th, 15th, 31st and April 1st 2016. Round 2 visits occurred on May 10th, 11th, 12th, as well as on June 1st, 9th and 10th 2016. Round 3 visits occurred on July 12th, 18th and 19th, 2016. Figure 4.5.3.1 displays HDFs identified during the desktop phase as well as features visited. A photographic inventory of HDFs is included in Appendix F.

Rapid Assessments

In order to provide insight into existing geomorphic conditions on a reach basis, field reconnaissance was conducted throughout the summer and fall of 2016. Rapid assessment techniques, Rapid Geomorphic Assessment (RGA) and the Rapid Stream Assessment Technique (RSAT) were applied to determine the dominant geomorphic processes affecting each reach.

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 4.5.1).

Table 4.5.1	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.

Detailed Characterization

Based on the results of the rapid geomorphic assessments, six detailed geomorphic field sites were established as part of this study within the subwatershed study area. In addition to the newly established sites, five previously established monitoring sites, installed as part of the Subwatershed Update Study (SUS; 2013) were re-assessed allowing for additional erosion threshold and monitoring assessments to be carried out. The MP4 Landowners' Group established five geomorphic monitoring sites within the Primary Study Area. These sites under went field verification by the Towns' consultants and the data collected used to establish erosion threshold within the MP4LG lands. Results of the detailed field investigation can not only be used to characterize pre-development flow conditions, but can also be used to establish targets for stormwater management that may be required under future development scenarios.

As part of the detailed field assessment, standard protocols and know field indicators were used to quantify bankfull cross-sectional dimensions throughout a reach, specifically bankfull width and depth. A modified Wolman pebble count was used to characterize the channel bed substrate materials. These measurements were completed for ten to twelve cross sections per site along with a total station survey of the channel profile which provides a measure of the local energy gradient and bed morphology. For each site, one top of bank control cross section was permanently installed in order to monitor future change.

Selection of the newly established detailed sites focuses on selecting an appropriate reach based on existing instability (sensitivity to land use change), representative spatial distribution, and extent of channel alteration. Reaches that are located further downstream, or reaches having a greater drainage area, are more frequently selected as they are more likely to be impacted by land use changes. Channel alteration is also considered; unaltered reaches are preferred as they offer a more accurate depiction of channel processes under existing conditions.

Monitoring

A monitoring program was initiated as part of this study. The purpose of the monitoring program is to provide a baseline inventory of the geomorphic form of watercourses within the Primary and Supplemental Study Areas that can subsequently be re-measured in the future. The intent of continued monitoring is to identify future changes to the form and function of the watercourses as a result of changing surrounding land use and development. At each of the newly established detailed geomorphic field sites surveyed, one top of banks control cross section was permanently installed in order to monitor future changes in morphology. The control cross section typically represents a 'riffle' location within the reach when riffle-pool morphology is observed.

4.5.4 Interpretation / Key Findings

Historical Assessment

In 1954, the Primary and Supplemental Study Areas are dominated by agricultural land use with associated rural residential dwellings. Separating individual fields, more extensive woody riparian buffers are observed. Generally, channel planforms in 1954 closely match existing alignments however some meander migration and widening is evident particularly within unconfined reached of the upper subwatersheds. Additional observations include:

- Weir/dam located on Middle Sixteen Mile Creek within current Royal Ontario Golf Club property extents (MSMC(2)) immediately downstream from the confluence with TMSMS(2)2-1. Backwatering is observed for approximately 800 m upstream,

- Pond located on the current Van Dongen Garden Centre property, corresponding to reach TSMC(7)1-2c but no extensive backwatering is observed. Within the same property, ESMC(7) flows through wooded riparian corridor.
- ESMC(6) and ESMC(5) are highly sinuous, and ESMC(4) displays several additional meander bends then current conditions,
- ESMC(3) is not visible along its current alignment, and is believed to cross Trafalgar Road further south to confluence
- ESMC(2) meanders towards its western valley slope contact, crossing Britannia Road 240 m west of Trafalgar Road. Additional meander scars of the watercourse are visible within the floodplain.
- Confined reaches of major watercourses (ESMC(1b), SMC(3)) have near identical planforms.

Between 1954 and 1978, land use remains relatively unchanged. However, additional rural residential housing is in place and many riparian corridors separating individual fields have been cleared. Numerous greenhouse nursery farms have established along with the Trafalgar Golf and Country Club. Additional observations include:

- Highway 401 corridor has been developed along the norther boarder of the Primary Study Area,
- MESMC(1) has been realigned south of the Highway 401 corridor and no longer crosses Sixth Line,
- ESMC(7) has been impounded to allow for irrigation practices,
- A horse track and stables are present adjacent to MSMC(2) within the Royal Ontario Golf Club Property, and Wyldewood Golf and Country Club has become established with multiple cart bridges across Middle Sixteen Mile Creek,
- ESMC(4) has been straightened downstream from Trafalgar Road and an online pond established,
- Both ESMC(3) and ESMC(2) have been realigned to their current planforms approaching Britannia Road.

Between 1978 and 2016 changes to land use were minimal, with the exception of additional golf clubs establishing within the Primary and Supplemental Study Area. Over the period of historical record, confined reaches and their associated riparian (valley) extents have remained untouched. If development occurs surrounding a permanent watercourse, confined or unconfined, the watercourse corridor is left untouched and flow unimpeded. Some straightening of lesser tributaries is observed through agricultural fields, in some cases bank erosion and meander migration tendencies within these straightened reaches has led to a reintroduction of sinuosity over time. The majority of HDFs are also visible over the course of historical record, however the influence of agricultural practices (i.e., ploughing and cultivation) as well as the likely influence of seasonal variation in the amount of rainfall and snowmelt experienced means that some features are not always visible.

100 Year Erosion Rates

From a geomorphic perspective, the 100 year erosion rate quantifies the lateral and downstream movement of meander features making such analysis a useful indicator of channel planform adjustment and provides a means of quantifying the rate of channel widening or bank erosion over time. Channel erosion rates were assessed along select permanent unconfined watercourses within the Primary Study Area.

The 100 year erosion rate was calculated for both MESMC(1) and ESMC(11). Both of these permanent watercourses are located towards the upstream extent of the Primary Study Area, south of highway 401, west of Sixth Line and east of Trafalgar Road. Due to their close proximity to one another, these reaches have experienced similar changes in surrounding land use, including: the development of the Highway 401 corridor and introduction of a Hydro corridor. Over the 62 year period of historical record assessed (i.e., 1954 to 2016) ESMC(11) has an average erosion rate of 0.08m per year while MESMC(1) has an average erosion rate of 0.04m per year, however both reaches have similar maximum erosion rates of 0.125m per year and 0.11 m per year respectively. The maximum erosion rates were both observed in the time period from 1954 to 1978 when the majority of surrounding land use alteration occurred. Specifically, within the time period the introduction of the Hydro corridor that traverses the two reaches required the clearing of trees and other vegetation from within the associated watercourse floodplains. It is believed that this clearing of vegetation allowed the channel to more easily erode its banks. Additionally, the development of Highway 401 in this time period also required local realignment of watercourses, and higher than normal erosion would be expected as the watercourses regain equilibrium.

Meander Belt and Hazard Corridor Assessment

Figure 4.5.4.2 illustrates meander belt widths delineated on a reach basis using digital mapping for the Primary and Supplemental Study Areas. Table 4.5.2 indicates the meander belt width for each reach within the study area, as well as an additional erosion setback component. Due to the broad-scale nature of this Subwatershed Study, in lieu of calculating the 100-year migration rate for each reach, a factor of safety was generally calculated as 20% of the meander belt width (10% on either side of the meander belt width).

In addition to the meander belt width and factor of safety, a 15 m setback for major valley systems and a 7.5 m setback for minor valley systems are required. The total extend of which is regulated by Conservation Halton. These setbacks include the 6 m erosion access allowance. Sixteen Mile Creek, along with all of their associated tributaries, are considered major valley systems within Conservation Halton's regulatory policy documentation.

Table 4.5.2 Meander Belt Widths for Unconfined Reaches

Reach	Belt Width (m)	10% Factor of Safety Either Side of Channel	Preliminary Belt Width (m)
West Branch			
TSMC(1)3-2	30	6	36
TSMC(1)6-2	40	8	48
TSMC(1)6-3	30	6	36
TSMC(1)7-2	50	10	60
TSMC(1)7-3	30	6	36
TSMC(1)7-3c	20	4	24
TSMC(1)9-2	50	10	60
Lower Middle Branch			
TESMC(1b)11-1b	20	4	24
TESMC(1b)11-2	36	7.2	43.2
TESMC(1b)12-2	40	8	48
TESMC(1b)12-2b	25	5	30
TESMC(1b)12-3	60	12	72
TESMC(1b)16-2	25	5	30
TESMC(1b)18-2	36	7.2	43.2
TESMC(1b)23-1a	20	4	24
TESMC(1b)23-2	32	6.4	38.4
TESMC(1b)23-3	30	6	36
TESMC(2)2-2	38	7.6	45.6
TESMC(2)2-2a	25	5	30
TESMC(2)2-2t	25	5	30
TESMC(2)2-3	25	5	30
TESMC(2)2-4	25	5	30
TESMC(2)2-5	25	5	30
TESMC(2)4-1	30	6	36
TESMC(2)4-2	25	5	30
East Branch			
TESMC(4)1-1c	20	4	24
TESMC(4)1-1d	20	4	24
TESMC(4)1-3	40	8	48
ESMC(5)	40	8	48
ESMC(6)	40	8	48
TESMC(6)3-1	25	5	30
ESMC(7)	n/a	n/a	n/a
TESMC(7)1-3	25	5	30
TESMC(7)1-4	25	5	30
TESMC(7)1-5	20	4	24

Table 4.5.2 Meander Belt Widths for Unconfined Reaches			
Reach	Belt Width (m)	10% Factor of Safety Either Side of Channel	Preliminary Belt Width (m)
TESMC(7)1-6	20	4	24
ESMC(8)	45	9	54
ESMC(9)	65	13	78
ESMC(10)	40	8	48
ESMC(11)	70	14	84
ESMC(12)	85	17	102
Middle Branch			
MSMC(1)	70	14	84
MSMC(2)	70	14	84
MSMC(3)	140	28	168
TMSMC(3)1-1	20	4	24
TMSMC(3)2-1	65	13	78
TMSMC(3)2-2	35	7	42
TMSMC(3)2-3	20	4	24
MSMC(4)	90	18	108
TMSMC(4)1-1	25	5	30
Middle East Branch			
MESMC(1)	120	24	144

Table 4.5.3 Hazard Corridor Delineations for Confined Reaches			
Reach	Valley Floor Width (m)	Average Slope Height (m)	Total Hazard Corridor (m)
West Branch			
SMC(1)	80	20	210
TSMC(1)1-1	20	28	198
TSMC(1)3-1	20	23	168
TSMC(1)4-1	15	10	85
TSMC(1)5-1	15	12	97
TSMC(1)6-1	40	10	110
TSMC(1)6-1a	15	11	91
TSMC(1)6-1b	15	10	85
TSMC(1)6-1d	15	6	61
TSMC(1)7-1	30	12	112
TSMC(1)7-1a	30	10	100
TSMC(1)9-1	40	17	152
TSMC(1)9-1b	20	11	96
TSMC(1)9-1g	15	7	67

Table 4.5.3 Hazard Corridor Delineations for Confined Reaches

Reach	Valley Floor Width (m)	Average Slope Height (m)	Total Hazard Corridor (m)
SMC(2)	70	16	175
SMC(3)	240	12	322
Lower Middle Branch			
ESMC(1a)	150	27	322
TESMC(1a)1-1	15	28	193
TESMC(1a)2-1	15	25	175
TESMC(1a)2-1a	18	17	130
ESMC(1b)	100	20	230
TESMC(1b)3-1	15	6	61
TESMC(1b)4-1	15	8	73
TESMC(1b)5-1	20	6	66
TESMC(1b)6-1	20	12	102
TESMC(1b)7-1	20	12	102
TESMC(1b)10-1	20	21	156
TESMC(1b)11-1	40	18	158
TESMC(1b)11-1a	15	15	115
TESMC(1b)12-1	40	16	146
TESMC(1b)12-1a	15	14	109
TESMC(1b)12-1c	15	12	97
TESMC(1b)13-1	20	6	66
TESMC(1b)14-1	20	8	78
TESMC(1b)15-1	15	6	61
TESMC(1b)16-1	20	8	78
TESMC(1b)17-1	20	10	90
TESMC(1b)18-1	18	16	124
TESMC(1b)19-1	20	8	78
TESMC(1b)20-1	15	8	73
TESMC(1b)21-1	15	12	97
TESMC(1b)22-1	18	12	100
TESMC(1b)23-1	32	10	106
ESMC(2)	120	8	175
TESMC(2)2-1	32	4	67
TESMC(2)3-1	15	8	73
East Branch			
ESMC(3)	30	6	76
TESMC(3)5-1	25	6	71
ESMC(4)	65	4	99
TESMC(4)1-1	50	2	

Rapid Assessments

Due to the extensive scale of the study area, the rapid assessment work concentrated on the Primary Study Area followed by the Supplemental Study Area. As mentioned previously, the Primary and Supplemental Study Areas are located with five subwatersheds of Sixteen Mile Creek (West Branch, Lower Middle Branch, Middle Branch, Middle East Branch and East Branch). Appendix F provides a photographic record of general geomorphic conditions observed within each reach, while Table 4.5.4 provides a summary of the rapid assessment scoring results. Figure 4.5.4.3 provides a visual indication of assessed condition of the watercourses. The following sections provide a more detailed account of the rapid assessment results for the main branches of Sixteen Mile Creek and major tributaries within the Primary and Supplemental Study Areas. Due to the size of the Study Areas and un-obtained permissions to enter, not all watercourse reaches were assessed during the 2016 field season. Attempts will be made during 2017 to fill any gaps, where possible with priority given to watercourses likely to fall outside of the regional NHS.

Assessed Watercourses of the West Branch Subwatershed

SMC(1)

Sixteen Mile Creek, (SMC), is the main watercourse located within the West Branch subwatershed drainage area. Reach SMC(1), is the first geomorphic reach located upstream from the confluence with East Sixteen Mile Creek. Bankfull dimensions along reach SMC(1) ranged from 14.7-18.4 m wide and 0.41-0.5 m deep. The reach is located within a confined valley setting; the valley bottom is approximately 100m wide and is left unmaintained. The shallow bankfull depths of the watercourse allow for inundation of the floodplain during high flow. This was evidenced by the observation of cobble material, characteristic of riffle substrate throughout the reach, deposited on the floodplain. The reach is bedrock controlled; bedrock was observed along the bed of the channel at several 'pool' locations. In addition, the channel meanders along floodplain between valley wall contacts with exposed shale is present. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach is 'widening' as evident through steep bank angles, toe erosion through riffle, woody debris, exposed trees roots and fracture lines along the top of banks. As the reach is bedrock confined, overall degradation of the channel would be limited; therefore the dominance of widening processes throughout the reach is expected. Reach SMC(1) has nine associated tributaries that flow into it.

SMC(2)

Reach SMC(2) is the second upstream reach of Sixteen Mile Creek, extending upstream from the confluence with reach TSMC(1)9-1 until the confining valley widens approximately 1500m downstream from the Britannia Road crossing. This reach is a permanently flowing watercourse with bankfull dimensions along the reach ranging from 10-15m m wide and 0.5-0.8m deep. Similar to reach SMC(1), this reach flows through a confined valley with a floodplain approximately 70m wide. Cobble substrate dominated along the bed with few instances of exposed bedrock within pools. During the field investigation wetted depths ranged from 10m wide to 0.3-0.65m deep. Island formation was also observed. RGA results indicated that the reach was stressed or

Transitional. The prevailing geomorphic processes affecting this reach are 'widening' as indicated by exposed tree roots, steep bank angles and undercutting, woody debris and toe erosion on both sides of the riffle.

SMC(3)

Reach SMC(3) is the third upstream reach of Sixteen Mile Creek and was assessed within the Supplemental Study Area downstream from Britannia Road. This reach is a permanently flowing watercourse with bankfull dimensions 12-18m m wide and 0.5-0.7m deep. Within this reach, while still confined, the width of the valley bottom increases to approximately 200m. Similar to the downstream reaches, the floodplain is fully accessible during flows above the bankfull level. Tree roots are commonly exposed throughout the reach, and outer banks are undercutting. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach are 'widening' as indicated by exposed tree roots, steep bank angles and undercutting, and woody debris.

Assessed Watercourses of the Lower Middle Branch Subwatershed

ESMC(1b)

Reach ESMC(1b) is the second reach of East Sixteen Mile Creek upstream from the confluence with SMC(1) and is located within the Lower Middle Branch subwatershed. Bankfull dimensions along reach ESMC(1b) ranged from 16.4-21.6 m wide and 0.4-0.5 m deep. The watercourse flows in a sinuous planform alternating between valley wall contacts. The valley bottom within this reach is approximately 75m wide. Terracing is observed along local sections of the watercourse. Channel banks are typically well vegetated with grasses and shrubs, however outer channel banks can be undercut with active erosion. Exposed bedrock is observed along the channel bed at 'pool' sections that are adjacent to valley wall contacts. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach are 'widening' and 'degradation' as indicated by leaning trees and exposed tree roots, fracture lines along the top of bank, observations of woody debris, exposed bedrock, suspended armour layer on bank. As the reach is bedrock confined, overall degradation of the channel would be limited; therefore the dominance of widening processes throughout the reach is expected. Reach ESMC(1b) has 23 associated tributaries that flow into it.

ESMC(2)

Reach ESMC(2) is the third upstream reach of East Sixteen Mile Creek upstream from the confluence with SMC(1) and is located within the Lower Middle Branch subwatershed. Bankfull dimensions along reach ESMC(2) ranged from 9-12m wide and 0.8-1.0 m deep. No exposed bedrock was observed within this reach; however valley walls still confine the watercourse. Valley wall contacts still occur, however exposed shale or extensive slope erosion was not observed. Due to the absence of bedrock control, scour pools within the channel were frequently observed at 1m standing water depth. Bank heights throughout the reach range from 0.5-1.5m tall. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach are 'degradation' and 'widening' as indicated by elevated tree roots, deep scour pools and exposed clay bed, increased bank heights, leaning trees and fracture lines along the top of bank.

Assessed Watercourses of the East Branch Subwatershed

ESMC(3)

Reach ESMC(3) is the first upstream reach of East Sixteen Mile Creek within the East Branch subwatershed. Bankfull dimensions along reach ESMC(3) ranged from 4-5m wide and 0.5-0.8m m deep. The presence of a weir structure within the reach (downstream from Trafalgar Road), greatly affects the overall morphology of the channel. The weir structure spans the watercourse and has a 1.5m wide low flow V-Notch at the center of the channel. The drop height of the weir is 0.8m. Downstream from the weir, degradation and widening occurs as the permanent watercourse bisects the valley slope to confluence with Middle Sixteen Mile Creek. Evidence of includes elevated and exposed tree roots, increased bank heights, and lack of depositional features, and organic debris. Upstream from the weir, 'aggradation' dominate with soft bed and embedded riffle features. RGA results indicated that the reach was stressed or Transitional.

ESMC(4)

Reach ESMC(4) is the second upstream reach East Sixteen Mile Creek within the East Branch subwatershed. Bankfull dimensions along reach ESMC(4) ranged from 3-5.5m wide and 0.6-1m deep. The watercourse follows an sinuous planform and is confined between valley walls. Extensive beaver activity within the reach ensures that water is consistently backwatered and near bankfull level. As a result multiple cutoff channels have developed within the floodplain. Banks are well vegetated with long grasses, however banks are often oversaturated and slump easily. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach are 'aggradation' and 'widening' as evidenced by embedded riffle features, siltation in pools, unconsolidated bed and deposition around structures, organic debris, fracture lines along the top of bank and exposed tree roots.

ESMC(6)

Reach ESMC(4) is the fourth upstream reach East Sixteen Mile Creek within the East Branch subwatershed and extends upstream from the Royal Ontario Golf Club property. Bankfull dimensions along reach ESMC(6) ranged from 5-7m wide and 0.8-1m deep. Extensive erosion is observed along the channel banks, undercutting and detached banks are common occurrences along with the formation of soft unconsolidated lateral bars. Surrounding landuse of the reach is a broad, 250m plus, unmaintained meadow corridor. Few trees are present in the vicinity of the watercourse to help mitigate erosion. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach is 'widening' as indicated by organic debris, exposed tree roots, bank erosion, basal scour and fracture lines along the top of bank.

ESMC(7)

Reach ESMC(7) is located upstream from ESMC(6) and is associated with the Van Dongen Garden Centre and Arbor Garden Centre properties. Due to irrigation practices required to support a garden centre, East Sixteen Mile Creek and its tributary, TESMC(7)1-1, have been impounded by a series of dam structures creating extensive pond reservoirs. Two large ponds have formed along ESMC(7) with an additional two ponds having formed on TESMC(7)1-1.

Affects from backwater has additionally impacted upstream reaches of ESMC(8) as well as TESMC(7)1-3. Water levels within the ponds were such that the maximum depth could not be safely measured. It is assumed that any previous channel morphology present historically has been destroyed. Between the two ponds on ESMC(7), multiple low flow pathways and cut-off channels are present with bankfull dimensions of 2.5m wide and 0.5m deep. Tree roots are often exposed and woody debris is frequent. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach is 'widening' and 'aggradation' as indicated by leaning trees and fence posts, exposed tree roots, bank erosion, fracture lines along the top of bank, deposition on the overbank, unconsolidated bed material, and deposition on point bars.

ESMC(8)
Reach ESMC(8) extends upstream from the ponded reach of ESMC(7). The overall planform of the reach is straight and is affected by backwatering from the downstream garden centres as well as beaver activity. Bankfull dimensions along reach ESMC(8) ranged from 9-10m wide and 0.6-0.75m deep. Water is consistently turbid throughout the reach; however aggradation along the bed was limited to the bank toe indicating that most of the fine sediment in suspension is being transported downstream. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach is 'widening' and 'aggradation' as indicated by exposed tree roots, bank erosion, unconsolidated bed material, and embedded riffles.

ESMC(11)
Reach ESMC(11) is located towards the northern extent of the Primary Study Area, between Sixth Line and Trafalgar Road and upstream of the rail line. Bankfull dimensions along reach ESMC(11) ranged from 6-8m wide and 0.8-1.0 deep. The channel planform is sinuous and flows through a broad riparian corridor approximately 70m-170m wide. Tall grasses dominate the vegetation along the reach. Numerous beaver dams were observed throughout the reach, promoting backwatering and scour. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach is 'aggradation' and 'widening' as indicated by siltation, deposition on bar forms deposition around instream structures, embedded riffles, organic debris jams and fracture lines along the top of bank.

ESMC(12)
Reach ESMC(12) is the upstream most reach of East Sixteen Mile Creek within the Primary Study Area, extending east from Trafalgar Road and north of Auburn Road. Bankfull dimensions along reach ESMC(12) ranged from 6-8m wide and 0.8m-1.0m deep. Within this reach extensive woody debris jams promotes bank scour and the development of chute channels. Several 'relic' channel were observed abandoned within the floodplain. Substrate within the reach is comprised of cobble material, however fresh sand deposits are common on point bars. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach are 'aggradation', 'widening' and 'planform adjustment'. These processes were observed as formation of deposition bar features, siltation in pools, deposition on floodplain, falling and leaning trees along with extensive woody debris, formation of islands, cutoff channels and chute channels.

Assessed Watercourses of the Middle Branch Subwatershed

MSMC(1).

Reach MSMC(1) is the first upstream reach of Middle Sixteen Mile Creek within the Middle Branch subwatershed. Bankfull dimensions along reach MSMC(1) ranged from 9-15m wide and 0.8m m deep. This reach is located downstream from the Wyldewood Golf and Country Club, in which part of the downstream reach extents have been impacted by a historical channel realignment to accommodate weir placement upstream from Britannia Road. Riffles substrate is comprised of cobbles and gravels and bank erosion is observed on both sides of the riffle. There is one noticeable valley wall contact within the reach; however it remains unconfined for the most part. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach is ‘aggradation’ as indicated by formation of lateral bars, embedded riffle, deposition along point bars and around instream structures.

MSMC(2)

Reach MSMC(2) is located on the Wyldewood Gold and Country Club property and is the second upstream reach of Middle Sixteen Mile Creek within the Middle Branch subwatershed. Bankfull dimensions along reach MSMC(2) ranged from 6.5-9m wide and 0.5-1.0m deep. This reach is unconfined by valley walls, however the channel shows some indication of degradation thought elevated tree roots and bank heights of over 1.5m tall. Bank erosion is typical in the vicinity of cart bridges. Point bars form with gravel and sand substrate along the inside meander bends. Throughout the reach, the flow is generally slow moving and turbid. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach is ‘widening’ as indicated by falling and leaning trees, exposed roots, erosion on both banks over riffles, steep bank angles and fracture lines along the top of bank.

MSMC(3)

Reach MSMC(3) is located upstream from the Wyldewood Gold and Country Club property and is the third upstream reach of Middle Sixteen Mile Creek within the Middle Branch subwatershed. Bankfull dimensions along reach MSMC(3) ranged from 6-12m wide and 0.8-1.5m deep. A local portion of the reach, towards the downstream extent, is confined by a valley wall contact to the west; however the remainder of the reach is unconfined. The watercourse is permanently flowing with a sinuous planform through a riparian corridor ranging from 150-250m wide. Thick canopy cover offers shade to the majority of the reach; however there are local sections that remain unshaded. Surrounding Landuses of this reach includes agricultural lands and the Trafalgar Golf and Country Club. Extensive beaver activity is observed throughout the reach. Beaver dams impound flow and promote bank scour and erosion. This reach has one major tributary, TMSMC(3)2-1 and associated upstream reaches. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach is ‘aggradation’ as indicated by as indicated by formation of lateral bars, embedded riffle, deposition along point bars and around instream structures.

MSMC(4)

Reach MSMC(4) is the fourth upstream reach of Middle Sixteen Mile Creek. The permanent watercourse flows through an unconfined sinuous planform. Lack of riparian vegetation allows for extensive bank erosion, particularly along outer meander bends. Bankfull dimensions along reach MSMC(3) ranged from 6-10m wide and 0.6-1.0m deep. Water extraction was taking place to accommodate irrigation practices for a local garden nursery, no impoundment of flow was observed and the loss of water did not appear to affect the downstream channel. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach is 'widening' as indicated by fracture lines along the top of bank, slumping and detached banks, under cut banks, leaning trees and exposed roots.

Assessed Watercourses of the Middle East Branch Subwatershed

MESMC(1)

Reach MESMC(1) is the first upstream reach of the Middle East Branch Subwatershed. This reach follows a sinuous planform through a 140m forested riparian corridor. Cobble and gravel substrate dominates the bed substrate, fine sands and clays are introduced through bank erosion where slumping, undercutting and exposed roots are observed. Bankfull dimensions along reach MESMC(1) ranged from 8-9m wide and 1.0-1.2m deep. Bank heights frequently exceed 1.5m tall indicating a moderate entrenchment. RGA results indicated that the reach was stressed or Transitional. The prevailing geomorphic processes affecting this reach is 'widening' as indicated by slumping and detached banks, under cut banks, falling and leaning trees and exposed roots and basal scour on the inside of meander bends.

Table 4.5.4 Rapid Assessment Results for the Study Area

Reach	RSAT Score	RSAT Condition	RGA Score	RGA Condition
West Branch				
SMC(1)	33	Moderate	0.36	Transitional
TSMC(1)3-1	--	Not Assessed	--	Not Assessed
TSMC(1)3-2	30	Moderate	0.06	In Regime
TSMC(1)4-1	--	Not Assessed	--	Not Assessed
TSMC(1)5-1	--	Not Assessed	--	Not Assessed
TSMC(1)6-1	--	Not Assessed	--	Not Assessed
TSMC(1)6-2	--	Not Assessed	--	Not Assessed
TSMC(1)6-3	--	Not Assessed	--	Not Assessed
TSMC(1)7-1	--	Not Assessed	--	Not Assessed
TSMC(1)7-2	--	Not Assessed	--	Not Assessed
TSMC(1)7-3	--	Not Assessed	--	Not Assessed
TSMC(1)8-1	--	Not Assessed	--	Not Assessed
TSMC(1)9-1	28	Moderate	0.39	Transitional
TSMC(1)9-1b	24	Moderate	0.29	Transitional
TSMC(1)9-1g	25	Moderate	0.06	In Regime
TSMC(1)9-2	27	Moderate	0.20	In Regime
SMC(2)	32	Moderate	0.25	Transitional
SMC(3)	32	Moderate	0.25	Transitional

Table 4.5.4 Rapid Assessment Results for the Study Area

Reach	RSAT Score	RSAT Condition	RGA Score	RGA Condition
Lower Middle Branch				
ESMC(1a)	--	Not Assessed	--	Not Assessed
TESMC(1a)1-1	--	Not Assessed	--	Not Assessed
TESMC(1a)2-1	--	Not Assessed	--	Not Assessed
TESMC(1a)2-1a	--	Not Assessed	--	Not Assessed
ESMC(1b)	29	Moderate	0.32	Transitional
TESMC(1b)10-1	--	Not Assessed	--	Not Assessed
TESMC(1b)11-1	27	Moderate	0.26	Transitional
TESMC(1b)11-1a	29	Moderate	0.21	Transitional
TESMC(1b)11-1b	--	Not Assessed	--	Not Assessed
TESMC(1b)11-2	19	Low	0.15	In Regime
TESMC(1b)12-1	27	Moderate	0.32	Transitional
TESMC(1b)12-1a	29	Moderate	0.39	Transitional
TESMC(1b)12-1c	29	Moderate	0.39	Transitional
TESMC(1b)12-2	27	Moerate	0.14	In Regime
TESMC(1b)12-2b	20	Low	0.13	In Regime
TESMC(1b)12-3	27	Moderate	0.15	In Regime
TESMC(1b)13-1	--	Not Assessed	--	Not Assessed
TESMC(1b)14-1	--	Not Assessed	--	Not Assessed
TESMC(1b)15-1	--	Not Assessed	--	Not Assessed
TESMC(1b)16-1	--	Not Assessed	--	Not Assessed
TESMC(1b)16-2	--	Not Assessed	--	Not Assessed
TESMC(1b)17-1	--	Not Assessed	--	Not Assessed
TESMC(1b)18-1	--	Not Assessed	--	Not Assessed
TESMC(1b)18-2	--	Not Assessed	--	Not Assessed
TESMC(1b)19-1	--	Not Assessed	--	Not Assessed
TESMC(1b)20-1	--	Not Assessed	--	Not Assessed
TESMC(1b)21-1	--	Not Assessed	--	Not Assessed
TESMC(1b)22-1	--	Not Assessed	--	Not Assessed
TESMC(1b)23-1	--	Not Assessed	--	Not Assessed
TESMC(1b)23-1a	--	Not Assessed	--	Not Assessed
TESMC(1b)23-2	18	Low	0.16	In Regime
TESMC(1b)23-3	24	Moderate	0.16	In Regime
ESMC(2)	36	High	0.24	Transitional
TESMC(2)2-1	--	Not Assessed	--	Not Assessed
TESMC(2)2-2	29	Moderate	0.24	Transitional
TESMC(2)2-2a	23	Moderate	0.13	In Regime
TESMC(2)2-2t	29	Moderate	0.24	Degradation
TESMC(2)2-3	24	Moderate	0.13	In Regime
TESMC(2)2-4	19	Low	0.1	In Regime

Table 4.5.4 Rapid Assessment Results for the Study Area

Reach	RSAT Score	RSAT Condition	RGA Score	RGA Condition
TESMC(2)2-5	20	Low	0.14	In Regime
TESMC(2)3-1	--	Not Assessed	--	Not Assessed
TESMC(2)4-1	20	Low	0.06	In Regime
TESMC(2)4-2	27	Moderate	0.16	In Regime
East Branch				
ESMC(3)	30	Moderate	0.23	Transitional
TESMC(3)5-1	--	Not Assessed	--	Not Assessed
ESMC(4)	19	Low	0.34	Transitional
TESMC(4)1-1	--	N/A - Pond	--	N/A - Pond
TESMC(4)1-1a	27	Moderate	0.16	In Regime
TESMC(4)1-1c	28	Moderate	0.19	In Regime
TESMC(4)1-1d	25	Moderate	0.17	In Regime
TESMC(4)1-2	30	Moderate	0.17	In Regime
TESMC(4)1-3	--	N/A - Pond	--	N/A - Pond
ESMC(5)	--	Not Assessed	--	Not Assessed
ESMC(6)	23	Moderate	0.28	Transitional
TESMC(6)3-1	15	Low	0.16	In Regime
ESMC(7)	22	Moderate	0.34	Transitional
TESMC(7)1-1	22	Moderate	0.34	Transitional
TESMC(7)1-2	--	N/A - Pond	--	N/A - Pond
TESMC(7)1-3	--	Not Assessed	--	Not Assessed
TESMC(7)1-4	--	Not Assessed	--	Not Assessed
TESMC(7)1-5	22	Moderate	0.34	Transitional
TESMC(7)1-6	23	Moderate	0.13	In Regime
ESMC(8)	26	Moderate	0.24	Transitional
ESMC(9)	--	Not Assessed	--	Not Assessed
ESMC(10)	--	Not Assessed	--	Not Assessed
ESMC(11)	22	Moderate	0.21	Transitional
ESMC(12)	30	Moderate	0.38	Transitional
Middle Branch				
MSMC(1)	32	Moderate	0.28	Transitional
MSMC(2)	24	Moderate	0.33	Transitional
TMSMC(2)1-1	--	Not Assessed	--	Not Assessed
TMSMC(2)2-1	--	Not Assessed	--	Not Assessed
MSMC(3)	32	Moderate	0.31	Transitional
TMSMC(3)1-1	--	Not Assessed	--	Not Assessed
TMSMC(3)2-1	31	Moderate	0.25	Transitional
TMSMC(3)2-2	--	Not Assessed	--	Not Assessed
TMSMC(3)2-3	31	Moderate	0.19	In Regime
MSMC(4)	30	Moderate	0.22	Transitional

Table 4.5.4 Rapid Assessment Results for the Study Area

Reach	RSAT Score	RSAT Condition	RGA Score	RGA Condition
TMSMC(4)1-1	--	Not Assessed	--	Not Assessed
TMSMC(4)1-1a	--	Not Assessed	--	Not Assessed
Middle East Branch				
MESMC(1)	30	Moderate	0.28	Transitional

Detailed Field Investigation

The detailed field assessment was completed at six sites within the Primary and Supplemental Study Areas. Known field indicators, such as changes in vegetation and inflection points in the bank profiles, were 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 were compiled to establish the grain size distribution for the extent of the field site.

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. Existing average bankfull channel dimensions for all survey reaches are provided in Table 4.5.5. Bankfull flow estimates based on the measured cross sections are provided in Table 4.5.6.

SMC(1)

Throughout the surveyed reach of SMC(1), average bankfull width was 16.23m, with a range of 14.7m to 18.4m. Average bankfull depth was 0.45m, ranging from 0.41m to 0.50m. The average maximum depth was 0.68m, with a range of 0.59m to 0.73m. These dimensions produced an average cross-sectional area of 8.11m^2 with a range of 7.92m^2 to 8.33m^2.

For reach SMC(1), the smallest material measured along riffle cross sections consisted predominantly of coarse gravels (D_{10} = 16mm). The dominant bed material consisted of small cobbles (64mm-96mm) resulting in a D_{50} of 94mm. This material was seen in transition areas and riffles where velocities were sufficient to flush away fines. The coarsest material consisted of large cobbles (D_{90} = 180mm) with a maximum stone size recorded at 193mm recorded.

The average bankfull discharge was 23.26m^3/s (at 0.92% slope and n = 0.025), with a range of 17.77m^3/s to 27.42m^3/s. At the average bankfull flow, the channel produces average and maximum velocities of 2.2m/s and 3.6m/s, respectively. Average and maximum shear stresses are 44.4N/m^2 and 60.87N/m^2, respectively.

ESMC(1b)

Within the surveyed reach of ESMC(1b) average bankfull width was 19.51m, with a range of 16.4m to 21.58m. Average bankfull depth was 0.41m, ranging from 0.33m to 0.54m. The average maximum depth was 0.73m, with a range of 0.54m to 0.92m. These dimensions produced an average cross-sectional area of 9.6m^2 with a range of 6.2m^2 to 13.47m^2.

For reach ESMC(1b), the smallest material measured along riffle cross sections consisted predominantly of coarse gravels (D_{10} = 22mm). Similar to reach SMC(1), the dominant bed material consisted of small cobbles (64mm-96mm) resulting in a D_{50} of 94mm. The coarsest material consisted of large cobbles (D_{90} = 188mm) with a maximum stone size recorded at 210mm recorded.

The average bankfull discharge was 21.07m^3/s (at 0.42% slope and n = 0.025), with a range of 16.19m^3/s to 37.08m^3/s. At the average bankfull flow, the channel produces average and maximum velocities of 1.41m/s and 2.72m/s, respectively. Average and maximum shear stresses are 19.49N/m^2 and 29.34N/m^2, respectively.

TESMC(1b)23-2

Within the surveyed reach of TESMC(1b)23-2 average bankfull width was recorded as 3.94m, with a range of 3.5m to 4.8m. Average bankfull depth was 0.09m, ranging from 0.07m to 0.1m. The average maximum depth was 0.2m, with a range of 0.15m to 0.27m. These dimensions produced an average cross-sectional area of 0.34m^2 with a range of 0.23m^2 to 0.43m^2.

For reach TESMC(1b)23-2, bed material consisted primarily of clay soils protected by extensive grassy vegetation growth. The dominant bed material consisted of particles smaller than course sand (0.05mm-2mm) resulting in a D_{50} of <2mm. The coarsest material measured consisted of pebbles (0.5mm-0.6mm) with a maximum stone size recorded at 5mm recorded. Rip-rap was observed acting as scour protection immediately downstream from the Britannia Road crossing; this material is not natural to the watercourse and therefore was not considered.

The average bankfull discharge was 0.06m^3/s (at 0.32% slope and n = 0.035), with a range of 0.04m^3/s to 0.08m^3/s. At the average bankfull flow, the channel produces average and maximum velocities of 0.14m/s and 0.25m/s, respectively. Average and maximum shear stresses are 2.59N/m^2 and 5.95N/m^2, respectively.

ESMC(2)

Within the surveyed reach of ESMC(2) average bankfull width was 9.82m, with a range of 9.18m to 10.45m. Average bankfull depth was 0.57m, ranging from 0.47m to 0.61m. The average maximum depth was 0.93m, with a range of 0.87m to 1.03m. These dimensions produced an average cross-sectional area of 6.47m^2 with a range of 5.24m^2 to 7.71m^2.

For reach ESMC(2), the smallest material measured along riffle cross sections consisted predominantly of medium sand (D_{10} = 3mm). The dominant bed material consisted of coarse gravels (16mm-63mm) resulting in a D_{50} of 34mm. The coarsest material observed was small cobbles (D_{90} = 96mm) with a maximum stone size recorded at 112mm recorded. Upstream from the surveyed reach, north of Britannia Road, a weir structure impounds flow and impedes downstream sediment movement limiting the amount and size of coarse grain material present throughout the reach.

The average bankfull discharge was 9.98m^3/s (at 0.19% slope and n = 0.025), with a range of 9.5m^3/s to 10.45m^3/s. At the average bankfull flow, the channel produces average and maximum velocities of 1.09m/s and 1.76m/s, respectively. Average and maximum shear stresses are 11.77N/m^2 and 16.95N/m^2, respectively. This reach is considered slightly entrenched, with the maximum capacity of the channel (i.e., allowable discharge before the channel banks are overtopped and flow spills onto the surrounding floodplain) exceeding bankfull flow.

ESMC(11)
Reach ESMC(11) is the furthest upstream watercourse surveyed. Throughout the surveyed reach of ESMC(11), average bankfull width was 7.89m, with a range of 6.85m to 8.7m. Average bankfull depth was 0.6m, ranging from 0.5m to 0.73m. The average maximum depth was 1.1m, with a range of 0.95m to 1.27m. These dimensions produced an average cross-sectional area of 4.69m^2 with a range of 3.99m^2 to 5.64m^2.

For reach ESMC(11), the smallest material measured along riffle cross sections consisted predominantly of medium sand (D_{10} = 3mm). The dominant bed material consisted of medium gravels (8mm-12mm) resulting in a D_{50} of 10mm. The coarsest material observed was coarse gravels (D_{90} = 40mm) with a maximum stone size recorded at 56mm recorded. Similar to the impoundment observed within reach ESMC(2), upstream from the surveyed reach a series of beaver dams impounds flow and impedes downstream sediment movement limiting the amount and size of coarse grain material present throughout the reach.

The average bankfull discharge was 8.45m^3/s (at 0.30% slope and n = 0.025), with a range of 6.45m^3/s to 10.34m^3/s. At the average bankfull flow, the channel produces average and maximum velocities of 1.36m/s and 2.38m/s, respectively. Average and maximum shear stresses are 15.35N/m^2 and 31.94N/m^2, respectively.

MSMC(3)
Throughout the surveyed reach of MSMC(3), average bankfull width was 8.0m, with a range of 7.0m to 9.8m. Average bankfull depth was 0.62m, ranging from 0.27m to 0.72m. The average maximum depth was 0.88m, with a range of 0.85m to 0.92m. These dimensions produced an average cross-sectional area of 5.1m^2 with a range of 3.97m^2 to 7.1m^2.

For reach MSMC(3), the smallest material measured along riffle cross sections consisted of material smaller than sand (D_{10} = <2mm). The dominant bed material consisted of medium gravels (8mm-12mm) resulting in a D_{50} of 9mm. The coarsest material observed was small cobbles (D_{90} = 100mm) with a maximum stone size recorded at 133mm recorded. Throughout the MSMC(3) reach, beaver dams impounds flow and impedes downstream sediment movement limiting the amount and size of coarse grain material present throughout the reach.

The average bankfull discharge was 7.84m^3/s (at 0.24% slope and n = 0.025), with a range of 5.57m^3/s to 11.75m^3/s. At the average bankfull flow, the channel produces average and maximum velocities of 1.35m/s and 1.84m/s, respectively. Average and maximum shear stresses are 13.67N/m^2 and 19.79N/m^2, respectively.

Table 4.5.5 Channel Characteristics for the Detailed Geomorphic Field Sites

Parameter	SMC(1)	ESMC(1b)	TESMC(1b)23-2	ESMC(2)	ESMC(11)	MSMC(3)
Bankfull Width (m)	16.23	19.51	3.94	9.82	7.89	8.0
Average Bankfull Depth (m)	0.45	0.41	0.09	0.57	0.6	0.62
Maximum Bankfull Depth (m)	0.68	0.73	0.2	0.93	1.1	0.88
Bankfull Width: Depth	36.68	48.3	46.71	17.47	13.48	12.76
Cross-sectional Area (m^2)	8.11	9.6	0.34	6.47	4.69	5.1
Wetted Perimeter (m)	16.56	19.81	4.07	10.38	9.02	8.62
Hydraulic Radius (m)	0.49	0.48	0.08	0.62	0.52	0.58
Left Bank Angle (°)	14.47	7.5	6.17	23.77	17.91	22.68
Right Bank Angle (°)	19.63	8.56	11.5	33.73	30.75	21.35
D_{50} (mm)	94	94	<2	34	10	9

Table 4.5.6 Bankfull Channel Hydraulics for the Detailed Geomorphic Field Sites						
Parameter	SMC(1)	ESMC(1b)	TESMC(1b)23-2	ESMC(2)	ESMC(11)	MSMC(3)
Bankfull Discharge (m^3/s)	23.26	21.07	0.06	9.98	8.45	7.84
Bankfull Gradient	0.92%	0.42%	0.32%	0.19%	0.3%	0.24%
Average Bankfull Velocity (m/s)	2.2	1.41	0.14	1.09	1.36	1.35
Maximum Bankfull Velocity (m/s)	3.6	2.72	0.25	1.76	2.38	1.84
Average Shear Velocity (m/s)	0.21	0.14	0.05	0.11	0.12	0.12
Stream Power (W/m)	2087.47	859.68	1.8	188.97	248.68	184.53
Stream Power per unit Width (W/m^2)	131.85	42.79	0.45	19.19	31.9	22.41
Average Shear Stress (N/m^2)	44.4	19.49	2.59	11.77	15.35	13.67
Maximum Shear Stress (N/m^2)	60.87	29.34	5.95	16.95	31.94	19.79

Erosion Thresholds

Data from the detailed field assessment are 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 are used (Neill, 1967; Komar, 1987; Fischenich, 2001) to calculate the critical shear stress or velocity for each detailed field site. Once these values are established, an iterative approach using existing channel conditions was applied to evaluate the critical discharge, or erosion threshold. The erosion thresholds are determined by modelling a "dry" channel and increasing water levels in small increments (1 mm) until the average velocities or shear stresses exceed the critical values defined. The discharge under which the critical values are generated within each cross-section defines the critical discharge of the transect. Results of the analysis are then generally averaged across the entire detailed site but individual transects can be isolated or excluded from the modeling process as necessary.

Selection of the appropriate threshold is also based on an understanding of site conditions and the assumptions and ranges of conditions under which the entrainment equations are applicable. 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 SMC(1) and reach ESMC(1b) was Neill (1967). This method relates competent mean velocity to grain size, specific gravity and depth of flow to predict conditions under which bed material will be 'first displaced. The equation:

$$\frac{\rho Vmc^2}{\Upsilon_s' Dg} = 2.50\left(\frac{Dg}{d}\right)^{-0.20}$$

Where ρ is specific weight of water, Vmc is competent mean velocity, Υs is specific weight of sediment, Dg is effective grain size and d is depth of flow. The equation was developed from uniformed particles ranging from 6 to 30 mm in size and correlated to published comparable data on material up to 140 mm. This method cannot be directly compared with Shields (shear stress) equations. The erosion threshold analysis was calculated for each representative cross-section and then averaged to determine the governing threshold for the reach. Results are presented in Table 4.5.7. The calculated discharge in reach SMC(1) is 13.75 m^3/s. This indicates that bedload is transported at 59% of bankfull discharge with a critical velocity of 1.79m/s. The calculated discharge for reach ESMC(1b) is 17.25 m^3/s. This discharge represents 82% of the estimated bankfull discharge and has a critical velocity of 1.36 m/s. Bankfull data estimated from the detailed field survey was compared with HEC-RAS results within the vicinity of the ESMC(1b) survey site in order to provide additional context for the threshold value. Data pulled from the HEC-RAS model indicates that the 2.5 year, 2 year and 1.5 year average discharges are 47, 37.6 and 28.2 m^3/s respectively, with average velocities of 2.0, 1.84 and 1.67 m/s. Further review of water surface elevations for this range of discharge indicated that the channel banks are overtopped and the floodplain becomes inundated at flows above the 1.5year event. The estimated bankfull discharge for reach ESMC(1b) and the associated threshold values closely match flow data to of the 1.5year flow. Whereas bankfull discharge has typically been associated with the 2year flow event, the controlling nature of underlying bedrock throughout the reach is thought to account for the 'undersized' channel capacity.

A different approach was used to determine the threshold values for reach TESMC(1b)23-2. Due to the highly vegetated nature of the reach, the method used for determining an erosion threshold is based on Fischenich (2001). As the variability of channel boundary conditions (i.e, armourstone; cobbles; sands; grassy vegetation) can influence erosion predictions, it would not be adequate to simply predict the discharge required to entrain the median grain size within this reach, as the amount and distribution of grasses along the channel bed act as an armouring barrier to sediment transport. Based on permissible shear stress values for reed plantings provided by Fischenich (2001), an estimate of discharge required to exert the shear stress conditions necessary to initiate erosion on existing boundary conditions was determined at 0.14 m^3/s. In order to calculate this threshold discharge, representative cross sections representing the entire vegetated corridor dimensions where used as the estimated bankfull hydraulics are not considered adequate for portraying the erosion potential of the grass lined channel. The threshold discharge is approximately equal to 2.3-times (233% greater) then average bankfull discharge and has a critical velocity of 0.26 m/s). This discharge is contained within the overall corridor cross section.

The selected method for reach ESMC(2), reach MSMC(3) and reach ESMC(11) was Komar (1987). This method uses 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. 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 calculated discharge in reach ESMC(2) is 7.93 m^3/s. This indicates that bedload is transported at 79% of bankfull discharge with a critical velocity of 1.06 m/s. The calculated discharge for reach MSMC(3) is 5.62 m^3/s. This discharge represents 72% of the estimated bankfull discharge and has a critical velocity of 1.17 m/s. The threshold discharge for reach ESMC(11) is 0.8 m^3/s and represents 9.5% of bankfull discharge. The critical velocity for this discharge is 0.7 m/s. It is assumes that due to a series of beaver dams within the reach upstream from the survey sites at MSMC(3) and ESMC(11), these reaches have a distinct lack of coarse grain material. Average grain size recorded for these reaches is approximately 10 mm (1 cm). This material is considered highly mobile and would be easily transported at flows below bankfull conditions. For this reason, the D_{84} particle size was used for threshold analysis.

Table 4.5.7 presents the erosion thresholds quantified for the study area (Figure 4.5.4.4). In all cases, a comparison between the critical and bankfull discharge indicates that bed material is likely fully mobilized at bankfull flows. This implies that sediment can be entrained below bankfull flows and that any increase in discharge within these systems may lead to increased sediment transport and would likely exacerbate natural rates of channel erosion.

Table 4.5.7 Threshold Characteristics Estimated for the Detailed Geomorphic Field Sites

Parameter	SMC(1)	ESMC(1b)	TESMC(1b)23-2	ESMC(2)	MSMC(3)	ESMC(11)
Bankfull Geometry						
Average Bankfull Width (m)[a]	16.23	19.51	3.94	9.82	8.0	7.89
Average Bankfull Depth (m)[a]	0.45	0.41	0.09	0.57	0.62	0.6
Bankfull Gradient (%)	0.92	0.4	0.32	0.19	0.24	0.3
Bed Material						
D_{50} (mm)	94	94	<2	34	9	10
D_{84} (mm)	170	162	4	78	85	27
Manning's 'n'[b]	0.025	0.025	0.075	0.025	0.025	0.025
Bankfull Hydraulics						
Average Bankfull Discharge (m^3/s)	23.26	21.07	0.06	9.98	7.84	8.45
Average Bankfull Velocity (m/s)	2.2	1.4	0.14	1.09	1.35	1.36
Average Shear Stress (N/m^2)	44.4	19.5	2.59	11.77	13.67	15.35
Thresholds						
Method of Analysis	Neill (1967)	Neill (1967)	Fischenich (2001)	Komar (1987)	Komar (1987)	Komar (1987)
Critical Particle Size	D_{50}	D_{50}	n/a	D_{84}	D_{84}	D_{84}
Critical Discharge (m^3/s)	13.75	17.25	0.14	7.93	5.62	0.8
Percent of Bankfull Discharge (%)	59	82	233	79	72	9.5
Critical Velocity (m/s)	1.79	1.36	0.26	1.06	1.17	0.7
Critical Shear Stress (N/m^2)	41.37	33.46	4.79	14.3	15.31	7.3
Critical Flow Depth (m)	0.37	0.4	0.12	0.53	0.53	0.23

[a] Riffle data only; [b]Based on visual estimate

HDF Management Recommendations

Headwater Drainage Features management recommendations have been developed in accordance with TRCA/CVC (2014) guidelines for features ranging from 'limited' function to 'important' function. Figure 4.5.4.5 illustrates reach specific management recommendations for headwater features within the Primary and Supplemental Study Areas.

Protection

Headwater reaches with the 'protection' designation offer important functions to both the upstream and downstream connected reaches as well as to the surrounding environment. Typically headwater reaches of this nature can exhibit: perennial drainage through seeps or springs, have woody riparian cover, offer permanent fish habitat, offer amphibian breeding habitat and or provide habitat to SAR. Within the Primary and Supplemental Study Areas, protected reaches are designated due to the presence of fish and permanent fish habitat. Under the recommended 'protection' management practices, these reaches must be protected and/or enhanced in-situ. For these reaches, the hydroperiod must be maintained, and use of natural channel design or LID techniques can be used to incorporate additional shallow groundwater and base flow protection as well as restore and enhance existing habitat features although not realignments can be performed. Future SWM systems are to be designed and located to avoid impacts to both sediment and temperatures to the feature.

Conservation

Headwater features with the 'conservation' designation offer valued functions to both the upstream and downstream connected reaches as well as to the surrounding environment. Typically headwater reaches of this nature can exhibit: seasonal fish habitat with woody riparian cover, and/or amphibian breeding habitat. Within the Primary and Supplemental Study Areas, conservation reaches are designated as a result of either: presence of fish within immediately downstream reaches, presence of water within the third site visit or due to the presence of a woody riparian zone. For these reaches, the feature must be maintained within its riparian zone corridor however relocations are allowed through the use of natural channel design principles and techniques such that the overall productivity of the reach is maintained or enhanced. Flows both on-site and external must be maintained or replaced and the feature must connect downstream. If any segment of the reach has been previously removed or will be removed; all lost functions must be restored through lot level controls.

Mitigation

Headwater features with the 'mitigation' designation offer contributing functions to both the upstream and downstream connected reaches as well as to the surrounding environment. Typically headwater reaches of this nature can exhibit: meadow vegetation within riparian corridor and contributing (i.e., sediment and nutrient transport through feature) fish habitat. Within the Primary and Supplemental Study Areas, mitigation reaches are designated as a result of either: having a meadow riparian corridor, flow present in both the first and second site visit, and/or the feature is upstream from a 'conservation' or permanent flowing watercourse. For these reaches functions have to be replicated or enhances through lot level conveyance measures (i.e., vegetated swales, LID). Flows through the feature should initiate at the upstream extent in order to maintain functions and if any segment of the reach has been previously removed or will be removed; all lost functions must be restored.

No Management Required

Headwater features with the 'no management required' designation offer limited functions to both the upstream and downstream connected reaches as well as to the surrounding environment. Typically, features receiving this recommendation have no/or minimal flow, are within cropped land that is annually ploughed and cultivates with no riparian vegetation and do not offer fish or amphibian habitat. Within the Primary and Supplemental Study Areas, these reaches are designated as a result of either: lack of observed flow during the first visit. These features were originally identified during the desktop assessment phase and field verified to confirm that no feature and/or functions associated with a headwater drainage feature are present on the ground. No management recommendations are required.

Sediment Budget

Based on the field assessment program (reach walks and detailed characterization), areas of excessive erosion and deposition have been identified. For select watercourse reaches where excessive erosion was identified an annual migration rate analysis was performed in order to provide an estimate of the amount of sediment being provided. For HDFs located within traditional agricultural field settings, the Revised Universal Soil Loss Equation for Ontario (RUSLE2) was used to estimate a volumetric amount of sediment contributed to subwatersheds as a result of sheet and rill erosion caused by rainfall and overland flow.

Through extensive reach walks of the Primary and Supplemental Study Areas, three typical areas of sediment erosion can be characterized. The first typical areas of sediment erosion identified are along HDF features, particularly features that are seasonally ploughed and where vegetation has not developed. These features provide a source of fine grain (clay, silt, sand) to a receiving watercourse. This fine grain material is generally very mobile, and once in the system will be carried easily downstream as part of the wash load. During HDF assessment site visits, flow within these features is described as turbid indicating that material is being transported downstream. Select HDF features were assessed using the RUSLE2 program to help quantify a potential volume of sediment contributed. Table 4.5.8 outlines results of this analysis. Based on the results of this analysis, it is clear that the overall slope of the fields where the HDFs are located has a direct effect on the volume of sediment contributed to the watershed, with increased slopes contributing the highest volume of sediment and the lesser slopes contributing the least about of sediment.

Table 4.5.8 RUSLE2 Output Results for Select HDFs

	TESMC(1b)11-4a	TSMC(1)9-2b	TESMC(1b)11-3a	TESMC(4)1-5	TESMC(2)2-5a
	HDF	HDF	HDF	HDF	HDF
Length (m)	740	766	1265	1072	1212
Adjusted Length* (m)	427	427	427	427	427
Slope (%)	0.27	0.51	0.32	0.23	0.33
Potential Soil Loss (tonnes/acre/year)	1.7	3.0	1.9	1.5	2.0

*The RUSLE2 program has a maximum slope length of 1400 ft/427m

The second area of sediment erosion identified is along watercourses within the upper reaches of the Primary Study Area that display active meandering processes within the unconfined floodplain, and where there is a lack of floodplain vegetation to help stabilize channel banks from fluvial erosion. Channel reaches such as ESMC(11) has a calculated annual erosion rate of 0.08m per year in which bank erosion contributes both fine and coarse grain (gravel) material into the subwatershed.

The third area of sediment erosion identified where the watercourse makes contact with valley walls within the lower confined reaches of the subwatershed and locations of head-cutting along valley slopes where tributaries flow down slope. These locations would typically contribute coarse grain particles into the system which would comprise the bedload fraction of particle movement. It is understood that valley wall erosion due to fluvial action is less than what is recorded for unconfined reaches that are not bedrock controlled.

In addition to the areas of erosion identified, two typical areas of sediment deposition have been characterized for the Primary and Supplemental Study Areas. The first area of deposition identified can be attributed to local sections of a reach where a physical barrier is present. Several types of physical barriers were identified and include: beaver dam, woody debris jam, weir structure and physical impoundment or under capacity bridge. The latter two barriers are seen in associated with greenhouse operations within the Primary and Supplemental Study Areas in which the watercourses are intentionally impounded to accommodate required irrigation. Depending on the severity of the physical barrier, backwatering can occur within the channel for several hundred meters to kilometers upstream. Backwatering is particularly exacerbated in reaches with low overall channel gradient. Due to these barriers, it is believed that much of the coarse grain material becomes trapped, whereas fine grain particles will still be transported downstream as part of the wash load. As a result of the entrapment of coarse grain material, the channel immediately downstream from the barrier if often sediment starved. Due to lack of coarse grain material, riffles are often poorly formed or non-existent and exposed clay beds are often observed. At these locations where a physical barrier is present, sediment deposition and storage is believed to be long term.

The second area of sediment deposition characterized within the Primary and Supplemental Study Area is located at the base of a confined valley tributary where there is an abrupt gradient change as the tributary enters the valley bottom of a larger watercourse. At this location, sediment transported down slope through the valley tributaries becomes deposited in a ‘fan’ until it can be transported further by appropriate flows of the larger receiving watercourse. This type of deposition is considered to be short term.

4.5.5 Interpretation / Key Findings

Geomorphic Constraint Ranking

The role of the stream corridors is multipurpose from a geomorphic standpoint. They not only provide flow and sediment storage during high flow events, but they also acts as a filter to prevent sediment and particulate inputs from surface runoff from embedding coarse substrates within the streams. The maintenance of riparian vegetation within the stream corridor acts to stabilize banks and also provides inputs of organic materials and debris which aid in creating a diverse morphology. The meander belt width incorporated into the corridor allows the channel to migrate naturally within its floodplain without the loss of property or structural integrity. For the purposes of this study, a constraint ranking system was established based on the findings of the desktop and field assessments discussed in the above sections. The constraint system identifies three categories of high, medium and low constraint which essentially establish the preferred management approach of the stream on a reach basis from a geomorphic perspective. Figure 4.5.4.6 summarizes the geomorphic constraint rankings on a reach basis for the study area. The basis for each category of geomorphic constraint has been provided below:

1. High Geomorphic Classification: These corridors contain a defined channel with a well-developed channel morphology (i.e., riffle-pool) and/or a well-defined valley. These corridors offer both form and function and have been identified as 'no touch' reaches that must be maintained undisturbed in their present condition. They have been deemed high-quality systems that could not be re-located and replicated in a post-development scenario.
2. Medium Geomorphic Classification: These reaches may or may not have a well-defined morphology (form) but do maintain geomorphic function and have potential for rehabilitation. In many cases, these reaches are presently exhibiting evidence of geomorphic instability or environmental degradation due to historic modifications and land use practices. Management options for these reaches include the following:
    a. Do nothing: leave the corridors in their present condition and develop outside of their boundaries.
    b. Enhance existing conditions: maintain the present location of the corridor but enhance the existing conditions (e.g. bank stabilization, re-establish a meandering planform, connect channel to functioning floodplain).
    c. Re-locate and enhance existing conditions: many of the reaches within the study area have undergone extensive straightening and modification for agricultural drainage purposes. As such, they are not as sensitive to re-location and would benefit from enhancements such as the re-establishment of a meandering planform with functioning floodplain and development of a riffle-pool morphology. In the event that these reaches are re-located, the corridor width associated with each reach must, at a minimum, be maintained.
3. Low Geomorphic Classification: these reaches consist of ephemeral headwater systems that lack defined bed and banks (form) but do perform a geomorphic function through the conveyance of flow and sediment. Management options for these reaches include the following:
    a. Do nothing: leave the drainage feature intact and develop the surrounding lands, with a minimal buffer (i.e., a corridor width is not prescribed for these systems).
    b. Combination of stormwater management and open conveyance techniques: the function of headwater streams can be mimicked through the combined implementation of stormwater management techniques with sufficient maintenance of open conveyance systems such as backyard swales to meet drainage density targets. A corridor width is not prescribed for these systems.
    c. Open conveyance techniques: the function of the ephemeral swales is replicated entirely through a system of open conveyance techniques (e.g. backyard swales).

4.6 Surface Water Quality

4.6.1 Importance / Purpose

The surface water quality assessment provides a characterization of the aquatic health of the subwatersheds and tributaries with respect to contaminant loadings under existing land use conditions, and establishes a baseline condition which would be used to verify the performance of the recommended stormwater quality management plan as part of subsequent phases of study and monitoring.

4.6.2 Background Information

The following information has been provided for use and reference to characterize the surface water quality within the Sixteen Mile Creek Watershed:

Reports

- Sixteen Mile Creek Subwatershed Update Study (AMEC et. al., November 2015).
- Ninth Line Lands Scoped Subwatershed Study Phase 1: Background Report Study Area Characterization (Amec Foster Wheeler et. al., January 2015 Draft).
- Ninth Line Lands Scoped Subwatershed Study Phase 2: Impact Assessment and Management Strategy (Amec Foster Wheeler et. al., March 2017 Draft).
- Premier Gateway Scoped Subwatershed Study Phase 1: Study Area Characterization (Amec Foster Wheeler et. al., February 2016 Draft).

Data

- LEMP water quality sampling results for East Oakville Creek at Lower Base Line (ref. Station SXM-205) and West Oakville Creek at Lower Base Line (ref. Station SXM-216).

4.6.3 Methods / Analysis

The surface water quality characterization has been completed based upon a desktop review and statistical assessment of the background information provided for use and reference in this study. Water quality monitoring within the Sixteen Mile Creek, downstream of the South Milton SWS study area has been completed by Conservation Halton as part of the LEMP. Water quality data has been provided for the following stations and corresponding periods of record:

LEMP Station	Period of Record
SXM-205	1975 – 1996 2002 – 2010 2012 – 2014
SXM-216	2002 - 2014

Water quality monitoring at these locations has been conducted using grab sampling. The data provided for use do not distinguish between sampling during dry weather and wet weather conditions. The water quality parameters reported at each location are summarized in Table 4.6.1:

Table 4.6.1 Summary of Water Quality Parameters Monitored at Each Monitoring Station Within Sixteen Mile Creek Watershed

Water Quality Parameter	Monitoring Station	
	SXM-205	SXM-216
ALKALINITY, TOTAL	X	X
ALUMINIUM, UNFILTERED TOTAL	X	X
AMMONIUM, TOTAL FILTER.REAC	X	
AMMONIUM, TOTAL UNFIL.REAC	X	X
ARSENIC, UNFILTERED TOTAL	X	
BARIUM, UNFILTERED TOTAL	X	X
BERYLIUM,UNFILTERED TOTAL	X	X
BISMUTH, UNFILTERED TOTAL	X	X
BOD, 5 DAY, TOTAL DEMAND	X	
CADMIUM, UNFILTERED TOTAL	X	X
CALCIUM, UNFILTERED TOTAL	X	X
CARBON, DISSOLVED INORGANIC	X	X
CARBON, DISSOLVED ORGANIC	X	X
CHLORIDE, UNFIL.REAC	X	X
CHROMIUM, UNFILTERED TOTAL	X	X
COBALT, UNFILTERED TOTAL	X	X
CONDUCTIVITY, 25C	X	X
CONDUCTIVITY, AMBIENT	X	X
COPPER, UNFILTERED TOTAL	X	X
DISSOLVED OXYGEN	X	X
HARDNESS, TOTAL	X	X
IRON, UNFILTERED TOTAL	X	X
LEAD, UNFILTERED TOTAL	X	X
LITHIUM, UNFILTERED TOTAL	X	X
MAGNESIUM,UNFILTERED TOTAL	X	X
MANGANESE,UNFILTERED TOTAL	X	X
MERCURY, UNFILTERED TOTAL	X	
MOLYBDENUM,UNFILTERED TOTAL	X	X
NICKEL, UNFILTERED TOTAL	X	X
NITRATE, FILTERED REACTIVE	X	
NITRATES TOTAL, FILTER.REAC	X	
NITRATES TOTAL, UNFIL.REAC	X	X
NITRITE, FILTERED REACTIVE	X	
NITRITE, UNFILTERED REACTIVE	X	X
NITROGEN,TOT,KJELDAHL/UNF.REA	X	X
NITROGEN; TOTAL	X	X

Table 4.6.1 Summary of Water Quality Parameters Monitored at Each Monitoring Station Within Sixteen Mile Creek Watershed		
Water Quality Parameter	Monitoring Station	
	SXM-205	SXM-216
PH (-LOG H+ CONCN)	X	X
PH FIELD	X	X
PHOSPHATE,FILTERED REACTIVE	X	X
PHOSPHORUS,UNFILTERED TOTAL	X	X
POTASSIUM,UNFILTERED TOTAL	X	X
RESIDUE,FILTERED	X	X
RESIDUE,PARTICULATE	X	X
RESIDUE,TOTAL	X	X
SELENIUM, UNFILTERED TOTAL	X	
SILICATES,UNFILTERED REACTIVE	X	X
SILVER, UNFILTERED TOTAL	X	X
SODIUM, UNFILTERED TOTAL	X	X
STREAM CONDITION	X	X
STRONTIUM, UNFILTERED TOTAL	X	X
SULPHATE, UNFILTERED REACTIVE	X	
TEMPERATURE, WATER	X	X
TIN UNFILTERED TOTAL	X	X
TITANIUM, UNFILTERED TOTAL	X	X
TURBIDITY	X	X
URANIUM, UNFILTERED TOTAL	X	X
VANADIUM, UNFILTERED TOTAL	X	X
ZINC, UNFILTERED TOTAL	X	X
ZIRCONIUM, UNFILTERED TOTAL	X	X

The information in Table 4.6.1 indicates that the water quality monitoring stations within the Sixteen Mile Creek Watershed have not evaluated the same suite of water quality parameters. A further review of the monitoring data indicates that the parameters evaluated for a given station have varied over time (i.e. the same suite of parameters have not been evaluated for each year of the monitoring program), hence the sample population of monitoring data for a given monitoring station varies among the water quality parameters.

Statistical analyses have been completed based upon the monitoring data to determine the range, mean, and median concentrations for representative indices of surface water chemistry. The results of the assessment are presented in Tables 4.6.2 and 4.6.3.

Table 4.6.2	Statistical Summary of Water Quality Data for Conservation Halton East Oakville Creek Station (LEMP Code SXM-205)		
Contaminant	Range	Mean	Median
BOD/CBOD (mg/L)	0.11 – 8.1	1.27	1
E.coli (#/100mL)			
TKN (mg/L)	0.013 – 3.3	0.62	0.53
Total P (mg/L)	0.007 – 1.2	0.059	0.028
TSS (mg/L)[1.]	0.5 – 292	16.2	6.4
Copper (mg/L)	0.0005 – 0.056	0.0033	0.0022
Zinc (mg/L)	0.000052 – 0.075	0.0046	0.0024
Lead (mg/L)	0 – 0.03	0.0046	0.0050
Nitrate+Nitrite (mg/L)	0.006 – 3.10	0.67	0.44

NOTE: [1]Particulate Residue samples from Water Quality Data has been considered as TSS

Table 4.6.3	Statistical Summary of Water Quality Data for Conservation Halton West Oakville Creek Station (LEMP Code SXM-216)		
Contaminant	Range	Mean	Median
BOD/CBOD (mg/L)			
E.coli (#/100mL)			
TKN (mg/L)	0.05 - 3	0.58	0.48
Total P (mg/L)	0.008 – 0.74	0.047	0.019
TSS (mg/L)[1.]	0.5 - 327	16.4	4.2
Copper (mg/L)	0.00121 – 0.0141	0.0032	0.0027
Zinc (mg/L)	0.00084 – 0.0816	0.012	0.0096
Lead (mg/L)	0.000165 – 0.0136	0.0038	0.0028
Nitrate+Nitrite (mg/L)	0.505 – 6.269	2.40	2.03

NOTE: [1]Particulate Residue samples from Water Quality Data has been considered as TSS

The median concentrations determined from the statistical analyses completed at the two LEMP monitoring stations downstream of the South Milton SWS study area have been compared with the median concentrations determined for water quality monitoring data collected for other subwatershed studies and scoped subwatershed studies within the Sixteen Mile Creek Watershed. As noted previously, the monitoring data provided for Stations SXM-205 and SXM-216 did not distinguish between wet weather and dry weather monitoring, hence these comparisons have been completed for wet weather and dry weather monitoring results reported for other studies.

The results of these comparisons are presented in Tables 4.6.4 and 4.6.5.

Table 4.6.4 Comparison of Median Concentrations with Findings from Other Studies for Wet Weather Flow Conditions

Contaminant	Sixteen Mile Creek Subwatershed Update Study				Ninth Line Scoped Subwatershed Study		Premier Gateway Scoped Subwatershed Study	South Milton Subwatershed Study	
	Q1	Q2	Q3	Q4	Railway	Britannia		SXM-205	SXM-216
BOD/CBOD (mg/L)	2	4	2	3	2.6	<0.163	3	1	
E.coli (#/100mL)	363	3200	242	10	2850	1600	126		
TKN (mg/L)	1.15	2	1.4	4	1.50	1.135	1.2	0.53	0.48
Total P (mg/L)	0.076	0.2	0.078	0.24	0.154	0.150	0.205	0.028	0.019
TSS (mg/L)	17	51	92	49	17.7	45.4	10	6.4	4.2
Copper (mg/L)	0.0035	0.012	0.002	0.007	0.0040	0.0050	0.003	0.0022	0.0027
Zinc (mg/L)	0.014	0.015	0.014	0.020	0.0117	0.0251	0.008	0.0024	0.0096
Lead (mg/L)	0.001	0.0031	0.00205	0.0046	<0.0007	0.00157	0.0006	0.0050	0.0028
Nitrate+Nitrite (mg/L)	0.6	1.7	0.65	0.9	<0.175	<0.163	0.25	0.44	2.03

Table 4.6.5 Comparison of Median Concentrations with Findings from Other Studies for Dry Weather Flow Conditions

Contaminant	Sixteen Mile Creek Subwatershed Update Study				Ninth Line Scoped Subwatershed Study		Premier Gateway Scoped Subwatershed Study	South Milton Subwatershed Study	
	Q1	Q2	Q3	IC	Railway	Britannia			
BOD/CBOD (mg/L)	4	3	3	5.5	<2	2.5	3	1	
E.coli (#/100mL)	86	8600	126	30	250	230	126		
TKN (mg/L)	1.35	3.4	1.2	2.8	0.73	0.72	1.2	0.53	0.48
Total P (mg/L)	0.123	0.54	0.205	0.225	0.073	0.082	0.205	0.028	0.019
TSS (mg/L)	24	22	10	30.5	14	41.6	10	6.4	4.2
Copper (mg/L)	0.0035	0.010	0.003	0.0025	<0.0062	<0.00705	0.003	0.0022	0.0027
Zinc (mg/L)	0.0105	0.027	0.008	0.0295	<0.01845	<0.02185	0.008	0.0024	0.0096
Lead (mg/L)	0.0014	0.0046	0.0006	0.0007	<0.002815	<0.003235	0.0006	0.0050	0.0028
Nitrate+Nitrite (mg/L)	4	ND	0.25	ND	<0.6	<0.625	0.25	0.44	2.03

The results in Tables 4.6.4 and 4.6.5 indicate the following:

- Median concentrations of nutrients (i.e. BOD_5, TKN, and Total P) at LEMP stations SXM-205 and SXM-216 tend to be below median concentrations reported elsewhere in the Sixteen Mile Creek Watershed for both dry weather and wet weather conditions.
- Median concentrations of Nitrate + Nitrite at LEMP station SXM-205 are below median concentrations reported elsewhere in the Sixteen Mile Creek Watershed for wet weather conditions, however are comparable to results reported elsewhere for dry weather conditions.
- Median concentrations of Nitrate + Nitrite at LEMP station SXM-216 are higher than median concentrations reported elsewhere in the Sixteen Mile Creek for wet weather conditions, and are toward the upper limit of concentrations reported elsewhere in the watershed for dry weather conditions.
- Median concentrations of TSS at LEMP stations SXM-205 and SXM-216 tend to be below median concentrations reported elsewhere in the Sixteen Mile Creek Watershed for both dry weather and wet weather conditions.
- Median concentrations of certain metals (i.e. copper and zinc) at stations SXM-205 and SXM-216 tend to be below median concentrations reported elsewhere in the Sixteen Mile Creek Watershed for wet weather conditions; median concentrations of copper at LEMP station SXM-205 are comparable to results reported elsewhere in the Sixteen Mile Creek Watershed for dry weather conditions, and median concentrations of zinc at LEMP station SXM-216 are below median concentrations reported elsewhere in the Watershed for dry weather conditions.
- Median concentrations of certain metals (i.e. lead) at stations SXM-205 and SXM-216 tend to be at or above median concentrations reported elsewhere in the Sixteen Mile Creek Watershed.

The water quality results for Stations SXM-205 and SXM-216 have been compared with current Provincial Water Quality Objectives (PWQO's) for various contaminants, in order to determine the number of exceedances under existing land use conditions. Contaminants have been listed when available guidelines have been provided within the PWQO's or within The Canadian Council of the Ministers of the Environment (CCME) Water Quality Index. A summary of PWQO exceedances based upon the contaminant concentrations provided in the raw water quality data has been provided within Table 4.6.7.

Table 4.6.6 Provincial Water Quality Objective Exceedances at LEMP Stations

Contaminants	Limit	Monitoring Site	
		SMX-205	SMX-216
Chloride	252 mg/L	0 (311)	3 (89)
Nitrite	0.06 mg/L	2 (102)	1 (87)
Nitrate	2.9 mg/L	1 (101)	30 (86)
Escherichia coli	100 CFU/100mL		
Arsenic	100 ug/L	0 (170)	
Beryllium	1100 ug/L	0 (71)	0 (47)
Cadmium	0.2 ug/L	56 (76)	51 (64)
Cobalt	0.9 ug/L	11 (73)	15 (61)
Copper	5 ug/L	28 (251)	9 (87)
Iron	300 ug/L	78 (252)	16 (86)
Lead	25 ug/L	4 (208)	0 (39)
Nickel	25 ug/L	0 (239)	0 (84)
Selenium	100 ug/L	0 (19	
Silver	0.1 ug/L	14 (14)	11 (12)
Zinc	30 ug/L	3 (237)	5 (87)

Note: The number in brackets represents the number of samples

The results in Table 4.6.6 indicate relatively low concentrations of chloride, nitrate, and nitrite at Stations SXM-205 and SXM-216 compared to the PWQO's, although somewhat higher concentrations of nitrate are noted at station S2M-216 compared to the PWQO's. The results further indicate low concentrations of certain metals, although PWQO exceedances are frequently noted for other metals (i.e. silver, cadmium cobalt, and iron). Although median concentrations of lead were noted to exceed median concentrations determined elsewhere in the Watershed, the information presented in Table 4.6.7 indicates the concentrations of lead are typically below the PWQO.

4.6.4 Interpretation / Key Findings

The water quality monitoring samples received from Conservation Halton indicate that the existing surface water quality along the Sixteen Mile Creek downstream of the South Milton SWS study area is generally of relatively high quality. Concentrations of organics, nutrients, and TSS are lower than have been reported in other areas of the watershed for Sixteen Mile Creek for largely agricultural land use conditions, and concentrations of various metals are below values reported elsewhere in the Watershed as well as PWQO's. The lower concentrations are considered potentially attributable to the influence of stormwater management practices within urbanized areas of the watershed. PWQO exceedances are noted for silver, with some exceedances occurring for cadmium, cobalt, copper, and iron. Although concentrations of lead were noted to be higher at the monitoring stations downstream of the South Milton SWS study area compared to other locations in the watershed, PWQO exceedances were noted to be highly infrequent.

4.7 Aquatic Resources

4.7.1 Importance / Purpose

Fish communities are key biological components of aquatic ecosystems and reflect the physical, chemical and biological characteristics of watercourses. Key physical characteristics include flow, stream morphology, water temperature and suspended solids/turbidity. Key chemical characteristics include nutrient and dissolved oxygen concentrations, contaminant concentrations, and hardness which affects contaminant toxicity. The fish species present in a stream or waterbody and their abundance provides insight into the overall quality and sensitivity of the feature. Significant changes in habitat are likely to result in changes in the fish community. The fish community is also affected by factors in the riparian zone, such as the types of vegetation present. Linkages to other ecosystem components include the consumption of fish and crayfish by birds and mammals and the consumption of adult (flying) stages of aquatic insects by birds.

4.7.2 Background Information

The fish sampling information contained in the Conservation Halton fish database was provided in GIS format by Conservation Halton. The Ontario Ministry of Natural Resources and Forestry provided maps showing the locations of historic fish collections, with numbers linking these locations to the corresponding paper files in the OMNRF Aurora District files. The OMNRF office in Aurora was visited and the paper files were retrieved and photographed. These files were then compared to the Conservation Halton database to determine approximately the date from which all previous OMNRF fish collections records were included. Several random checks of the data in the Conservation Halton database were also completed to evaluate the accuracy of the database. The Conservation Halton database was found to be complete up to approximately 2008 and the records that were checked were accurate.

More recent fish collection information, in the form of scanned or electronic Fish Collection Reports (FCR), were also provided by OMNRF. These mandatory reports are submitted as a requirement of all Fish Collection Licences for Scientific Purposes that are issued in Ontario. These FCRs were screened for their location and those located within the Primary Study Area were compared to the Conservation Halton database. Those records that were not in the Conservation Halton database were entered into the project GIS database, except for records that represented a repeat collection at locations within the main Sixteen Mile Creek watercourses which did not result in additional species for that location.

Finally, fish collections from the Centre Tributary and the Omagh Tributary that were undertaken as part of the various Milton Phase 1 and Milton Boyne studies, and reported in the Subwatershed Update Study (AMEC, 2015), were used to supplement the fish community and distributional information for those tributaries. The locations for which fish collection data were available and the source of those data are shown in Figure 4.7.1

All existing fish collections were evaluated for potential misidentifications. Emerald Shiner (*Notropis atherinoides*), Spottail Shiner (*Notropis hudsonius*), Alewife (*Alosa pseudoharengus*), Yellow Bullhead (*Ameiurus natalis*), and Fallfish (*Semotilus corporalis*) have been recorded from the Primary Study Area, but are likely to be the result of misidentifications or transcription errors. Therefore, we have removed these species from the list of Sixteen Mile Creek fishes based on the following rationale.

- Emerald Shiner is typically a fish of larger lakes, and would only be expected in the downstream reaches of Sixteen Mile Creek close to Lake Ontario. Emerald Shiner is very similar in appearance to Silver Shiner, which is a stream fish. Silver Shiner is found within the Study Area, and it is likely that fish identified as Emerald Shiner are actually Silver Shiner. It should be noted that Rosyface Shiner is also very similar to Emerald Shiner and Silver Shiner, and has also been reported to occur in the Study Area. Rosyface Shiner is typically found in habitats similar to that of the main streams of the Study Area. Records of Rosyface Shiner were retained.
- Spottail Shiner is typically a fish of larger lakes and would only be expected in the downstream portions of Sixteen Mile Creek, close to Lake Ontario. Fish identified as Spottail Shiners are often misidentified Bluntnose Minnows due to their superficial resemblance and the fact that the usual dichotomous key used by biologists to identify members of Cyprinidae (minnow family) contains a difficult to discern characteristic that, if missed, can lead to this common misidentification. Since Bluntnose Minnow is known from Sixteen Mile Creek, we have assumed that any records of Spottail Shiners are misidentified Bluntnose Minnows.
- Alewife is an open water fish found in the Great Lakes and marine habitats. It does not resemble any of the known fish species in Sixteen Mile Creek. We believe the single record of this species must be the result of a transcription error.
- Yellow Bullhead is not a commonly observed fish in this part of Ontario, and has only been reported once from Sixteen Mile Creek. Given that the similar and ubiquitous Brown Bullhead has been identified from numerous locations throughout the Sixteen Mile Creek watershed, we have assumed that this one fish is a misidentified Brown Bullhead.
- The one Fallfish reported from Sixteen Mile Creek is far outside the known range of this species. Therefore, it has been assumed that this fish is a misidentified Creek Chub, which is a closely related species that is found throughout the Sixteen Mile Creek watershed.

Lists of the fish species that have been captured within the study area, separated into the drainage basins of the main branches and major tributaries, were compiled using the updated fish collection database of existing information and the results of fish sampling conducted during this study.

Descriptions of habitat in the larger watercourses in the Primary Study Area that were available in existing sources (Conservation Halton, 2013; AMEC, 2010), were reviewed and the descriptions were updated as appropriate. For watercourses where existing descriptions of habitat did not exist, descriptions were prepared based on C. Portt and Associates staff (G. Coker, C. Portt) field investigations within the Study Area since 1998, and with reference to aerial photography and the results of the 2016 field investigations.

The habitat ratings determined by Conservation Halton using a fish community based Index of Biotic Integrity for their long term environmental monitoring program locations (Conservation

Halton, 2013) are presented in Table 4.7.1. The methodology used to determine these ratings is discussed in Section 4.7.3. Locations on the Lower Middle Branch are rated as fair or good, except for Location SXM-38 which was rated poor in 2005. The locations in the East Branch and West Branch were rated as either poor or fair, depending upon the year. Conservation Halton (2013) provides the following caution regarding this index:

"It should be noted that with the IBI methodologies, assessment appears to be sensitive to the capture of particular species such as darters, trout and suckers. Generally, a year catch that fluctuated by the number of darter, sucker or trout species could shift the IBI scores significantly. Scores may also fluctuate in response to Catch Per Unit Effort (CPUE) as annual changes in summer staff may effect [sic] catch efficiency. It is also important to note that if suitable information is not collected (i.e. the number or biomass of fish) IBI analysis cannot be completed. For this reason, analysis based on historical information may not be possible."

Table 4.7.2 Fish community based index of biotic integrity scores and habitat classes at Conservation Halton's long term environmental monitoring locations that are within the study area. Source: Conservation Halton, 2013. Refer to Figure 4.7.2 for the locations.

Watercourse	Station	Metric	2005	2006	2007	2008	2009	2011
Lower Middle Branch	SXM-38	Score	16.00	-	-	-	29.25	25.00
		Class	Poor				Good	Fair
	SXM-205	Score	-	22.50	24.75	-	29.25	Not Sampled
		Class		Fair	Fair		Good	NA
	SXM-435	Score	-	-	-	-	22.50	29.00
		Class					Fair	Good
East Branch	SXM-436	Score	-	-	-	-	22.50	18.00
		Class					Fair	Poor
West Branch	SXM-216	Score	23.00	20.25	20.25	22.50	24.75	15.75
		Class	Fair	Poor	Poor	Fair	Fair	Poor

The water quality ratings determined by Conservation Halton based on the 2011 benthic invertebrate communities at their long term environmental monitoring program locations (Conservation Halton, 2013) are presented in Table 4.7.3. The methodology used to determine these ratings is discussed in Section 4.7.3. Location SXM-435 was rated possibly impaired and the other three locations were rated unimpaired.

Table 4.7.3 Benthic invertebrate community based water quality rating at Conservation Halton's long term environmental monitoring locations that are within the study area. Source: Conservation Halton, 2013. Refer to Figure 4.7.2 for the locations

Watercourse	Lower Middle Branch		East Branch	West Branch
Index	SXM-38	SXM-435	SXM-436	SXM-216
# of EPT taxa	9	9	6	9
Richness(# of Taxa)	18	18	16	21
% Oligochaeta	3.5	2.1	2.8	3.2
% Chironomidae	32.6	41.1	38.0	34.8
% Isopoda	0.0	1.8	0.3	11.7
% Gastropoda	0.3	0.0	0.0	0.0
% Diptera	35.5	42.3	41.4	43.4
% Insects	87.2	94.1	85.0	76.3
Hilsenhoff (MFBI)	5.1	5.1	5.2	5.5
SDI per sample	1.4	1.3	1.6	1.8
SDI per site	2.5	2.4	2.7	2.9
Water quality rating				
EPT	P	P	P	P
Richness(# of Taxa)	U	U		U
% Oligochaeta	U	U	U	U
% Chironomidae	P		P	P
% Isopoda	U	P	U	I
% Gastropoda	U	P	P	P
% Diptera	U	U	U	U
% Insects	P	I	P	U
Hilsenhoff (MFBI)	U	U	U	U
SDI per site	I	I	I	I
Unimpaired	6	4	5	5
Possibly Impaired	3	3	4	3
Impaired	1	3	1	2
OVERALL	U	P	U	U

u=unimpaired, p=possibly impaired, i=impaired

Water temperature monitoring in 2011 at SXM-435 on the Lower Middle Branch and at SXM-216 on the West Branch (Figure 4.7.2) indicated that the thermal regime was warmwater at both of these locations, using the thermal classification method of Chu et al (2009).

4.7.3 Methods / Analysis

4.7.3.1 Fish Use of Headwater Drainage Features and Ponds

Spring field examinations were conducted by C. Portt and Associates staff (C. Portt) on May 5 and 6, 2016, to evaluate watercourse flow conditions in headwater drainage features in both the Primary and Supplemental Study Areas. Watercourses were examined, primarily at road crossings, to determine where water was present and fish sampling was warranted. Georeferenced photographs were taken at numerous locations to document site conditions.

Follow-up field investigations at the locations where water was present on May 5 and 6, plus other locations at road crossings and within public and private lands, were conducted on May 11, 12, 16, 19 and 20, 2016, by C. Portt and Associates staff (G.A. Coker, M.G. Coker). Fish sampling was conducted in most locaitons where water was present in sufficient quantity to support fish, using a Halltech Model HT 2000B Mrk 5 backpack electrofisher. At a few locations where the water was generally inaccessible to a backpack electrofisher (i.e. within low culverts) a dipnet was used to collect fish. All fish collected were identified to species by G. Coker, counted, and released near the point of capture. As a measure of fishing effort, the number of electroseconds (duration that the water was being electrified) were recorded as were the voltage and frequency applied. All field observations, photographs and fish collections, were georeferenced using a Garmin GPSmap 76CSx hand-held gps receiver. Photographs were taken at most locations to document site conditions.

As the summer progressed flow was further reduced overall and many watercourses ceased flowing altogether. Locations in headwater features where it was thought, based on the earlier field investigations, that there was potential for water to persist were re-examined on August 10 and 15 by C. Portt and Associates staff (G.A. Coker, M.G. Coker). Additional locations identified as having flowing or standing water by the project fluvial geomorphologist (J. Henshaw, Matrix-Solutions) were also examined on those dates. Where water was present, fish sampling was conducted using the same equipment and methods as were used in May, and at most locations georeferenced photographs were taken. Observations of habitat and flow conditions at specific locations were also made during a subwatershed tour on September 20, 2016.

Additional field investigations of potential fish refuge habitat were conducted on October 31 and November 7 (G.A. Coker with Savanta Inc. staff) and November 11 (G.A. Coker, J. Reid), 2016. If water was present, fish sampling was conducted as described above.

If the areas examined during the 2016 field investigations were on private property, permission to enter was obtained either through the landowner group's consultant (Savanta Inc.) or by direct contact with landowners. When lands represented by Savanta Inc. were visited, a Savanta staff member accompanied C. Portt and Associates staff.

The results of the field observations and fish collections were entered into, and organized using GIS software (QGIS 2.8.5 Wein).

4.7.3.2 Fisheries Constraint Rating for Watercourses and Headwater Drainage Features

Fish habitat evaluation of constraints to development was guided by the Credit Valley Conservation and Toronto and Region Conservation document "Evaluation, Classification and Management of Headwater Drainage Features: Interim Guidelines (2009)". The habitat class definitions are provided below.

i. *Permanent* - Provides direct habitat onsite (e.g. feeding, breeding, and/or migration) as a result of year round groundwater discharge and/or permanent standing surface water within a storage feature (i.e. ponds, wetlands, refuge pools, etc.). Habitat may be either existing or potential (i.e. isolated by a barrier). Permanent habitat also may include critical fish habitat (i.e. habitat that is limited in supply, essential to the fish life cycle, and generally habitat that is not easily duplicated or created).
ii. *Seasonal* - Provides limited direct habitat onsite (e.g. feeding, breeding, migration and/or refuge habitat), as a result of seasonally high groundwater discharge or seasonally extended contributions from wetlands or other surface storage areas that support intermittent flow conditions, or rarely ephemeral flow conditions. Occasionally, limited permanent refuge habitat may be identified within seasonal habitat reaches.
iii. *Contributing* - Provides indirect (contributing) habitat to downstream reaches – functions generally increase with flow and/or as flows move downstream with increasing length of channel or channel density (e.g. extent of contributing area). There are two types of contributing habitat:
    a. Complex contributing habitat – generally as a result of intermittent (or less commonly ephemeral) surface flows, can have marginal sorting of substrates – generally well vegetated features that influence flow conveyance, attenuation, storage, infiltration, water quality, sediment, food (invertebrates) and organic matter/nutrients (i.e. there are two types of nutrients, e.g. dissolved nutrients, and course/fine matter). Generally, two structural types: a) defined features with natural bank vegetation consisting of forest, scrubland/thicket or meadow (as defined in OSAP or ELC); or b) poorly defined features (swales) typically distinguished by hydrophilic vegetation.
    b. Simple contributing habitat – generally as a result of ephemeral (or less commonly intermittent) surface flows – generally not well-vegetated features that influence flow conveyance, attenuation, storage, infiltration, water quality and sediment transport. Generally two types: a) defined features characterized by crop cultivation, mowing or no vegetation; or b) poorly defined features (swales) may contain terrestrial vegetation.
iv. *Not Fish Habitat* - The pre-screened drainage feature has been field verified to confirm that no features and/or functions associated with headwater drainage features is present – generally characterized by no definition or flow, no groundwater seepage or wetland functions, and evidence of cultivation, furrowing, presence of a seasonal crop, lack of natural vegetation, and fine textured soils (i.e. clay and/or silt).

Recharge Zone – Hydrogeologic characterization is a separate component of this study which addresses recharge. Therefore, recharge was not explicitly considered as part of the fish habitat classification.

The upstream limit of permanent fish habitat was determined by direct sampling, or by examining the habitat at the farthest upstream location where fish were collected and then extending upstream to where the habitat changed to something less likely to support fish on a permanent basis. Similarly, the upstream limit of seasonal fish habitat was determined by examining the habitat at the farthest upstream location where fish were seasonally present, and then extending upstream to where of the habitat changed to something less likely to support fish for a biologically significant length of time at any time of year.

Broad-Level Constraints

The following management classes are presented in the *Evaluation, Classification and Management of Headwater Drainage Features: Interim Guidelines* (ref. CVC and TRCA, March 2009). Broad-level constraints (High, Medium, Low) have been assigned to each sub-class of management classes to feed into the Integrated Constraint Rating for each watercourse section.

A fisheries high constraint relates to perennial watercourses that support good quality habitat utilized by fish, whereas a medium constraint has been assigned to watercourse reaches without perennial flow that support seasonal or permanent standing-water habitats utilized by fish, or have the potential to do so. A low fisheries constraint is assigned to watercourses that are not considered fish habitat, or have little potential to contribute to fish habitat based on the flow regime identified.

i. **Protection** – Permanent Fish Habitat, Critical Habitat and Species at Risk (SAR).

Protection 1 ***(High Constraint)*** – permanent, critical fish habitat or habitat associated with species at risk. Generally associated with permanent groundwater discharge or wetland storage – either habitat and/or flow source characteristics may be difficult to replicate or maintain.

Protection 2 ***(High Constraint)*** – permanent fish habitat generally with permanent standing surface water associated with a wetland and/or pond.

ii. **Conservation** – Seasonal Fish Habitat.

Conservation 1 ***(Medium Constraint)*** – seasonal fish habitat associated with seasonally high groundwater discharge or seasonally extended contributions from wetlands. Actual or otential permanent refuge habitat may be provided by a storage feature.

Conservation 2 ***(Medium Constraint)*** – seasonal fish habitat associated with intermittent surface flows.

iii. **Mitigation** – Contributing Fish Habitat

Mitigation 1 ***(Medium Constraint)*** – Complex contributing fish habitat: flows conveyed through natural vegetation communities that support complex, contributing fish habitat i.e. influences water quality, sediment, organic matter, food and nutrients to the downstream habitat.

Mitigation 2 ***(Medium Constraint or Low Constraint)*** – Simple contributing fish habitat: flows that support simple contributing fish habitat, i.e. influences flow conveyance, attenuation and storage to downstream reaches.

iv. **No Management Recommendation Required *(Low Constraint)*** – Not Fish Habitat.

Baseline Benthic Invertebrate Community and Fish Community Data Collection

The baseline monitoring locations are shown in Figure 4.7.3. The five baseline monitoring locations that were originally established for flow, water temperature and water quality monitoring were examined and benthic invertebrate and fish community sampling were conducted if the watercourses at those locations were flowing. A sixth monitoring location was established on the Centre Tributary following discussions with Conservation Halton and the Technical Advisory Committee in June, 2016, after the time for collecting benthic invertebrates in 2016 was past. Therefore, no benthic sampling was conducted at that location in 2016.

Benthic Invertebrate Communities

The benthic invertebrate sampling was conducted following the Ontario Benthic Biomonitoring Network (OBBN) protocol (Jones *et al*, 2007) on May 25 and 26, 2016, at four of the six base-line monitoring locations. The watercourse at the fifth base-line site, Trafalgar South, was dry at the time and, as mentioned above, the Sixth Line location was not established until after the date by which benthic invertebrate sampling was to be completed. At each location, three kick and sweep samples were collected – two in riffles and one in a pool or run – using a 500 µm mesh dip net. Each sample was preserved in 7% buffered Formalin for subsequent sorting and identification. The habitat characteristics at each site were characterized according to the OBBN protocol and the coordinates of the sampling locations were determined using a Garmin 76CSx handheld GPS.

Each benthic invertebrate sample was placed in a 500 µm brass sieve and rinsed with water for several minutes to remove the remaining preservative and to eliminate fine particulate matter. Large rocks, twigs, and debris were thoroughly rinsed and removed. The remaining dewatered sample was weighed to the nearest gram using a Sartorius Model BL6 electronic balance and transferred to a white plastic tray. A small amount of water was added to create a slurry. The sample was lightly mixed and small sub-samples were removed using a teaspoon and placed in a clear 9 mm square polycarbonate counting dish. Sorting was done with the aid of a dissecting microscope using 6X magnification. Benthos were removed, rinsed, tallied with a hand counter and placed in plastic vials containing 70% ethanol fitted with screw caps for subsequent identification. Sub-sampling continued until 100 organisms were recovered. The sub-sample containing the 100th organism was picked until no more invertebrates were found. All sorted material was transferred to the 500 µm sieve and weighed to the nearest gram. The proportion of the sample that was sorted was calculated by dividing the weight of the sorted material by the weight of the whole sample. Sorted and unsorted portions of sediment were placed in separate sample containers and preserved with the original Formalin solution. A label containing sample identification information was placed inside all sample containers.

The specimens were identified by William Morton to the lowest practical level -- species where possible. The taxonomic references used for the identifications are provided in Appendix G. A voucher collection containing representatives of each taxon recorded was created for future referral.

Ten benthic invertebrate indices that are used to provide an indication of habitat impairment were calculated for each location. The indices, which are calculated based on the three samples from each location combined, are taxa richness, relative abundances (percents) of EPT (Ephemeroptera, Trichoptera and Plecoptera), Oligochaeta, Chironomidae, Isopoda, Gastropoda, Diptera, and insects, as well as the the Hilsenhoff Biotic index (HBI) and the Shannon-Weiner diversity index (SDI). These are the indices used by Conservation Halton (2013) except that they use number of EPT taxa instead of % EPT.

Shannon-Weiner diversity was calculated for three sub-samples combined for each location as:

$H=-\Sigma p_i \ln p_i$
where p_i is the proportion of the sample comprised of species i.

The Hilsenhoff Biotic Index (HBI) was calculated for the three sub-samples combined for each location and sampling date as:

$HBI=\Sigma n_i T_i/\Sigma n_i$ where
Σn_i is the number of individuals of species i, and
T_i is the tolerance value of species i from the literature.

The HBI tolerance values are directly or inferred from Hilsenhoff (1982, 1987) and Bode (1988a). The habitat impairment status indicated by each index was evaluated using the values from Conservation Halton (2013; Table 4.7.5), except that % EPT was used instead of number of EPT taxa. The method used to calculate the overall impairment status at each location is presented in Table 4.7.4.

Table 4.7.5 Criteria used to determine the impairment status at a location based on individual benthic invertebrate indices (adapted from Conservation Halton, 2013)

Index	Impairment status		
	Unimpaired	Possibly impaired	Impaired
Taxa richness	>13		<13
% EPT	>10	5-10	<5
% Oligochaeta	<10	10-30	>30
% Chironomidae	<10	10-40	>40
% Isopoda	<1	1-5	>5
% Gastropoda	1-1-	0 or >10	
% Diptera	20-45	15-20 or 45-50	<15 or >50
% Insect	50-80	40-50 or 80-90	<40 or >90
HBI	<6	6-7	>7
SDI	>4	3-4	<3

Table 4.7.6 Criteria used to calculate an overall impairment status based on the cumulative results from 10 individual benthic invertebrate based indices (adapted from Conservation Halton, 2013)

# of indices indicating "unimpaired"	# of indices indicating "possibly Impaired"	# of indices indicating "impaired"	overall rating
>5			unimpaired
5		<4	unimpaired
5		≥4	possibly impaired
≥4		5	possibly impaired
<4		5	impaired
		>5	impaired
all other combinations			possibly impaired

Fish Communities and Habitat

The six baseline monitoring locations that were established for flow, water temperature and water quality were examined and fish community sampling were conducted if the watercourses at those locations were flowing. Fish community and habitat sampling were conducted following the Ontario Stream Assessment Protocol (OSAP; Stanfield, 2013). Sites were established according to Module S1.M1 and georeferenced using a Garmin 76CSx handheld gps. Fish were sampled following the protocol for a single pass electrofishing survey using a Halltech HT 2000B Mrk 5 backpack electrofisher with one operator and two people collecting the fish with dip nets. All fish were identified in the field, processed according to the OSAP protocol, and released. The number of individuals of each species captured, their bulk weight and their size range were determined for non-game species. Individual weights and lengths were determined for game species. Habitat data were collected following Module S4.M2 of the OSAP protocol (Point-Transect Sampling for Channel Structure, Substrate and Bank Conditions). The fish catch and habitat data were entered into Excel and summarized.

An Index of Biotic Integrity (IBI) is used by Conservation Halton to rate stream quality based on the fish community that is present (Conservation Halton, 2013). The approach is modified from Steedman (1988) and uses a composite IBI score derived by summing the scores from either nine (9) sub-indices (for coldwater streams) or 8 sub-indices (for warmwater streams). The scores for warmwater streams are standardized by multiplying them by 1.125. The sub-indices are:

Species Richness

- Number of native fish species present divided by the predicted maximum number of native fish species present
- Number of darter and/or sculpin species present divided by the predicted maximum number of darter and/or sculpin species present
- Number of sunfish and/or trout species present divided by the predicted maximum number of sunfish and/or trout species present
- Number of sucker and/or catfish species present divided by the predicted maximum number of sucker and/or catfish species present

Local Indicator Species

- Presence or absence of Brook Trout (coldwater stations only)
- Percent of the sample that is composed of blacknose and longnose dace (*Rhinichthys atratulus, R. cataractae*)

Trophic Composition

- Percent of the sample that is composed of omnivores
- Percent of the sample that is composed of piscivores

Fish Abundance

- Catch per minute of sampling

The predicted maximum number of native species, darter and/or sculpin species, sunfish and/or trout species and sucker and/or catfish species that could be present are calculated using equations that were derived by Steedman (1988) based on data from the Credit River, Humber River, Don River, Rouge River and Duffins Creek. The equations used to predict the maximum number of species that could be present are as follows:

- Maximum native species richness = 8.24 log10(watershed area) - 0.47
- Maximum darter/sculpin species richness = 3.33 log10(watershed area) - 0.25
- Sunfish/trout species richness = 2.06 log10(watershed area) + 0.48
- Sucker/catfish species richness = 1.45 log10(watershed area) + 0.42, where
- Watershed area = the drainage area upstream from the sampling location.

For their calculations, Conservation Halton determined which species are omnivores and which are piscivores based on information for adults of the species in Coker et al (2001), which ranks the utilization/preference of fish species for nine food types (Andrea Dunn, personal communication with C. Portt, February 21, 2017). The feeding group classifications used for the calculation of the IBI in this study are provided in Appendix G. We categorized the fish species present as omnivore, piscivores, or neither, based on information in the draft Humber River Fisheries Management Plan (O.M.N.R. and T.R.C.A., 2005) with the following exceptions. Creek chub was described as an insectivore, omnivore and piscivore in O.M.N.R. and T.R.C.A. (2005) and was categorized as neither a piscovore or an omnivore for this study. Green sunfish was not present in the Humber River (O.M.N.R. and T.R.C.A., 2005). It was categorized as neither a piscivore nor an omnivore for this study.

The scores for each of the IBI sub-indices are provided in Table 4.7.7**Error! Reference source not found.** and the criteria used to determine the quality rating based on the composite score are provided in Table 4.7.8.

Table 4.7.7 Scoring criteria for the sub-indices used to calculate the fish community IBI.

Sub-index	IBI score		
	5	3	1
Proportion of predicted maximum number of native species	≥0.67	<0.67 and ≤ 0.33	<0.33
Proportion of predicted maximum number of darter and/or sculpin species	≥0.67	<0.67 and ≤ 0.33	<0.33
Proportion of predicted maximum number of sunfish and/or trout species	≥0.67	<0.67 and ≤ 0.33	<0.33
Proportion of predicted maximum number of sucker and/or catfish species	≥0.67	<0.67 and ≤ 0.33	<0.33
Percent of the sample that is composed of blacknose and longnose dace	<50%		>50%
Percent of the sample that is composed of omnivores	<20%	20% to 40%	>40%
Percent of the sample that is composed of piscivores	>2%		<2%
Catch per minute of sampling	4 to 25	>25	<4

Table 4.7.8 IBI scores used to assign the fish community IBI quality rating

Modified IBI score	IBI quality rating
9 - 20	poor
21 - 27	fair
28 - 37	good
38 - 45	very good

Conservation Halton (2013) offers the following caution with respect to the use of the fish community based IBI:

> "It should be noted that with the IBI methodologies, assessment appears to be sensitive to the capture of particular species such as darters, trout and suckers. Generally, a year catch that fluctuated by the number of darter, sucker or trout species could shift the IBI scores significantly. Scores may also fluctuate in response to Catch Per Unit Effort (CPUE) as annual changes in summer staff may effect [sic] catch efficiency. It is also important to note that if suitable information is not collected (i.e. the number or biomass of fish) IBI analysis cannot be completed. For this reason, analysis based on historical information may not be possible. Table 1 provides a summary of IBI ratings and associated scores."

Results

Fish Utilization of headwater Drainage Features and Ponds

The results of fish sampling in headwater drainage features and ponds are summarized in Table 4.7.9 and the locations of dry sites and sites where common fish communities were found are presented in Figures 4.7.4, 4.7.5, and 4.7.6, for the May 9-20, August 10 – September 20, and October 31 – November 11, 2016, sampling periods, respectively. Flow and sampling information for individual locations are provide in Appendix G.

Fish were present in approximately half of the headwater drainage features that were sampled in May; Brook Stickleback and Fathead Minnow were the most frequently encountered species at that time, with one or both of these species, and no other species, captured at 22 of the 30 headwater drainage locations where fish were captured. These species were also the most frequently encountered species in the ponds that were sampled in May.

Most of the headwater drainage features were dry by late summer and fish, again Brook Stickleback and Fathead Minnow, were only captured at one of the four sites where water was present. Four ponds were sampled during this period and fish were present in all of them. Pumpkinseed was the species most commonly captured in the ponds (Appendix G).

Sampling during the period Oct. 31 - Nov. 11, 2016 focused on ponds. Six of the ponds that were examined were dry. Fish were captured from nine of the 12 ponds where water was present and the landowner of one other pond stated that several fish species were present. Brook Stickleback and Pumpkinseed were each captured from four ponds and Fathead Minnow were captured from three (Appendix G).

Table 4.7.9 Number of locations observed and sampled, gear type (NS=not sampled, EF=electrofished, DIP=dipnet, V=visual observation) and the fish community present, by sampling period and feature type (HDF=headwater drainage feature)

Sampling Dates	Feature type	Fish community	Gear				Total
			NS	EF	DIP	V	
May 9 - 20, 2016	HDF	dry	27				27
		no fish captured/seen		24	5	3	32
		Brook Stickleback only		9	2		11
		Fathead Minnow only		8			8
		Fathead Minnow and Brook Stickleback only		3			3
		other species		8			8
	pond	no fish		1			1
		Brook Stickleback only		3			3
		Fathead Minnow only		1			1
		other species		1			1
	Total		27	58	7	3	95
August 10 - Sept. 20, 2016	HDF	dry	26				26
		no fish captured		1	2		3
		Fathead Minnow and Brook Stickleback only		1			1
		unidentified fish observed				1	1
	pond	other species		4			4
	Total		26	6	2	1	35
Oct. 31 - Nov. 11, 2016	HDF	dry	12				12
		no fish captured		1			1
	pond	dry	6				5
		no fish captured		2			3
		Brook Stickleback only		2			2
		Fathead Minnow only		1			1
		Fathead Minnow and Brook Stickleback only		1			1
		other species		6			6
	Total		18	13			31

Baseline Monitoring

Benthic Invertebrate Communities

Location Trafalgar South was dry when the benthic sampling was conducted so no sampling was conducted there. The UTM coordinates of the benthic invertebrate sampling locations and the habitat characteristics at each are presented in Appendix G, and photographs are also provided. There was little flow and hydraulic head (a surrogate for water velocity) was zero at all of the locations except Trafalgar North. Trafalgar North was also the only one of these locations that was not dry by late July.

The number of individuals of each taxon that was identified in each sample are provided in Appendix G. The values for ten benthic invertebrate indices and the impairment status that is indicated by each, as well as the overall impairment status at each location, are presented in Table 4.7.8. The invertebrate communities at Trafalgar North and Fifth Line North were dominated by Isopods. The invertebrate community at Thompson South was dominated by Chironomids and the invertebrate community at Fifth Line South was dominated by oligochaete worms. The overall impairment rating was "impaired" at Thompson South and "possibly impaired" at the other three locations. All of the locations except Trafalgar North were dry later in the summer of 2016. This suggests that the 'impairment' at those three sites may simply be absence of flow.

Table 4.7.10 Values for benthic invertebrate indices and impairment rating at each sampling location

Location	Trafalgar North	Fifth Line South	Thompson South	Fifth Line North
Date	16.05.26	16.05.25	16.05.25	16.05.25
Index values				
number of EPT taxa	2	0	4	0
taxa richness	17	13	29	16
% EPT	3.1	0	5.3	0
% Oligochaeta	9.9	60.3	13.7	13.4
% Chironomidae	16.7	32.1	59.3	18.6
% Isopoda	59.8	4.9	6.2	61.4
% Gastropoda	0.0	0.3	0.3	0.3
% Diptera	17.0	33.8	59.6	20.3
% Insects	20.4	34.1	71.4	21.9
Hilsenhoff Biotic Index	7.5	8.8	6.9	7.8
Shannon-Weiner diversity	1.2	1.4	2.4	1.4
Impairment rating				
Richness (# of Taxa)	unimpaired	unimpaired	unimpaired	unimpaired
% EPT	possibly impaired	impaired	impaired	impaired
% Oligochaeta	possibly impaired	possibly impaired	possibly impaired	possibly impaired
% Chironomidae	impaired	possibly impaired	impaired	possibly impaired
% Isopoda	impaired	impaired	impaired	impaired
% Gastropoda	unimpaired	unimpaired	possibly impaired	unimpaired
% Diptera	impaired	unimpaired	impaired	unimpaired
% Insects	unimpaired	impaired	unimpaired	impaired
Hilsenhoff (MFBI)	possibly impaired	unimpaired	unimpaired	unimpaired
SDI per site	impaired	impaired	impaired	impaired
Unimpaired	3	4	3	4
Possibly Impaired	3	2	2	2
Impaired	4	4	5	4
Overall rating	possibly impaired	possibly impaired	impaired	possibly impaired

Fish Habitat and Communities

Fish community and habitat sampling was conducted at the two baseline monitoring locations where there was flow in late July -- Trafalgar North and Sixth Line. The other four sites were either dry (Fifth Line North, Trafalgar North, Trafalgar South) or reduced to a few standing pools (Fifth Line South). The wetted channel dimensions, hydraulic head (an indicator of velocity), and substrate dimensions are summarized in Appendix G. The sampling site dimensions, electrofishing effort, and catches are summarized in Table 4.7.9. Only one fish, a 16 g Creek Chub, was captured at the Sixth Line location. Agricultural workers at that location stated that the Centre Tributary was dry at this location earlier in the summer, which is consistent with the paucity of fish.

At the Trafalgar North location a total of nine fish species were captured including three darter species, Rock Bass, and a 275 g Northern Pike. The sampling site was divided into two sections by a very shallow area. The Northern Pike and very few other fish were captured in the downstream section while fish were noticeably more abundant in the upstream section. At the flows which prevailed at the time of sampling, the Northern Pike would not have been able to move through the shallow area between the two sections and it is likely that predation by the Northern Pike was responsible for the low numbers of fish in the downstream section of this site.

Table 4.7.11 Sampling date, site dimensions, electrofishing effort, number of individuals and total weight for each fish species captured, and fish community indices for locations where base line fish community data were collected in 2016

Location	Sixth Line		Trafalgar North	
Date	7/28/2016		7/20/2016	
Station length (m)	53.7		44.7	
Mean station width (m)	1.8		2.3	
Station area (m^2)	97		101	
Upstream drainage area (km^2)	9.746		29.34	
Electroseconds	1526		1068	
Electroseconds per m^2	16		11	
Sampling duration (minutes)	27		25	
Species	Number	Weight (g)	Number	Weight (g)
Brown Bullhead			4	132
Common Carp			1	1
Creek Chub	1	16	38	275
Fantail Darter			1	1
Johnny Darter			2	2
Northern Pike			1	276
Rainbow Darter			3	5
Rock Bass			4	42
White Sucker			1	11
Total	1	16	55	745
Number of species	1		9	

Table 4.7.12 Fish community Index of Biotic Integrity metrics, scores and rating

Location	Sixth Line	Trafalgar North
Upstream drainage area (km^2)	9.746	29.34
Date	7/28/2016	7/20/2016
Elapsed time (minutes)	27	25
Total catch	1	55
Number of species	1	9
Number of native species	1	8
Number of darter and/or sculpin species	0	3
Number of sunfish and/or trout species	0	1
Number of sucker and/or catfish species	0	2
Percent of sample that is Rhinichthys species	0	0
Percent of samples that is omnivores	0	9.1
Percent of samples that is piscivores	0	9.1
Catch per minute of sampling	0	2.2
Predicted number of native species	8	12
Predicted number of darter and/or sculpin species	3	5
Predicted number of sunfish and/or trout species	3	4
Predicted number of sucker and/or catfish species	2	3
IBI Scores		
Number of native species	1	3
Number of darter and/or sculpin species	1	3
Number of sunfish and/or trout species	1	1
Number of sucker and/or catfish species	1	3
Percent of sample that is Rhinichthys species	5	5
Percent of samples that is omnivores	5	5
Percent of samples that is piscivores	1	5
Catch per minute of sampling	1	1
Overall IBI	18	29
IBI rating	poor	good

4.7.4 Interpretation / Key Findings

Watershed Overview

The Sixteen Mile Creek watershed is approximately 372 square kilometres in size and drains to Lake Ontario. The main branches of the creek originate along the Niagara Escarpment and then flow southward through a variety of rural and urban settings. The watershed contains coldwater, coolwater, and warmwater streams. The coldwater streams are associated with groundwater discharge and are primarily in the headwaters and near the Niagara Escarpment (Conservation

Halton, 2013). The streams that are further south, where there is little groundwater discharge, tend to be either coolwater or warmwater (Conservation Halton, 2013).

The Primary Study Area for this project encompasses 32.8 square kilometres, which is about 9% of the Sixteen Mile Creek watershed. Most of the primary Study Area is located within the East Branch drainage area, but a small portion is located within the West Branch drainage area. "Approximately 68 fish species" have been recorded in the Sixteen Mile Creek watershed since the early 1900s (Conservation Halton, 2013). The species that have been reported from each of the major sub-catchments within the study area are provided in Table 4.7.13.. The characteristics of the main watercourse(s) in those sub-catchments are summarized below. The locations of the sub-catchments are provided in Figure 4.7.7.

Table 4.7.13 Fish species that have been reported from each of the sub-catchments that are discussed in this report. P indicates the species is present. Highlighted cells indicate that the presence of this species is first documented as a result of fish sampling conducted during this study. Number of stations includes both historic sampling locations and locations sampled during this study

		Sub-catchment								
		West Branch	Lower Middle Branch [1]	Lower Middle Branch [2]	Middle Branch	East Middle Branch	East Branch	Lower Middle Tributary	Centre Tributary	Omagh Tributary
Number of Stations		24	26	26	5	7	39	24	19	17
Number of Species		23	26	27	17	18	20	10	15	6
Common name	Scientific name									
Black Crappie	*Pomoxis nigromaculatus*		P	P						
Blacknose Dace	*Rhinichthys atratulus*	P	P	P	P	P	P			
Blacknose Shiner	*Notropis heterolepis*			P						
Bluegill	*Lepomis macrochirus*			P	P					
Bluntnose Minnow	*Pimephales notatus*		P	P	P	P	P		P	P
Brook Stickleback	*Culaea inconstans*	P	P		P	P	P	P	P	P
Brook Trout	*Salvelinus fontinalis*					P				
Brown Bullhead	*Ameiurus nebulosus*	P	P	P	P		P	P	P	
Chinook Salmon	*Oncorhynchus tshawytscha*		P							
Common Carp	*Cyprinus carpio*		P	P		P	P	P	P	
Common Shiner	*Luxilus cornutus*	P	P	P	P	P	P		P	
Creek Chub	*Semotilus atromaculatus*	P	P	P	P	P	P	P	P	P
Fantail Darter	*Etheostoma flabellare*	P	P	P		P	P			
Fathead Minnow	*Pimephales promelas*	P	P	P		P	P	P	P	P
Golden Redhorse	*Moxostoma erythrurum*			P						
Golden Shiner	*Notemigonus crysoleucas*						P			
Goldfish	*Carassius auratus*	P							P	
Hornyhead Chub	*Nocomis biguttatus*	P								
Johnny Darter	*Etheostoma nigrum*	P	P	P	P	P	P		P	
Largemouth Bass	*Micropterus salmoides*	P	P	P		P	P	P	P	
Longnose Dace	*Rhinichthys cataractae*	P	P	P	P	P	P			
Northern Hog Sucker	*Hypentelium nigricans*	P	P	P	P	P				
Northern Pike	*Esox lucius*			P			P		P	
Northern Redbelly Dace	*Chrosomus eos*					P	P			
Pumpkinseed	*Lepomis gibbosus*	P	P	P		P	P	P	P	P
Rainbow Darter	*Etheostoma caeruleum*	P	P	P	P	P	P		P	
Rainbow Trout	*Oncorhynchus mykiss*	P	P							
River Chub	*Nocomis micropogon*	P	P	P	P					
Rock Bass	*Ambloplites rupestris*	P	P	P	P	P	P	P		

Table 4.7.13 Fish species that have been reported from each of the sub-catchments that are discussed in this report. P indicates the species is present. Highlighted cells indicate that the presence of this species is first documented as a result of fish sampling conducted during this study. Number of stations includes both historic sampling locations and locations sampled during this study

		Sub-catchment								
		West Branch	Lower Middle Branch [1]	Lower Middle Branch [2]	Middle Branch	East Middle Branch	East Branch	Lower Middle Tributary	Centre Tributary	Omagh Tributary
Number of Stations		24	26	26	5	7	39	24	19	17
Number of Species		23	26	27	17	18	20	10	15	6
Common name	Scientific name									
Rosyface shiner	*Notropis rubellus*	P	P	P	P					
Sea Lamprey	*Petromyzon marinus*			P						
Silver Shiner	*Notropis photogensis*	P	P	P						
Smallmouth Bass	*Micropterus dolomieu*	P	P	P	P		P	P		
Stonecat	*Noturus flavus*	P	P	P	P				P	
Striped Shiner	*Luxilus chrysocephalus*		P							
White Sucker	*Catostomus commersonii*	P	P	P	P	P	P	P	P	P

1 – Lower Middle Branch downstream from the primary study area.
2 - Lower Middle Branch within the primary study area.

West Branch

The West Branch of Sixteen Mile Creek passes through the western-most portion of the Study Area and its drainage boundary is approximately the western boundary of the Primary Study Area. This branch begins at the confluence of the Kelso Branch and the North Branch in downtown Milton, where it is contained within a concrete channel. That channel continues downstream for approximately 1.2 km, and then transitions to a 547 m long section of interlocking concrete structures that ends approximately 260 m upstream of Derry Road. This hardened section suffers from a lack of habitat structure, riparian vegetation, and natural substrate. From the end of the interlocking concrete channel downstream, the channel is essentially natural and contained within a defined valley, with a typical pool/riffle/run morphology, though it is constrained in a few location by roads and bridge structures. The West Branch joins with the Lower Middle Branch at the edge of the Supplemental Study Area. Summer flow in the West Branch is augmented by discharge from the Kelso Reservoir and the Milton Wastewater Treatment Plant also discharges to the West Branch.

Twenty-three species of fish have been recorded from the West Branch within the Primary Study Area and downstream to Lower Baseline Road (Table 4.7.13). Though the community is generally composed of coolwater and warmwater species, this portion of Sixteen Mile Creek is an important migratory route for Rainbow Trout, Brown Trout, and Chinook Salmon. These introduced species mainly spawn upstream of the Primary Study Area, from approximately Regional Road 25 upstream to the Kelso Dam, however, some spawning by these species has been observed at specific locations within the study area downstream of Regional Road 25 (Andrea Dunn, Conservation Halton. Personal communication with G. Coker, February 21, 2017). The fish species present are appropriately matched with the habitat in this part of Ontario, being typical inhabitants of medium to large sized watercourses with pool/riffle/run morphology with flow-sorted coarse to fine substrates; generally shallow (<1 m), but with a range of depths and current speeds from swift in the riffle sections to slow in the pools.

Of particular interest is the presence of Silver Shiner throughout this section of the West Branch based on its capture at five locations there in 2013. Silver Shiner are listed as "Special Concern" in Schedule 3 of the Federal Species At Risk Act (SARA) (http://www.sararegistry.gc.ca, February 15, 2017), and as "Threatened" under the Ontario Endangered Species Act (http://www.ontario.ca/environment-and-energy/species-risk-ontario-list, February 15, 2017). Silver Shiner are found in larger, clear, warmwater streams of moderate gradient and hard bottom, within the larger, deeper pools near ample current (Jenkins and Burkhead, 1993; Coad *et al*, 1995; Smith, 1985). Trautman (1981) states that it is most abundant in deep, swift riffles and in the swifter eddies and currents of the pools immediately below such riffles. Silver Shiners utilize the mid to upper reaches of the water column and may not be associated with the substrate (Jenkins and Burkhead, 1993), suggesting that hard substrates may not be a critical part of its habitat, but may simply be the most common substrate type in the type of stream it inhabits. Spawning is thought to occur from late May to mid-June, and though spawning habitat is poorly known, there is some evidence that spawning occurs in relatively deep riffles (COSEWIC, 2011).

The tributaries discharging to the West Branch of Sixteen Mile Creek within the Primary Study Area have their headwaters on the flat Peel Plain that surrounds the incised West Branch channel. These are usually heavily impacted by agriculture and historical ditching practices, except where they approach the valley of the West Branch, where they become steeper as they descend to the West Branch channel. These tributaries receive little or no groundwater and typically dry completely or to isolated standing pools during most summers.

The largest of the West Branch tributaries (TSMC(1)9, Figure 4.7.7) originates outside of the Primary Study Area, north of Britannia Road. TSMC(1)9 drains a sizable portion of the Primary Study Area on the east side of the West Branch through a network of swales, ditches and watercourses with defined channels, and then drops into a steep-gradient, incised channel that turns west to connect with the West Branch.

The fish community in intermittent watercourses is usually composed of a few fish species that are tolerant of the conditions that occur in the isolated pools during the summer. These conditions include warm temperatures, low dissolved oxygen concentrations and zero flow velocity. Less tolerant species may use these watercourses seasonally if they are accessible from higher quality downstream habitats. In TSMC(1)9, the fish community in the isolated pools located approximately 170 m upstream from the West Branch, was composed of White Sucker, Creek Chub, and Brook Stickleback, which are all relatively tolerant of poor instream conditions. Higher up in this watercourse at Britannia Road, which is 3.2 km upstream from the West Branch main channel, only Fathead Minnow were captured in a small isolated muddy pond. Fathead Minnows are found in a broad range of habitats, however, it is also very tolerant of low oxygen and high alkalinities (Scott and Crossman, 1973, Stewart and Watkinson, 2004; Jenkins and Burkhead, 1993), and consequently it is often the most abundant fish in pools or other habitats that become isolated during dry conditions (Stewart and Watkinson, 2004).

Middle and East Branches of Sixteen Mile Creek

The Middle and East Branches of Sixteen Mile Creek drain approximately 91% of the Primary Study Area. Three main watercourses enter the the Primary Study Area from north of Highway 401: the Middle Branch at approximately Fifth Line, the East Middle Branch at approximately Sixth Line, and the East Branch at approximately Trafalgar Road (Figure 4.7.7). The Middle Branch and the East Middle Branch are approximately equal in size and they join about 1.2 km southeast of Highway 401 to become the Lower Middle Branch. The East Branch is somewhat smaller and meanders in the vicinity of Trafalgar Road for approximately 8.7 km, crossing it twice, before joining with the Lower Middle Branch.

In this upper part of the Primary Study Area the Lower Middle Branch has a somewhat more defined valley than the East Branch, but both are meandering channels that are bordered in places by wetlands, and in other areas by agricultural operations. The Lower Middle Branch and the East Branch join approximately 330 m upstream of Britannia Road to become the Lower Middle Branch. The Lower Middle Branch flows in a southeast direction and occupies a broader and increasingly incised valley. It exits the Primary Study Area approximately 2.2 km downstream of Britannia Road. The Lower Middle Branch continues for another 9.3 km before it joins with the

West Branch of Sixteen Mile Creek, briefly entering the Primary Study Area again in the vicinity of Fifth Line and Baseline Road. There are four main tributaries of these watercourses: the Lower Middle Tributary, the Centre Tributary, the Omagh Tributary, and tribuary TESMC(1b)11.

Lower Middle Branch

For discussion purposes, the Lower Middle Branch is divided into two sections, within the Primary Study Area and downstream within the Supplemental Study Area. Within the Primary Study Area the Lower Middle Branch has a lower gradient and is less constrained by its valley, and consequently exhibits a more meandering form, than farther downstream. The general channel form is a series of pool/riffle/run habitats. The fish community includes 27 species (Table 4.7.13), retaining most of the species observed in the downstream section of the Lower Middle Branch in the Supplemental Study Area, but also having species typical of lower flow velocity and pond-like situations where aquatic plants may be more plentiful. This latter group of fish species include Blacknose Shiner, Bluegill, Golden Redhorse, Northern Pike and Northern Redbelly Dace. The Golden Redhorse is an oddity at this location, because a small population of this species apparently persists (captured in 1998 and 2014) in one location in the Sixteen Mile Creek watershed in the vicinity of Britannia Road, and this is the only known location for this species in the Ontario portion of the Lake Ontario watershed, although it is known from Lake Ontario tributaries in the state of New York. The Golden Redhorse is found in Ontario tributaries to Lakes Erie, St. Claire and southern Lake Huron (Scott and Crossman, 1973) and is not considered a species-at-risk in Ontario or Canada. The Silver Shiner is also known from the Lower Middle Branch, in the vicinity of Britannia Road.

Downstream from the Primary Study Area, within the Supplemental Study Area, 27 species of fish have been recorded in the Lower Middle Branch. The instream habitat in this part of the Lower Middle Branch is very similar to that in the West Branch within the Primary Study Area, being primarily pool/riffle/run, and with a similarly sized channel. It is therefore not surprising that these two watercourses have 20 fish species in common (Table 4.7.13). Similar to the West Branch, the fish community is generally composed of coolwater and warmwater species and, like the West Branch, this portion of the Lower Middle Branch is an important migratory route for Rainbow Trout which have been known to successfully spawn in the East Middle Branch upstream of the Primary Study Area (Andrea Dunn, Conservation Halton. Personal communication with G. Coker. February 21, 2017). Brown Trout and Chinook Salmon may also migrate through this area, but this has not been documented. There is currently no evidence of successful Rainbow Trout, Chinook Salmon, or Brown Trout spawning within the Primary Study Area (Andrea Dunn, Conservation Halton. Personal communication. February 21, 2017). The fish species present are typical inhabitants of medium to large, but relatively shallow, streams, with pool/riffle/run morphology, flow-sorted coarse to fine substrates, and a range of current speeds from swift in the riffle sections to slow in the pools. Silver Shiner has been captured throughout this portion of the Lower Middle Branch.

Middle Branch

Only about 3 km of the Middle Branch channel is within in the Primary Study Area and much of that is a meandering channel within a wetland. The habitat appears to be similar along its length, with a slight increase in gradient and flow velocity with distance upstream. The 17 species of fish that have been reported from this reach (Table 4.7.13) include species typical of both riffle and quiet-water habitats, both of which occur here. The lower number of fish species that have been reported, relative to the Lower Middle Branch, may reflect the lower diversity of habitats within this reach but could also be because there are only five sampling stations here, compared to twenty-two sampling stations in the Lower Middle Branch. While there are no records of Silver Shiner being captured in the Middle Branch within the Primary Study Area, it is possible that they do occur here because both Emerald Shiner (typically a lake species) and Rosyface Shiner, which are sometimes confused with Silver Shiner, have been reported.

East Middle Branch

Similar to the Middle Branch, most of the 2 km of meandering channel of the East Middle Branch that is within the Primary Study Area is situated within a wetland. In total, 18 species of fish have been captured at one or more of seven sampling locations (Table 4.7.13). The species are typical of both flowing and quiet-water habitats, both of which occur here. There are no records of Silver Shiner being captured, nor are there records of Rosyface or Emerald Shiners that might be misidentifications of Silver Shiner. Brook Trout have been captured in low numbers at the upstream end of this reach, in the vicinity of Hwy 401, and it is thought that this represents the downstream limit of a Brook Trout population that occurs upstream of the Primary Study Area (Andrea Dunn, Conservation Halton. Personal communication. February 21, 2017). The East Middle Branch is an important migratory route for Rainbow Trout, which have been known to successfully spawn in the East Middle Branch upstream of the Primary Study Area (Andrea Dunn, Conservation Halton. Personal communication. February 21, 2017).

East Branch

The East Branch flows for approximately 8.7 km within the Primary Study Area, from Highway 401 to where it joins the Lower Middle Branch about 330 m upstream from Britannia Road. It is a fairly small meandering channel within a broad shallow valley, bordered by wetland for approximately 50% of its length. There are a few locations where it appears to have been straightened, and there are two large, on-line ponds downstream of Derry Road. Instream habitat appears to be dominated by flatwater or run habitat, with some apparently deep channel sections. The on-line ponds provide pool-like habitats as well. Riffles are short, and make up a relatively small proportion of the available habitat, although they are more prevalent near the confluence with the Lower Middle Branch. There is a concrete weir near the downstream end of the East Branch, just downstream of Trafalgar Road. This weir would be a barrier to most fishes although species such as Rainbow Trout, with good jumping ability, might be able to pass over it.

In August of 2016 flow appeared to have ceased in the East Branch, but there was standing water in all of the places where it was examined.

There have been 20 species of fish captured in this branch at one or more of 39 locations (Table 4.7.13). These include three previously unreported species; Brown Bullhead, Northern Pike and Rainbow Darter, that were captured during the base line monitoring for this project. The base line monitoring site is located downstream from the migration barrier that is just downstream from Trafalgar Road, close to the Lower Middle Branch. The fish community is dominated by fishes that prefer slow flowing or quiet habitats (e.g. Bluntnose Minnow, Common Carp, Northern Redbelly Dace, Rock Bass), but also include a few species that prefer flowing water (e.g. Blacknose Dace, Creek Chub) and some species that prefer faster riffles (e.g. Fantail Darter, Longnose Dace).

Lower Middle Tributary

This tributary originates north of Derry Road east of Eighth Line and joins the Lower Middle Branch downstream from Britannia Road, just west of Trafalgar Road. Many of the headwater features upstream from Britannia Road are poorly defined, reflecting the limited flow and flat topography.

Though there appears to be some seasonal groundwater inputs to this watercourse just downstream of Derry Road that may extend the persistence of standing water into the summer, most of the tributary was dry in 2016. Water persisted in the ditched section within the wetland located approximately 750 m upstream of Britannia Road and at the culvert beneath Trafalgar Road. There are also a number of dug farm and golf course ponds within this catchment that contain water through the summer.

As in most watercourses that become dry or almost dry during most summers, the distribution of fish and the composition of the fish community is dictated by local differences in flow duration and the distribution of low flow refugia. The 10 fish species (Table 4.7.13) that have been captured at one or more of the 24 stations sampled in this tributary are generally warmwater species that inhabit slow moving stream and lake or pond habitats. Most of these fish are confined to the lowest reaches of the Lower Middle Tributary, where water and flow persist longer and where they can more easily recolonize from the permanent habitat in the Lower Middle Branch.

The fish community throughout most of this tributary is composed of Fathead Minnow and/or Brook Stickleback, both of which can survive in low oxygen/high temperature water in small isolated pools (Stewart and Watkinson, 2004), and have a tendency to disperse into these habitats during periods of higher flow in the spring. Pumpkinseed and Largemouth Bass also occupy some of the dug farm and golf course ponds in this tributary.

Centre Tributary

The Centre Tributary originates outside of the Study Area in the built Bristol Phase 1 development area of Milton. This watercourse is the boundary of the South Milton Primary Study Area from James Snow Parkway to its confluence with the Lower Middle Branch. The first 1.3 km in the Primary Study Area, east of James Snow Parkway, was historically straightened across agricultural fields and as a section of the Fifth Line roadside ditch, but is in the process of naturalizing. East of Fifth Line it enters a shallow valley and continues as a natural, meandering channel for 3.0 km to its confluence with the Lower Middle Branch, east of Sixth Line.

When examined in 1998 the Centre Tributary it was dry except for isolated pools and road culverts. After the Phase 1 lands were developed in the early 2000s the Centre Tributary began to flow permanently and the fish community became more diverse (AMEC, 2015). Fifteen fish species have been captured in the Centre Tributary (Table 4.7.13). Most of these fishes are adapted to slow-flowing watercourses with fine substrates, which is the dominant habitat in the watercourse. Rainbow Darter and Stonecat prefer higher velocities and coarser substrates (Holm *et al*, 2009) than are typical through most of this tributary, but they have only been captured at the downstream end, near its confluence with the Lower Middle Branch.

Omagh Tributary

The Omagh Tributary arises at the south border of the present Milton urban area and flows southeast, entering the Primary Study Area at the intersection of Britannia Road and Fourth Line. Just upstream of Britannia Road, it is the roadside ditch. Downstream of Britannia Road, in the Primary Study Area, this watercourse meanders through agricultural fields within a shallow valley feature. The substrate is soil. Downstream of Fifth Line the Omagh tributary enters a deeper wooded valley feature. Gradient increases and substrate becomes coarser as it descends to join the Lower Middle Branch in its deep valley.

During most years the Omagh Tributary dries to standing pools. In the summers of 1998 and 2007 the only water upstream of Fifth Line was observed to be within the culvert at Britannia Road (AMEC, 2015). In 2016 the watercourse appeared similarly dry, but a number of persistent pools were observed downstream of Fifth Line within the forested valley. Approximately 160 m downstream of Fifth Line the watercourse passes through a culvert/weir structure under a farm access lane, which blocks upstream movement of all fish. Of the 6 species of fish captured in the Omagh Tributary (Table 4.7.13), only Brook Stickleback and Creek Chub are known to occur upstream of this barrier.

Tributary TESMC(1b)11

TESMC(1b)11 originates along the north border of the Primary Study Area, in the vicinity of Britannia Road (Table 4.7.13). Except for the most downstream 840 m of this tributary that is within an incised wooded valley feature, TESMC(1b)11 is situated on the flat tablelands where it is essentially a series of headwater drainage features, impacted by agriculture. By May 11, 2016, flow had ceased at locations in the upper catchment area, and was less than 1 L/s in the main channel of the downstream portion of the catchment area. By August the watercourse was completely dry, but there was water in some farm ponds.

The fish community in intermittent watercourses is usually composed of a few fish species that disperse into headwater features during the spring, when most watercourses are flowing, and are tolerant of the conditions that occur in small isolated pools during the summer. The best examples of such fishes in southern Ontario are Brook Stickleback and Fathead Minnow, which were the only fish species captured in the watercourses of TESMC(1b)11 during the spring. Sampling during the fall of 2016, when all watercourses in this catchment were dry and the only remaining surface water was in dug farm ponds, captured Brook Stickleback and Fathead Minnow in one pond and Common Carp and Rock Bass were found in another. The dug farm pond containing the Common Carp and Rock Bass was isolated to the extent that it would be unlikely for such species to colonize this pond naturally; it is likely that these species were deliberately introduced at some time in the past.

Headwater Drainage Features

Headwater drainage features are, by definition, intermittent or ephemerally flowing features. Most headwater drainage feature flow during the spring freshette and are dry by mid-summer. The duration of flow can be affected by factors such as surface storage, seasonal groundwater discharge, vegetation cover, and watercourse slope. Some of these features may also flow after precipitation events if infiltration capacity and evapotranspiration are exceeded. These features are often not apparent except when they are flowing because they do not have a defined channel. However, water can persist for extended periods or all year along these watercourse features where there are natural ponds or wetlands, or, most often, in man-made features such as dug farm ponds, culvert or bridge crossings, or ditches. While headwater drainage features perform important flow attenuation and infiltration functions, and provide other ecological functions, their potential as fish habitat is limited by their flow regime and the persistence, or lack of persistence, of standing water. The provision of temporary connections that allow fish to invade more persistent headwater aquatic habitats can also be an important function.

Fathead Minnow and Brook Stickleback are the most common colonizers and, where water persists, occupants of these headwater habitats. The Fathead Minnow is known as a "pioneer" species, and in one of the first to invade intermittent drainage channels after rains, commonly progressing upstream into farm ponds via their spillways (Becker, 1983). The Fathead Minnow is tolerant of the warm temperatures and low dissolved oxygen concentrations that occur in isolated pools and ponds, (Becker, 1983; Stewart and Watkinson, 2004), surviving where other fish cannot. It shares this invasiveness with the Brook Stickleback (Stewart and Watkinson, 2004). While conducting field work in southern Ontario during the early spring, Fathead Minnows and/or Brook Stickleback are occasionally encountered in the water laying on saturated cultivated fields, or in small drainage furrows (George Coker, personal observation.). When flow ceases, the hardiness of these fishes allows them to persist in small pools of isolated water (Becker, 1983; Stewart and Watkinson, 2004) and even in flooded muskrat burrows (Becker, 1983).

4.8 Terrestrial Resources

4.8.1 Importance / Purpose

Terrestrial ecosystems encompass upland and wetland vegetation of natural and cultural origin, providing habitat for wildlife which may utilize features on a transitory, seasonal or permanent basis. Terrestrial ecosystems provide intrinsic functions or services regarding photosynthesis, storage, and processing of carbon, minerals, and nutrients as well as moisture. The above- and below-ground structure provided by vegetation interact with air and water to promote conservative management and cycling of water and soil resources, manage a more stable microclimate, and in the process helps to sustain other reliant biota such as wildlife species, fish, and invertebrates. The vertical and horizontal structure of vegetation systems, in conjunction with physical attributes of soil and water, is capable of sustaining many species and populations of plants and animals as habitat structure evolves in extent, age and complexity over decades and longer periods. At watershed and larger scales, these services are integral to sustaining the fundamental hydrologic and chemical cycles.

The purpose of terrestrial characterization is to further document and refine the understanding of existing conditions in the study area, regarding vegetative cover, flora and fauna, and ecosystem functions. The understanding of this system is hierarchical in nature and considers the ecological form, function, and linkage of species and natural features and areas within the broader landscape context; this will inform decisions on future development including refinement of the Regional Natural Heritage System (NHS).

4.8.2 Background Information

The South Milton Subwatershed Study Area is situated in southern Ontario at the western extent of the Greater Toronto Area (Map T1). The South Milton SWS is entirely within the watersheds of the Sixteen Mile creek and east Sixteen Mile creek (Map T1).

The South Milton SWS is within the northernmost extent of Ecodistrict 7E (Lake Erie - Lake Ontario), which is the most southern Ecoregion in Canada and Ontario (Crins et al. 2009). This Ecoregion also lies within the Deciduous Forest Region of Rowe (1972) and is known commonly as the Carolinian Zone. Ecoregion 7E is characterized by predominantly deciduous forests of Sugar Maple (*Acer saccharum*), American Beech (*Fagus grandifolia*), Ash species (*Fraxinus* sp), Eastern Hemlock (*Tsuga canadensis*), and Eastern White Pine (*Pinus strobus*), and in more southern areas by Tulip Tree (*Liriodendron tulipifera*), Black Gum (*Nyssa sylvatica*), Sycamore (*Platanus occidentalis*), Oak species (*Quercus* sp), and Hickory species (*Carya* sp). At a more local scale, the study area is within Ecodistrict 7E-4, which extends east from the Niagara Escarpment at the western tip of Lake Ontario to the Rouge River Valley, and from the shore of Lake Ontario north to the Oak Ridges Moraine. This Ecodistrict contains only 6% natural cover, which is predominantly till plain deciduous forest and till plain mixed forest, sand plain mixed forest, and swamp forest. The remainder is mostly agricultural and developed land (Henson & Brodribb 2005). The vicinity of the South Milton SWS is dominated by agricultural lands, with natural areas concentrated in the Sixteen Mile creek, east Sixteen Mile creek, and their major tributaries, and scattered woodlots and wetlands on the surrounding tablelands.

Various background reports and databases were reviewed for existing information on terrestrial natural heritage in the general area of the South Milton SWS. A brief description of these background studies, when they were completed, and the general area they covered are outlined below. Species records, vegetation community types, and other details related to the terrestrial ecological characteristics of the area were extracted, and are summarized in Appendix H1 and H2.

Federal and Provincial Species Atlases

- Ontario Breeding Bird Atlas (OBBA), 2001 – 2005 (Cadman *et al.* 2007);
- Atlas of the Mammals of Ontario (Dobbyn 1994);
- Ontario Reptile and Amphibian Atlas Interactive Range Maps (Ontario Nature 2015);
- Ontario Butterfly Atlas Online (Toronto Entomologists' Association 2015)
- Atlas of Ontario Odonata (Colin Jones, pers. comm. 2016)

Species at Risk Databases/ Correspondence

- Element Occurrence Data for Provincially tracked species, plant communities and wildlife concentration areas query (NHIC 2016);
- Consultation with Aurora District MNRF for Species at Risk (SAR) records (via an Information Request);
- Conservation Halton Element Occurrence and Rare Species Data (Conservation Halton 2016)

Regional Studies

- Great Lakes Conservation Blueprint for Terrestrial Biodiversity (Henson & Brodribb 2005);
- Halton NAI (Dwyer et al. 2006);
- Britannia Road Transportation Corridor Improvements: Environmental Study Report (North-South Environmental 2011 & 2013);
- North Oakville Creeks Subwatershed Study;
- Premier Gateway Subwatershed Study;
- 401 Corridor Integrated Planning Project, Town of Halton Hills: Scoped Subwatershed Plan (Dillon 2000);
- Sixteen Mile Creek Subwatershed Update Study/Functional Stormwater and Environmental Management Studies (AMEC Environment & Infrastructure et al., 2013);
- Sixteen Mile Creek Watershed Plan (Gore & Storrie Limited and Ecoplans Ltd., 1996)

Local Studies

- Milton Phase 3 Monitoring (D&A 2016);
- Milton Phase 2 Holistic Monitoring Study (D&A 2010 – 2014);
- Derry Green Corporate Business Park Subwatershed Impact Study – Study Area 5A (Savanta 2016);
- Boyne Secondary Plan Wildlife Survey Data (Dougan 2010)

Federal & Provincial Species Atlases

The following species atlases were queried for species records within and surrounding the Primary and Supplemental Study Areas:

- Ontario Breeding Bird Atlas (OBBA), 2001 – 2005 (Cadman *et al.* 2007);
- Atlas of the Mammals of Ontario (Dobbyn 1994);
- Ontario Reptile and Amphibian Atlas (Ontario Nature 2015);
- Ontario Butterfly Atlas Online (Toronto Entomologists' Association 2015)
- Atlas of Ontario Odonata (Colin Jones, pers. comm. 2016)

All of these sources used a corresponding 10 x 10 km grid square system; this provides consistent spatial coverage for a range of species that have been documented in the general area. The primary and Supplemental Study Areas are located within four 10 x 10 km grid squares: 17NJ91, 17NJ92, 17PJ01, and 17PJ02, as shown in Appendix H3. Square 17NJ91 encompasses most of the northern portion of the study area, while square 17NJ92 covers most of the southern section. Squares 17PJ01 and 17PJ02 only contain very small portions of the study area, therefore may not be as representative as those with more coverage. These squares were included nonetheless to ensure comprehensive coverage when performing species records queries. Because of the size of the atlas squares, the combined primary and Supplemental Study Area only covers a percentage of each 10 x 10 km square. Specifically, the Primary and Supplemental Study Areas together cover 31.9% of square 17NJ91, 23.5% of square 17NJ92, 2.2% of square 17PJ01, and only 0.79% of square 17PJ02.

Ontario Breeding Bird Atlas (OBBA), 2001 – 2005 (Cadman et al. 2007);

The Ontario Breeding Bird Atlas (Cadman et al. 2007) provides information on the distribution and status of Ontario birds. The Atlas was created using five years (2001 – 2005) of birding data from atlassers across the province. The online database was queried on November 1st, 2016 for records within grid squares 17NJ91, 17NJ92, 17PJ01 and 17PJ02. This resource was used to screen for potential species-at-risk in the area as well as to provide a comprehensive list of species to compare with those found during field investigations.

Atlas of the Mammals of Ontario (Dobbyn 1994);

The Atlas of the Mammals of Ontario (Dobbyn 1994) was created by the Federation of Ontario Naturalists and provides historical and recent distributional data for all wild mammals found in Ontario, based primarily on existing institutional data, and supplemented with volunteer records. The Atlas was searched for mammal records within 10 x 10 km atlas grid squares 17NJ91, 17NJ92, 17PJ01, and 17PJ02, mainly to provide a list of potential Species-at-Risk that could be residing in the study area. The age of the publication and low resolution of data, however only provide general guidance on potential occurrence of species for the South Milton SWS area.

Ontario Reptile and Amphibian Atlas (Ontario Nature 2015);

The Ontario Reptile and Amphibian Atlas was recently developed by Ontario Nature as a citizen-science based project that tracks the distribution of reptiles and amphibians across the province.

Because there are wetlands, ponds, and amphibian breeding habitat present within many of the subject properties, it was important to determine any historical records for this species group, particularly species-at-risk, within the subwatershed study area. The four 10 x 10 km atlas grid squares 17NJ91, 17NJ91, 17PJ01 and 17PJ02, were queried for all amphibian and reptilian records dating back to pre-1976.

Ontario Butterfly Atlas Online (Toronto Entomologists' Association 2016);

The Ontario Butterfly Atlas maps the distribution of butterfly species within the province, using mainly observation data but also some museum records that date back to 1879. The atlas was queried for all records in squares 17NJ91, 17NJ92, 17PJ01, and 17PJ02.

Atlas of Ontario Odonata (Colin Jones, pers. comm. 2016);

The Atlas of Ontario Odonata track the occurrences of odonate species in Ontario and maps their distribution across the province. Because this atlas is not currently available online, the Ministry of Natural Resources and Forestry's Natural Heritage Information Centre provided lists of odonate species documented for the 10 x 10 km atlas grid squares that encompass the South Milton SWS primary and Supplemental Study Areas: 17NJ91, 17NJ92, 17PJ01, and 17PJ02.

Provincially Tracked Species

Element Occurrence Data for Provincially Tracked Species, Plant Communities and Wildlife Concentration Areas query (NHIC 2016);

Terrestrial records from the MNRF were queried through the Natural Heritage Information Centre. The query included a search for element occurrence records for the appropriate 1 x 1 km squares that covering the primary and Supplemental Study Areas and extended 1km from the study area boundaries. This included over 100 grid squares that are displayed in Appendix H3.

Consultation with Aurora District MNRF for SAR records (via an Information Request);

A Species at Risk (SAR) information request form was sent to MNRF Aurora District on June 3, 2016, to acquire any species at risk records within or adjacent to the primary and Supplemental Study Areas.

Regional Studies

Conservation Halton Element Occurrence and Rare Species Data (Conservation Halton 2016);

Element occurrence and rare species data was received from Conservation Halton in May 2016. This data contained georeferenced species records for significant and rare birds, reptiles, amphibians, odonates and plants that have been observed within and adjacent to the primary and Supplemental Study Area.

Great Lakes Conservation Blueprint for Terrestrial Biodiversity (Henson and Brodribb 2005);

This document summarized available information on the biological diversity of the 39 ecodistricts across the Great Lakes ecoregion. It considers threats to biodiversity, including habitat loss, land use and development, exotic and invasive species, recreational uses, pollution, and climate change. This blueprint also includes information on prominent species and vegetation communities and conservation lands. Ecodistrict 7E-4 (Whitby) contains the South Milton SWS lands, encompassing the City of Toronto, Peel Region, Halton Region and York Region. The summary for this ecodistrict was reviewed for wildlife and vegetation species and vegetation community targets to compare with this study's findings.

Halton Natural Areas Inventory (Dwyer 2006);

The Halton Natural Areas Inventory is a collaborative effort among local naturalist clubs and government agencies to inventory and document flora and fauna occurring within the Region of Halton's natural areas, including existing and candidate Ecologically Significant Areas (ESAs) (Dwyer, 2006). A total of sixty-three (63) natural areas within the Region of Halton, extending from the Lake Ontario Shoreline to the Niagara Escarpment, are mapped and summarized. The ELC and botanical inventory data for two NAI features, Drumquin Woods and the Sixteen Mile Creek and extension, were obtained from Conservation Halton and reviewed. Additionally, species' status from the Halton NAI is used as the conservation status of species documented in the South Milton SWS area.

Britannia Road Transportation Corridor Improvements: Environmental Study Report (North-South Environmental 2011 & 2013);

The Britannia Road Environmental Study Report was completed for the Regional Municipality of Halton in 2014. The study area spans from Tremaine Road to Highway 407 along Britannia Road. Certain terrestrial field investigations including nocturnal amphibian calling surveys and breeding bird surveys were carried out in 2011 and 2013 by North-South Environmental. The vast majority of the Britannia Road study area is located within the South Milton SWS area, so the species observed are directly applicable to this study and will serve as a good comparison to species detected during Phase 4 investigations. These species records are summarized in Appendix H1 and H2.

North Oakville Creeks Subwatershed Study (2006);

The North Oakville Creeks Subwatershed Study combines analysis, characterization, implementation and management reports to plan for future urban development in the North Oakville Development Area, north of Dundas Street. The study area located south of the South Milton SWS lands and is bounded by Dundas Street to the south, Highway 407 to the north, Ninth Line to the east and Tremaine Road to the west. A number of catchment areas within the North Oakville Creek Subwatershed are relevant within the South Milton SWS, including Joshua's Creek, Morrison Creek, Fourteen Mile Creek, and Sixteen Mile Creek. The northern boundary of this study (Highway 407) partially overlaps with the southern portion of the Supplemental Study

Area; natural heritage information, including species records, from this study, may be relevant for this project but were not available as part of the report resources.

401 Corridor Integrated Planning Project, Town of Halton Hills: Scoped Subwatershed Plan (Dillon 2000);

The 401 Corridor Subwatershed Study was conducted to provide support for the Secondary Plan. The study was scoped to specific portions of Subwatersheds 3, 4, 5 and 6 of Sixteen Mile Creek within the 401 Corridor boundaries, which extend from Highway 401 to Steeles Avenue, and from James Snow Parkway east to Winston Churchill. The 401 Corridor study area extends south and partially into the South Milton SWS area, and therefore the terrestrial species records may provide a good comparison to the species found during field investigations within the study areas to date. These records were reviewed, and a list of species found are provided in Appendix H1 and H2.

Sixteen Mile Creek Subwatershed Update Study/ Functional Stormwater and Environmental Management Studies;

The Sixteen Mile Creek Subwatershed Update Study (SUS) (AMEC Environment & Infrastructure et. al., 2013) provides information about, and recommends management approaches for key resources in two subwatershed areas that encompass a large portion of the South Milton SWS, spanning from Trafalgar Road to Bronte Street, and Steeles Ave to south of Highway 407. Included as Technical Appendices to the SUS, are two Functional Stormwater and Environmental Management Strategies (FSEMS); one for the Derry Green study area (AMEC Environment & Infrastructure, 2013) and for the Boyne study area (AMEC Environment & Infrastructure et al. 2013). Both Derry Green and Boyne border the South Milton SWS area but do not overlap with it. The SUS and FSEMS are intended to be a high level of study, the findings of which are integrated into more detailed Subwatershed Impact Studies (SIS). The terrestrial species recorded during the SUS investigations can be found in Appendix H1 and H2.

Sixteen Mile Creek Watershed Plan (Gore & Storrie Limited and Ecoplans Ltd. 1996);

The Sixteen Mile Creek Watershed Plan was prepared as part of the Halton Urban Structure Review and provides management strategies for achieving goals presented for resource management during development. Subwatersheds 2 – 7 are located within the Primary and Supplemental Study Areas, and therefore this study was reviewed for species records and other features found in the background review for this study, which are summarized in Appendix H1 and H2. Data in this study, however, used species data from background sources (*e.g.* OBBA).

Local Studies

Milton Phase 3 Monitoring (Dougan 2016);

The Milton Phase 3 Monitoring study area borders the South Milton SWS to the northwest and many of the amphibian and breeding bird monitoring stations overlap or are directly adjacent to these lands. Monitoring stations that were located within the Primary and Supplementary stay areas and were visited in 2016 are discussed as part of the field investigation sections. All of the vegetation monitoring plots, as well as many of the amphibian and breeding bird stations, are located outside of the Supplemental Study Area, but still help to provide an overall context to the landscape. For this reason, records outside of the South Milton SWS are discussed as part of the background review and referenced in Appendix H1 and H2.

Milton Phase 2 Holistic Monitoring Study (Dougan 2010 – 2014);

The Milton Phase 2 (Sherwood) lands are located slightly northwest of the South Milton SWS, just north of Louis St-Laurent Ave. The Phase 2 study area is bordered by Ontario Street South to the east, Tremaine Road to the west and Highway 401 to the north. Dougan & Associates (D&A) conducted terrestrial monitoring surveys including breeding bird and nocturnal amphibian calling surveys in 2010, 2011 and 2014. This study involved creating a holistic monitoring plan for the Indian Creek and Sixteen Mile Creek Area 2 subwatersheds, aiming to assess the impacts of development on the subject watersheds and adjacent lands. This study was reviewed for breeding bird and herpetofauna records, which are provided in Appendix H1 and H2.

Derry Green Corporate Business Park Subwatershed Impact Study – Study Area 5A (Savanta 2016);

The Derry Green Subwatershed Impact Study is an ongoing study that contains a portion of the northeastern section of the South Milton SWS area. The Derry Green Corporate Business Park Secondary Plan Study Area is located between James Snow Parkway and Sixth Line, spanning the area south of the CP Railway, and north of Derry Road. This study was reviewed for any relevant natural heritage information including species records and other features. A summary of these findings are provided in Appendix H1 and H2.

Boyne Secondary Plan Wildlife Survey Data (Dougan 2010);

The Boyne Secondary Plan study area includes lands located between Tremaine Road and James Snow Parkway, just north of the South Milton SWS, between Britannia Road and Louis St Laurent Avenue. Through the scope of this study a variety of field investigations were carried out by D&A in 2010, and because of the close proximity to the study areas, species records from these studies were included as part of the background review and are summarized in Appendix H1 and H2.

4.8.3 Methods / Analysis

4.8.3.1 Ecological Land Classification

Methods

Vegetation communities within the South Milton SWS Primary and Supplemental Study Areas were characterized according to the Ecological Land Classification (ELC) System protocol for Southern Ontario, 1st approximation (Lee et. al., 1998). ELC classification and mapping for the South Milton SWS area was compiled from a combination of existing mapping, aerial photo interpretation, and confirmation through field surveys. The extent and resolution of existing ELC data was established at the outset of the study as part of the gap analysis and work plan refinement. Historical ELC mapping at Community Series level was available for some of the study area based on previous studies by D&A, Savanta, Conservation Halton, and the MNRF. This background information was overlain onto recent ortho-rectified aerial imagery (orthoimagery) to identify gaps and to determine areas that required updating through field investigation.

As part of the field exercise to update the ELC for the South Milton SWS, site visits were carried out by D&A between May 3, 2016, and November 11, 2016, on properties where access had been provided. Each polygon was visited between one and three times during the 2016 season. Savanta conducted ELC and botanical inventories between May 12, 2015, and October 12, 2015, within the MP4LG properties. Specific dates and staff for site visits are summarized in Appendix H4. All vascular plant species encountered were recorded following standard ELC protocol; this included identifying species within the canopy, sub-canopy, understory, or ground layer and recording relative abundance. Soil texture and moisture regime were also characterized by representative topographic positions (e.g. table lands, valley slope, bottom lands). Additional information collected for each polygon included human disturbance (e.g. trails, garbage), invasive species, and features requiring further investigation for potential candidate significant wildlife habitats such as cavity trees, seeps, and springs, or stands of mature or old growth forest.

Vegetation communities in the Primary Study Area and at least 120 m of the adjacent lands were classified to the highest level of detail possible; Ecosite or Vegetation Type for ground-truthed areas, and at least Communities Series for areas surveyed. All of the ELC data collected was compiled into a Microsoft Access database and linked to mapped ELC units in an ArcGIS feature class where it could be managed, reviewed for quality control, and exported for analysis and reporting.

Analysis

Background Review Results

The background sources listed in Appendix H1 were reviewed to determine the current extent of ELC coverage within the study area, and to identify where gaps in knowledge occur. ELC data was obtained from the from the following background resources:

- Sixteen Mile Creek Subwatershed Update Study/Functional Stormwater and Environmental Management Studies (AMEC Environment & Infrastructure et al., 2013);
- Milton Phase 3 Monitoring (D&A 2016);
- Milton Phase 2 Holistic Monitoring Study (D&A 2010 – 2014);
- Derry Green Corporate Business Park Subwatershed Impact Study – Study Area 5A (Savanta 2016);
- Boyne Secondary Plan Wildlife Survey Data (Dougan 2010)

This information was compiled into a geodatabase and used as base data that could be updated through field surveys and interpretation of aerial imagery.

Field Investigation Results

In total, 1868 distinct polygons were mapped as part of this study, including anthropogenic (263 units; e.g. residential, roads), agricultural (312 units), and natural (1266; e.g. forest, wetland, meadow) areas. An additional 11 polygons had no data collected; ELC for these areas will be determined in 2017. Appendix H6 is a detailed map of each individual polygon and corresponding Vegetation Types, which include some areas outside of the South Milton Subwatershed Study Area. For brevity, only the lands falling within the Primary and Supplemental Study Areas are summarized below. Map T2 shows the ELC mapping at the level of Community Series.

A total of 1784 polygons were mapped within South Milton SWS, of which 255 are anthropogenic (including roads), 299 are agricultural, 1219 are natural vegetation communities. The Primary and Supplemental Study Areas are approximately 3283 ha and 2313 ha in size, respectively, totaling 5596 ha for the whole South Milton SWS. As shown on Map T2, the majority of the study area, 55%, is comprised of agricultural lands, with natural areas comprising 27% and anthropogenic areas (including roads) 18% of the landscape.

Agricultural and anthropogenic areas occur mainly on the table lands, whereas most of the natural areas are concentrated the corridor and valleylands of the Sixteen Mile Creek except for scattered woodlots, wetlands, watercourses, and former agricultural lands (Map T2). A description of the ELC communities documented within the South Milton SWS is provided below, and a breakdown of each Community Series is provided in Table 4.8.1. A more detailed breakdown of the ELC communities by Vegetation Type is provided in Appendix H7.

The natural areas within the Primary and Supplemental Study Areas are comprised of 19 different ELC Community Series (Map T2), with most polygons further classified into one of 27 Ecosites and 52 Vegetation Types (Appendix H6). Cultural ELC communities (e.g. Cultural Meadow, Cultural Thicket) are treated as a natural area, because, even though many have resulted from anthropogenic influences such as agriculture, they are undergoing natural succession and provide ecological functions (e.g. wildlife habitat). Furthermore, many of these areas are included in the Greenbelt and Regional Natural Heritage Systems.

Cultural Types

Cultural community series make up the second largest proportion of natural vegetation communities (37%) within the Primary and Supplemental Study Areas, next to terrestrial forests (Table 4.8.1). These lands are primarily distributed across the tablelands where they border agricultural and anthropogenic features, as well as adjacent to the valley lands of the Sixteen Mile Creek and its tributaries (Map T2).

Cultural Meadow (CUM)

Cultural Meadows occupy 312 ha (21%) of the natural areas within the study area, which is the second most abundant community series next to Deciduous Forests (Table 4.8.1). These cultural meadow communities are scattered across the tablelands, most often occurring in agriculturally dominant areas as linear features along small watercourses, between fields, and adjacent to forested features (Map T2). The largest Cultural Meadows are located in the north half of the South Milton SWS within the Middle Branch, East Branch, and Lower Middle Tributary subwatersheds, as well as along the north side of the 407 corridor in the Supplemental Study Area.

The vegetation types in this community series are limited to Dry-Fresh Old Field Meadow Types (CUM1-1)(Appendix H7), but these features occasionally contain small inclusions of Meadow Marsh (MAM) and Cultural Woodland (CUW), or are complexed with Mineral Cultural Savannah (CUS1), Mineral Cultural Woodland (CUW1), Reed-canary Grass Mineral Meadow Marsh (MAM2-2), and Forb Mineral Meadow Marsh (MAM2-10).

Table 4.8.1 Natural Area within the South Milton Subwatershed Study Area (Primary and Supplemental Study Areas)

Vegetation Community		Primary Study Area (3283.1 ha)				Supplemental Study Area (2312.8 ha)				Total (5595.9 ha)			
Description	ELC Code	# of Features	Area (ha)	% Natural Area	% Study Area*	# of Features	Area (ha)	% Natural Area	% Study Area*	# of Features	Total Area (ha)	% Natural Area	% Study Area*
Cultural													
Cultural Meadow	CUM	151	182.41	22.63%	5.56%	74	130.01	18.93%	5.62%	225	312.41	20.93%	5.58%
Cultural Plantation	CUP	15	13.91	1.73%	0.42%	13	20.37	2.97%	0.88%	28	34.28	2.30%	0.61%
Cultural Savannah	CUS	9	5.39	0.67%	0.16%	1	4.08	0.59%	0.18%	10	9.47	0.63%	0.17%
Cultural Thicket	CUT	37	28.99	3.60%	0.88%	15	19.98	2.91%	0.86%	52	48.98	3.28%	0.88%
Cultural Woodland	CUW	53	49.59	6.15%	1.51%	28	20.52	2.99%	0.89%	81	70.10	4.70%	1.25%
Hedgerow	HR	124	46.56	5.78%	1.42%	119	29.99	4.37%	1.30%	243	76.54	5.13%	1.37%
Terrestrial Forest													
Coniferous Forest	FOC	6	5.08	0.63%	0.15%	1	0.29	0.04%	0.01%	7	5.37	0.36%	0.10%
Deciduous Forest	FOD	88	212.85	26.40%	6.48%	52	267.93	39.01%	11.58%	140	480.77	32.20%	8.59%
Mixed Forest	FOM	24	30.48	3.78%	0.93%	22	70.19	10.22%	3.03%	46	100.67	6.74%	1.80%
Wetland													
Marsh	MA	0	0.00	0.00%	0.00%	1	0.17	0.02%	0.01%	1	0.17	0.01%	0.00%
Meadow Marsh	MAM	106	133.47	16.56%	4.07%	43	45.06	6.56%	1.95%	149	178.53	11.96%	3.19%
Shallow Marsh	MAS	23	8.97	1.11%	0.27%	6	1.84	0.27%	0.08%	29	10.81	0.72%	0.19%
Deciduous Swamp	SWD	30	50.86	6.31%	1.55%	25	22.05	3.21%	0.95%	55	72.91	4.88%	1.30%
Mixed Swamp	SWM	0	0.00	0.00%	0.00%	1	3.80	0.55%	0.16%	1	3.80	0.25%	0.07%
Thicket Swamp	SWT	7	10.24	1.27%	0.31%	6	28.22	4.11%	1.22%	13	38.45	2.58%	0.69%
Aquatic													
Open Aquatic	OAO	48	23.88	2.96%	0.73%	59	20.04	2.92%	0.87%	107	43.93	2.94%	0.79%
Shallow Aquatic	SA	6	0.81	0.10%	0.02%	17	2.29	0.33%	0.10%	23	3.10	0.21%	0.06%
Floating-leaved Shallow Aquatic	SAM	3	0.37	0.05%	0.01%	0	0.00	0.00%	0.00%	3	0.37	0.03%	0.01%
Submerged Shallow Aquatic	SAS	6	2.25	0.28%	0.07%	0	0.00	0.00%	0.00%	6	2.25	0.15%	0.04%
Total		736	806.10	100.00%	24.55%	483	686.82	100.00%	29.70%	1219	1492.92	100.00%	26.68%

CUM1-1 (Dry-Moist Old Field Meadow Type)

A total of 225 Dry-Moist Old Field Meadow Type polygons were mapped within the South Milton SWS. These features were most often dominated by Awnless Brome (*Bromus inermis)* and Reed Canary Grass (*Phalaris arundinacea*), with associates including Kentucky Bluegrass (*Poa pratensis ssp. pratensis*), Canada Goldenrod (*Solidago canadensis var. canadensis)* and Eastern Late Goldenrod (*Solidago altissima ssp. altissima).* Cultural Meadows tended to be relatively low in terms of species richness; on average, only 13 native species were observed within these communities.

Cultural Plantation

Twenty-eight (28) Cultural Plantation polygons are mapped within the Primary and Supplemental Study Areas. These features totaled 34 ha or 2.3% of the natural areas within the whole study area (Table 4.8.1). Cultural Plantations are distributed throughout the South Milton SWS and subwatersheds of the Sixteen Mile Creek but are generally located adjacent to upland forests along the Sixteen Mile Creek (Map T2). Several large plantations are concentrated in the southeastern portion of the Primary Study Area bordering the lower middle branch of the Sixteen Mile Creek valley where they add to large contiguous blocks of deciduous and mixed forest. Smaller plantations are scattered across tableland areas within each of the Sixteen Mile Creek subwatersheds. The majority of plantations are coniferous (CUP3). However, several deciduous plantations of Oak (*Quercus* sp) and one mixed plantation were also present (Appendix H7).

CUP3-2 (White Pine Coniferous Plantation Type)

The single White Pine Coniferous Plantation within the South Milton SWS was dominated by White Pine *(Pinus strobus)* with occasional White Spruce (*Picea glauca).* The understory and shrub layers were typically dominated by White Pine and White Spruce, with some Box Elder (*Acer negundo),* European Buckthorn (*Rhamnus cathartica),* Tartarian Honeysuckle (*Lonicera tatarica)* and Sugar Maple (*Acer saccharum).* The ground layer within this plantation type was typically a sparse mix of species, including Garlic Mustard (*Alliaria petiolata),* Jack-in-the-pulpit (*Arisaema triphyllum),* Herb Robert (*Geranium robertianum),* and Thicket Creeper (*Parthenocissus inserta).* Species richness within this polygon was 43 species, including 30 native species.

CUP3-3 (Scotch Pine Coniferous Plantation Type)

The canopy layer of the single the Scotch Pine Coniferous Plantation within the South Milton SWS was dominated by Scotch Pine (*Pinus sylvestris)*, with associates including Bitternut Hickory (*Carya cordiformis),* Blue Spruce (*Picea pungens)* and Red Oak *(Quercus rubra).* The understory layer was also dominated by Scotch Pine, with abundant Bitternut Hickory and some American Basswood (*Tilia americana)*. The shrub layer was dominated by Tartarian Honeysuckle and European Buckthorn, while the ground layer was typically a mix of species including Garlic Mustard, Jack-in-the-pulpit, Broad-leaved Enchanter's Nightshade (*Circaea canadensis),* and Herb Robert. Species richness within this polygon was 28 species, including 19 native species.

Cultural Savannah

Ten (10) cultural savannah polygons were identified within thePrimary and Supplemental Study Areas, which account for approximately 9.5 ha (<1%) of the natural areas (Table 4.8.1). Individually, these features are generally small in area (<1 ha), with the exception of one 4 ha polygon (1987.801) north of the lower middle branch of the Sixteen Mile Creek, and are found within both tablelands and valleylands across the South Milton SWS (Map T2).

Two Cultural Savannah vegetation types were identified within the Primary and Supplemental Study Areas; CUS1 (Mineral Cultural Savannah) and CUS1-1 (Hawthorn Cultural Savannah) (Appendix H7). These communities are summarized below.

CUS1(Mineral Cultural Savannah)

The canopy layer of the Mineral Cultural Savannahs within the South Milton SWS was often dominated by Black Walnut (*Juglans nigra),* Trembling Aspen (*Populus tremuloides),* and Bur Oak (*Quercus macrocarpa),* with associates including Sugar Maple and White Spruce. The understory and shrub layers were a mix of species, dominated by Riverbank Grape (*Vitis riparia),* and occasional Common Red Raspberry (*Rubus idaeus ssp. idaeus),* Basket Willow (*Salix purpurea),* Green Ash (*Fraxinus pennsylvanica),* Box Elder and Black Walnut. The ground layer was dominated by Canada Goldenrod, Reed Canary Grass, Kentucky Bluegrass and Panicled Aster (*Symphyotrichum lanceolatum ssp. lanceolatum),* with associated species including Redtop (*Agrostis gigantea),* Garlic Mustard, Common Milkweed (*Asclepias syriaca),* Canada Thistle (*Cirsium arvense),* Fuller's Teasel (*Dipsacus fullonum)* and Wild Carrot (*Daucus carota).* Average species richness across the 6 polygons of this community type was 38 for all species and 22 for native species only.

CUS1-1 (Hawthorn Cultural Savannah)

The canopy and understory layers of the Hawthorn Cultural Savannahs within the South Milton SWS were dominated by Hawthorn species (*Crataegus sp.),* most commonly Dotted Hawthorn (*C. punctata),* with other associates including Black Maple (*Acer nigrum),* American Elm (*Ulmus americana),* Sugar Maple and European Buckthorn. The shrub layer generally consisted of a mix of species, dominated by Hawthorns and European Buckthorn, with occasional Choke Cherry (*Prunus virginiana).* The ground layer was typically dominated by European Buckthorn, Black Maple, and Sugar Maple seedlings, with occasional Trout-lily (*Erythronium sp.),* Blue-stemmed Goldenrod (*Solidago caesia)* and Common Dandelion (*Taraxacum officinale).* This community, found in one polygon (921.008; Appendix H6), is notable for several tall and large diameter (>50 cm dbh) Black Maple trees that tower over the canopy of Hawthorns. These trees are likely old growth based on their size and form, and would be remnants of the historic vegetation community in this area, Fresh-Moist Black Walnut Lowland Deciduous Forest Type (FOD7-5), which is still present upstream (Appendix H6). Species richness within this polygon was 40 for all species, including 22 native species.

Cultural Thicket

Cultural Thicket communities are numerous across the Primary and Supplmentary study areas (52 polygons), and total approximately 49 ha, or 3.28% of natural areas within the study area (Table 4.8.1). As shown on Map T2, Cultural Thickets are concentrated within the valleylands and adjacent uplands of the main branch of the Sixteen Mile Creek; however, several small features are also present in agricultural areas on the tablelands within each of the subwatersheds.

CUT1 (Mineral Cultural Thicket)

The canopy layers of the Mineral Cultural Thickets within the South Milton SWS were typically dominated by Box Elder, Hawthorn, Common Apple (*Malus pumila),* and Common Lilac (*Syringa vulgaris)* with associates including Hickory (*Carya sp.),* Green Ash, Trembling Aspen, Bur Oak and American Elm. The understories were most often dominated by European Buckthorn and Hawthorn species, including Dotted Hawthorn and English Hawthorn (*Crataegus monogyna).* Other abundant species included Green Ash and Common Apple, with occasional Box Elder, Black Cherry (*Prunus serotina*), and Bur Oak. The shrub layers were typically dominated by European Buckthorn, with associates including Gray Dogwood (*Cornus racemosa),* Hawthorn species, Tartarian Honeysuckle, Choke Cherry, Common Red Raspberry, Common Lilac and Riverbank Grape. The ground layers were mainly composed of Garlic Mustard, Fringed Sedge (*Carex crinita)*, Broad-leaved Enchanter's Nightshade, Gray Dogwood, Dame's Rocket (*Hesperis matronalis)*, Spotted Jewelweed (*Impatiens capensis),* Reed Canary Grass, Riverbank Grape, and Avens species (*Geum sp.).* On average, 38 species were documented within the 17 polygons of this vegetation type including an average of 38 native species (Appendix H7).

CUT1-4 (Gray Dogwood Cultural Thicket Type)

The most abundant species in the canopy layer of the Gray Dogwood Cultural Thicket types within the South Milton SWS were often Trembling Aspen and Red Oak. The understory was mainly comprised of European Buckthorn and Hawthorn species, with some Apple species (*Malus sp.).* The shrub layer was dominated by Gray Dogwood, with associates including Tartarian Honeysuckle and other Honeysuckle species, Eastern Cottonwood (*Populus deltoides ssp. deltoides),* and European Buckthorn. The ground layer was typically abundant with Red Oak and European Buckthorn seedlings and Arrow-leaved Aster (*Symphyotrichum urophyllum),* with occasional Sugar Maple, White Pine, Choke Cherry and European Privet seedlings, and Jack-in-the-pulpit. Gray Dogwood Cultural Thickets were represented by 6 polygons, which had an average richness of 45 species and 21 native species (Appendix H7).

CUT1-5 (Raspberry Cultural Thicket Type)

The most abundant species in the canopy layers of the Raspberry Cultural Thicket types within the study area were Sugar Maple and Hawthorn species, with occasional American Basswood. Hawthorn was also the most abundant species in the understory layers, with associates including Norway Maple (*Acer platanoides),* Shagbark Hickory (*Carya ovata),* American Basswood, and Riverbank Grape. The shrub layer was dominated by Common Red Raspberry accompanied by Hawthorn. The ground layer was typically abundant with Garlic Mustard, Broad-leaved Enchanter's Nightshade, Herb Robert and Thicket Creeper. An average species richness of 34, including 17 native species, was observed across the two raspberry Cultural Thicket polygons surveyed.

CUT1-7 (Hawthorn Cultural Thicket Type)

The canopy layer of the Hawthorn Cultural Thicket found within the South Milton SWS was sparse and comprised of occasional Bur Oak. This community type is not listed in Lee et al. (1998) but is included here because it best represents the species composition observed in this polygon. The understory layer was dominated by Hawthorn species including Dotted and English Hawthorn, as well as other unidentified *Crataegus* sp. Other occasional species found within this layer include Green Ash and Bur Oak. The shrub layers contained a mix of species, including Hawthorns, Tartarian Honeysuckle, Bur Oak and European Buckthorn. The ground layers contained occasional Spiked Sedge (*Carex spicata),* Broad-leaved Enchanter's Nightshade and White Avens (*Geum canadense).* Species richness was 49 for the single Hawthorn Cultural Thicket surveyed, including 27 (63%) native species (Appendix H7).

Cultural Woodland

Cultural Woodlands make up approximately 70 ha (4.70%) of the natural areas within the Primary and Supplemental Study Areas, across a total of 81 polygons (Table 4.8.1). As shown on Map T2, these features are generally small in size (<1 ha), though three polygons are larger than 4 ha in size. Cultural Woodlands are widely distributed throughout the South Milton SWS but tend to be concentrated along the main branch of the Sixteen Mile Creek, east of Trafalgar Road, and south of Britannia Road within the East Branch and Lower Middle Tributary subwatersheds (Map T2).

All of the Cultural Woodlands within the South Milton SWS were classified to the Ecosite level due to variability in canopy composition and limited diversity of Cultural Woodland vegetation types included in Lee et al. (1998). A summary of this Ecosite is provided below.

CUW1 (Mineral Cultural Woodland)

The canopy layers of the Mineral Cultural Woodlands within the South Milton SWS were dominated by Box Elder, Sugar Maple, Shagbark Hickory, Green Ash, Black Walnut, Bur Oak, Black Locust (*Robinia pseudoacacia)*, Weeping Willow (*Salix x pendulina*), and American Basswood. Other abundant species in this layer include Bitternut Hickory (*Carya cordiformis)*, Hawthorn species, White Ash (*Fraxinus americana),* Norway Spruce (*Picea abies)* and American Elm (*Ulmus americana).* The understories were mainly dominated by Green Ash, Black Walnut, and European Buckthorn, with associates including Box Elder, Hawthorn Species, American Elm, Bur Oak, White Ash, and Black Locust. The dominant species within the shrub layers include European Buckthorn and Honeysuckle species, with abundant Gray Dogwood, European Privet, Tartarian Honeysuckle, Common Red Raspberry, Black Raspberry (*Rubus occidentalis),* and Riverbank Grape. The ground layers were often dominated by Awnless Brome and Reed Canary Grass, with associates including Garlic Mustard, Greater Burdock (*Arctium lappa),* Wild Carrot, Dame's Rocket, Garden Bird's-foot Trefoil (*Lotus corniculatus)*, White Sweet-clover (*Melilotus albus),* Canada Goldenrod and Eastern Late Goldenrod. A total of 32 polygons were classified as

Mineral Cultural Woodland, which had an average species richness of 39 including 20 for native species only (Appendix H7).

Hedgerow

Hedgerows account for approximately 77 ha (5%) of all the natural areas within the South Milton SWS. (Table 4.8.1). A total of 243 hedgerow polygons were identified, primarily through interpretation of orthoimagery. These features are widely distributed among the agricultural areas, often providing connectivity between larger blocks of natural areas bordering the Sixteen Mile Creek corridors (Map T2).

Typically, the canopy of the hedgerow polygons South Milton SWSwas dominated by Box Elder, Hawthorn species, Black Walnut, and Bur Oak accompanied by Sugar Maple, Large-toothed Aspen (*Populus grandidentata),* and Red Oak. The understory layer was often dominated by European Buckthorn, with Hawthorn species, White Ash and Staghorn Sumac (*Rhus typhina).* The shrub layer was usually comprised of Gray Dogwood, English and Dotted Hawthorn, Bur Oak, and European Buckthorn. The ground layer was generally dominated by Awnless Brome, Bur Oak, and Eastern Late Goldenrod, with associates including Garlic Mustard, Wild Carrot, Fuller's Teasel, and Trout-lily Species. Across the 33 hedgerow polygons surveyed by D&A, an average of 24 species were encountered, including an average of 11 native species.

Terrestrial Forest

Terrestrial Forests make up the largest component of all of the natural areas within the Primary and Supplemental Study Areas, at approximately 587 ha (39%) (Table 4.8.1). These communities are present within 193 different polygons, which are distributed primarily within the Sixteen Mile Creek corridor and bordering tablelands, as shown on Map T2. Notable exceptions include Drumquin Wetland in the southernmost portion of the Lower Middle Tributary subwatershed north of East Lower Base Line, as well as several relatively large forest features in the Lower Middle Branch subwatershed west of Wildwood Golf and Country Club between Derry Road and Britannia Road.

Coniferous Forest

Coniferous Forests make up the smallest component of the terrestrial forests within the study area at 5.37 ha (0.36%) and are present in only two areas within the South Milton SWS (Table 4.8.1). The largest of these is a group of Fresh-Moist Hemlock Coniferous Forest polygons within the valley of the lower Sixteen Mile Creek, while the second, smaller polygon, is a narrow feature of the same type along the East Sixteen Mile Creek west of Trafalgar Road and South of Britannia Road (Map T2). A description of this community is provided in the following paragraph.

FOC3-1 (Fresh-Moist Hemlock Coniferous Forest Type)
The canopy layer of the Hemlock Coniferous forests South Milton SWSwas typically dominated by Eastern Hemlock (*Tsuga canadensis),* with associates including Eastern White Cedar (*Thuja occidentalis),* White Pine (*Pinus strobus),* and Trembling Aspen. The understory was dominated by Eastern White Cedar and Trembling Aspen. The shrub layer was sparse but contained

occasional Serviceberry species (*Amelanchier sp).* The ground layer contained a mix of species, including Garlic Mustard, Jack-in-the-pulpit, Broad-leaved Enchanter's Nightshade, Intermediate Fern (*Dryopteris intermedia)*, Herb Robert (*Geranium robertianum),* Avens species (*Geum sp)*, Common Motherwort (*Leonurus cardiaca),* and White Vervain (*Verbena urticifolia).* Species richness across the three polygons surveyed was 17, with an average of 12 native species observed (Appendix H7).

Deciduous Forest

Deciduous Forests make up approximately 481 ha (32%) of the natural areas within the Primary and Supplemental Study Areas, which is the largest Community Series within the South Milton SWS (Table 4.8.1). A total of 140 deciduous forest polygons were identified within the study areas. These features are distributed throughout the study area but are concentrated in the lower half along the Sixteen Mile Creek corridors and their tributaries (Map T2). In the northern half of the study area deciduous forests are more scattered, generally smaller in size, and more often occur on tableland areas rather than within the Sixteen Mile Creek corridors.

The deciduous forests are also the most diverse group of vegetation communities within the study area, with 22 vegetation types identified across 9 different Ecosites. Descriptions of these vegetation communities are provided below.

FOD (Deciduous Forest Type)

The deciduous forests encountered in the South Milton SWS were typically dominated by Sugar Maple and accompanied by Box Elder, Black Walnut, Eastern Hop-hornbeam (*Ostrya virginiana)*, Black Locust, American Basswood, American Elm, often with abundant Riverbank Grape throughout all of the forest layers. The understories were a mix of species, including Sugar, Silver and Freeman Maple, Box Elder, White and Green Ash, Black Walnut, Red Oak, and European Buckthorn. The shrub layers often contained a variety of species including Willow species, Common Red Raspberry, Choke Cherry, and Tartarian Honeysuckle. The ground layers were also quite diverse, with species such as Thicket Creeper, Canada Goldenrod, Common Red Raspberry, Garlic Mustard, Common and Greater Burdock, Chicory (*Cichorium intybus)*, Broad-leaved Enchanter's Nightshade, Running Strawberry Bush (*Euonymus obovatus),* Wild Strawberry (*Fragaria virginiana)*, Panicled Aster and New England Aster. On average, 22 species were documented in across the 6 polygons classified to this community series, including 14 native species.

FOD1-1 (Dry-Fresh Red Oak Deciduous Forest Type)

One Dry-Fresh Red Oak Deciduous Forest polygon was surveyed within the South Milton SWS. The canopy of this feature was dominated by Red Oak (*Quercus rubra)* and Sugar Maple, with abundant White Ash and Black Cherry. The understory was dominated by Sugar Maple, with occasional White Ash and Black Cherry. The dominant species within the shrub layer was Gray Dogwood and European Buckthorn, with some Box Elder, White Ash, Tartarian Honeysuckle, and Riverbank Grape. The ground layer was comprised of various species such as Running Strawberry Bush, Garlic Mustard, Wild Carrot, Yellow Avens (*Geum aleppicum),* Starved Aster

(*Symphyotrichum lateriflorum)* and Heart-leaved Aster (*Symphyotrichum cordifolium).* A total of 33 species were documented within this polygon, including 26 (84%) native species (Appendix H7).

FOD2 (Dry-Fresh Oak-Maple-Hickory Deciduous Forest Ecosite)

One Dry-Fresh Oak-Maple-Hickory Deciduous Forest Ecosite polygon was surveyed within the South Milton SWS. The canopy of this feature was dominated by Bur Oak, with an abundance of White Ash and White Pine, and occasional Sugar Maple, Shagbark Hickory, American Basswood and American Elm. The understory was largely comprised of Sugar Maple, White Ash, Eastern Hop-hornbeam, and Bur Oak. The dominant species in the shrub layer was Tartarian Honeysuckle, accompanied by Gray Dogwood, Hawthorn, European Buckthorn, Choke Cherry, Common Red Raspberry and Riverbank Grape. The ground layer contained a diversity of species, including Awnless Brome, Broad-leaved Enchanter's Nightshade, Large-leaved Aster (*Eurybia macrophylla)*, Avens species, Virginia Waterleaf (*Hydrophyllum virginianum),* Panicled Aster, and European Wood-sorrel (*Oxalis stricta).* A total of 32 species were documented within this polygon, including 20 (71%) native species (Appendix H7).

FOD2-2 (Dry-Fresh Oak-Hickory Deciduous Forest Type)

Three Dry-Fresh Oak-Hickory Deciduous Forest Type polygons were surveyed within the South Milton SWS. The canopy of this forest type in the context of the study area was dominated by Bur Oak, with an abundance of Shagbark Hickory and Red Oak, and occasional Sugar Maple, Bitternut Hickory, and Eastern Hop-hornbeam. In the understory, the most abundant species was Sugar Maple, accompanied by Shagbark Hickory, White Ash, Bur Oak, Red Oak, American Basswood, and American Elm. The shrub layer consisted of mainly Sugar Maple with occasional Shagbark Hickory, White Ash, Tartarian Honeysuckle, Choke Cherry, Common Red Raspberry, Bur Oak and Riverbank Grape. The ground layer was abundant with Sugar Maple and Shagbark Hickory seedlings, along with various other groundcover species including Running Strawberry Bush, Wild Strawberry, Herb Robert, and Broad-leaved Enchanter's Nightshade. An average of 35 species were documented within this polygon, including 26 native species (Appendix H7).

FOD2-4 (Dry-Fresh Oak-Hardwood Deciduous Forest Type)

One Dry-Fresh Oak-Hardwood Deciduous Forest Type polygon was surveyed within the South Milton SWS. The canopy of this forest type was dominated by Red Oak and accompanied by a mixture of species including Bur Oak, Sugar and Freeman Maple, Box Elder, Paper Birch (*Betula papyrifera),* Black Walnut, Eastern Hop-hornbeam, and American Basswood. The understory generally contained a similar mixture to the canopy, with the addition of Black Cherry and Choke Cherry. The shrub layer was comprised of Gray Dogwood, Hawthorn, Honeysuckle Species, European Buckthorn, Black Cherry, Choke Cherry and Cranberry Viburnum (*Viburnum opulus ssp. opulus).* The ground layer was a mixture of groundcover species and seedlings, including Bur and Red Oak, European Buckthorn, American Elm, Heart-leaved Aster, Blue-stemmed Goldenrod (*Solidago caesia),* Garlic Mustard, Canada Anemone (*Anemone canadensis),* and Wild Strawberry. A total of 69 species were documented within this polygon, including 34 (64%) native species (Appendix H7).

FOD3-1 (Dry-Fresh Poplar Deciduous Forest Type)

One Dry-Fresh Oak-Hardwood Deciduous Forest Type polygon was surveyed within the South Milton SWS. This forest type was dominated by large-toothed aspen, with occasional Green Ash, Black Cherry, Bur and Red Oak. The understory was a mix of Sugar Maple, Bitternut Hickory, European Buckthorn, American Basswood, and American Elm, while the shrub layer was comprised of Blue-beech, White Ash, Tartarian Honeysuckle, Black Cherry, Common Red Raspberry, American Basswood and American Elm. The ground layer contained a mix of species including Garlic Mustard, Jack-in-the-pulpit, Sedge Species (*Carex sp.)*, Lamb's Quarters (*Chenopodium album),* Broad-leaved Enchanter's Nightshade, Running Strawberry Bush, Herb Robert, Spotted Geranium (*Geranium maculatum)*, Climbing Nightshade (*Solanum dulcamara),* Violet Species (*Viola sp.)* and Poison Ivy (*Toxicodendron radicans).* A total of 69 species were documented within this polygon, including 34 (64%) native species (Appendix H7).

FOD4 (Dry-Fresh Deciduous Forest Ecosite)

One Dry-Fresh Deciduous Forest Type polygon was surveyed within the South Milton SWS. The canopy layer for this feature was dominated by Box Elder, Norway Maple, and Bur Oak. The understory had a similar tree composition, with the addition of European Buckthorn. The shrub layer was comprised of a mixture of species including Red-osier Dogwood (*Cornus stolonifera),* Tartarian Honeysuckle, Choke Cherry, Common Red Raspberry and Black Raspberry. The ground layer also contained a mixture of species, including Common Milkweed, Common Burdock, Awnless Brome, European Swallow-wort (*Cynanchum rossicum)*, Philadelphia Fleabane (*Erigeron Philadelphicus),* Thicket Creeper, Panicled Aster, New England Aster, Colt's-foot (*Tussilago farfara)* and Red Clover (*Trifolium pratense).* A total of 55 species were documented within this polygon, including 22 (42%) native species (Appendix H7).

FOD5-1 (Dry-Fresh Sugar Maple Deciduous Forest Type)

Five Dry-Fresh Sugar Maple Deciduous Forest Type polygons were surveyed within the Primary and Supplemental Study Areas. The dominant species in the canopy and understory layers for this community was Sugar Maple and Black Maple, with occasional Bitternut Hickory, American Beech (*Fagus grandifolia)*, White Ash, Black Walnut, White Pine, Bur Oak and American Basswood. The understory and shrub layers were completely dominated by Sugar Maple. The ground layer was abundant with Black Maple seedlings and some Sugar Maple seedlings, and a mixture Garlic Mustard, Running Strawberry Bush, Woodland Strawberry, Zigzag Goldenrod (*Solidago flexicaulis)*, Herb Robert, Devil's Beggarticks (*Bidens frondosa*) Broad-leaved Enchanter's Nightshade, Canada Clearweed (*Pilea pumila)*, Poison Ivy and Common Dandelion. An average of 43 species were documented within these polygons, including 32 native species (Appendix H7).

FOD5-2 (Dry-Fresh Sugar Maple-Beech Deciduous Forest)

Five Dry-Fresh Sugar Maple-Beech Deciduous Forest Type polygons were surveyed within the South Milton SWS. The canopy of this forest type South Milton SWSwas dominated by Silver and Sugar Maple, and American Beech, with a Silver Maple dominated understory. The shrub layer was also dominated by Sugar and Silver Maple shrubs, as well as the ground layer with seedlings.

Other species present in the ground layer included Wild Strawberry, Spotted Jewelweed, Thicket Creeper, False Solomon's Seal (*Maianthemum canadense),* Virginia Smartweed (*Persicaria virginiana),* Heart-leaved Aster and Starved Aster. An average of 31 species were documented within these polygons, including 25 native species (Appendix H7).

FOD5-3 (Dry-Fresh Sugar Maple-Oak Deciduous Forest)

Eleven Dry-Fresh Sugar Maple-Oak Deciduous Forest Type polygons were surveyed within the Primary and Supplemental Study Areas. In this forest type, the canopy was dominated by Sugar Maple, with an abundance of Bitternut Hickory, Bur Oak, Red Oak, and American Basswood. The understory was dominated by Sugar Maple, followed by Eastern Hop-hornbeam, and American Elm. Sugar Maple and European Buckthorn dominated the shrub layer, while the ground layer was dominated by Virginia Smartweed (*Persicaria virginiana)*, with an abundance of Sugar Maple, Garlic Mustard, Awnless Brome, and Poison Ivy. An average of 50 species were documented within these polygons, including 33 native species (Appendix H7).

FOD5-5 (Dry-Fresh Sugar Maple-Hickory Deciduous Forest Type)

Two Dry-Fresh Sugar Maple-Hickory Deciduous Forest Type polygons were surveyed within the South Milton SWS. The dominant species in the canopy and understory layers for this forest type were Sugar Maple, Bitternut Hickory, and Shagbark Hickory. In addition to Sugar Maple shrubs, European Buckthorn and Gray Dogwood were abundant in the shrub layer. Running Strawberry Bush dominated the ground layer, with associates including Garlic Mustard, Sedge species, Broad-leaved Enchanter's Nightshade, and Herb Robert. An average of 30 species were documented within this polygon, including 20 native species (Appendix H7).

FOD5-6 (Dry-Fresh Sugar Maple-Basswood Deciduous Forest Type)

One Dry-Fresh Sugar Maple-Basswood Deciduous Forest Type polygons was surveyed within the South Milton SWS. In this feature, the dominant canopy species was Sugar Maple, while American Basswood and White Ash were abundant. Sugar Maple also dominated in the understory, with the occasional Tartarian Honeysuckle and American Elm. The shrub layer only contained a few species, including Tartarian Honeysuckle, Wild Black Currant (*Ribes americanum)*, Choke Cherry, and Common Red Raspberry. The ground layer contained a mixture of species, including Eastern Helleborine (*Epipactis helleborine)*, Avens species, Running Strawberry Bush, Dame's Rocket, Virginia Waterleaf, Canada Moonseed (*Menispermum canadense),* Panicled Aster, Starved Aster, and Heart-leaved Aster. A total of 29 species were documented within this polygon, including 22 (79%) native species (Appendix H7).

FOD5-7 (Dry-Fresh Sugar Maple -Black Cherry Deciduous Forest Type)

One Dry-Fresh Sugar Maple-Black Cherry Deciduous Forest Type polygon was surveyed within the South Milton SWS. The canopy layer of this feature was dominated by Sugar Maple, followed by Black Cherry and Eastern Hemlock. Sugar Maple also dominated the understory and shrub layers, with occasional White Ash in the understory and Choke Cherry in the shrub layers. The ground layer was dominated by Sugar Maple and False Nettle (*Boehmeria cylindrica)*, with occasional Greater Burdock, Devil's Beggarticks, Broad-leaved Enchanter's Nightshade, Avens species, Fowl Mannagrass (*Glyceria striata)*, Reed Canary Grass, Choke Cherry, and Canada Goldenrod. A total of 48 species were documented within this polygon, including 36 (82%) native species (Appendix H7).

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

One Dry-Fresh Sugar Maple-White Ash Deciduous Forest Type polygon was surveyed within the South Milton SWS. The canopy layer in this feature was dominated by Black Maple and Sugar Maple, with occasional White Ash, Red Oak, Shagbark Hickory, American Beech, and Eastern Hemlock. Similar to the canopy, Sugar Maple dominated the understory, with associates including Shagbark Hickory, American Beech, White Ash, Eastern Hop-hornbeam, American Basswood, and Eastern Hemlock. The shrub layer was again dominated by Sugar Maple, with occasional Shagbark Hickory, Choke Cherry, Poison Ivy, and Riverbank Grape. The ground layer was abundant with Garlic Mustard, Broad-leaved Enchanter's Nightshade, and Running Strawberry Bush, with some Shagbark Hickory and White Ash seedlings, Intermediate Fern, Spotted Geranium, Herb Robert, Dame's Rocket, and Zigzag Goldenrod. A total of 42 species were documented within this polygon, including 34 (87%) native species (Appendix H7).

FOD6 (Fresh-Moist Sugar Maple Deciduous Forest Ecosite)

Three Fresh-Moist Sugar Maple Deciduous Forest Ecosite polygons were surveyed within the South Milton SWS. The canopy and subcanopy layers in these features were dominated by Sugar Maple, with some Silver and Freeman Maples. The shrub layers also contained occasional Choke Cherry. The ground layers included a mixture of species, including Garlic Mustard, Wild Leek, Jack-in-the-pulpit, Lady Fern (*Athyrium filix-femina var. angustum)*, Sedge species, Running Strawberry Bush, White Trout-lily (*Erythronium americanum),* Wild Strawberry, Herb Robert, May Apple (*Podophyllum peltatum),* and Poison Ivy. An average of 30 species were documented within these polygons, including 23 native species (Appendix H7).

FOD6-2 (Fresh-Moist Sugar Maple-Black Maple Deciduous Forest Type)

One Fresh-Moist Sugar Maple-Black Maple Deciduous Forest Type polygon was surveyed within the South Milton SWS. The canopy layer in this forest was dominated by Sugar Maple and Black Maple, with occasional Blue-Beech, American Beech, White Ash, and American Elm. The understory had a similar composition, with the addition of occasional Hawthorn species. The shrub layer was comprised of a few species including Tartarian Honeysuckle, European Buckthorn, and Wayfaring-tree (*Viburnum lantana).* The ground layer was dominated by Zigzag Goldenrod, with associates including Creeping Bentgrass (*Agrostis stolonifera),* Devil's Beggarticks, Broad-leaved Enchanter's Nightshade, Field Horsetail (*Equisetum arvense),* Spotted Joe-Pye Weed (*Eutrochium maculatum var. maculatum),* Wild Strawberry, and Tall Buttercup (*Ranunculus acris).* A total of 80 species were documented within this polygon, including 56 (76%) native species (Appendix H7).

FOD7 (Fresh-Moist Lowland Deciduous Forest Ecosite)

Four Fresh-Moist Lowland Deciduous Forest Ecosite polygons were surveyed within the South Milton SWS. The canopy layers within these features were dominated by Black Walnut and

American Basswood, with occasional Sugar Maple and Green Ash. The subcanopy layers were abundant with Riverbank Grape and Sugar Maple. Riverbank Grape and Black Raspberry were abundant in the shrub layer, with some Sugar Maple and Sandbar Willow (*Salix interior).* The ground layer was dominated by Awnless Brome, with associates including Garlic Mustard, Reed Canary Grass, Black Raspberry, Eastern Late Goldenrod, Erect Hedge-parsley (*Torilis japonica)*, and Riverbank Grape. An average of 46 species were documented within these polygons, including 47 native species (Appendix H7).

FOD7-2 (Fresh-Moist Ash Lowland Deciduous Forest Type)

One Fresh-Moist Ash Lowland Deciduous Forest Type polygon was surveyed within the South Milton SWS. The canopy layers in this forest were abundant with Sugar Maple and Green Ash, with occasional Eastern Cottonwood. Green Ash and Eastern Cottonwood dominated the understory, while the shrub layer contained Sugar Maple, Gray Dogwood, Eastern Cottonwood, Choke Cherry, Common Red Raspberry, and Riverbank Grape. In the ground layer, Awnless Brome and Canada Goldenrod were the most abundant species, with occasional associates including Wild Carrot, Fuller's Teasel, Avens species, Reed Canary Grass, and Panicled Aster. A total of 28 species were documented within this polygon, including 16 (62%) native species (Appendix H7).

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

Four Fresh-Moist Willow Lowland Deciduous Forest Type polygons were surveyed within the South Milton SWS. The canopy layers in this forest type were dominated by White Willow (*Salix alba),* and occasional Black Walnut. The subcanopy layers were a mixture of Norway Maple, Sugar Maple, Green Ash, American Basswood, and American Elm. In the shrub layers, Black Walnut, Thicket Creeper, Common Red Raspberry, and Riverbank Grape were the most abundant species, with associates including Sugar Maple, Green Ash, and European Buckthorn. The ground layers were abundant with Cleavers (*Galium aparine),* Spotted Jewelweed, Reed Canary Grass, and Goldenrod Species. An average of 86 species were documented within these polygons, including 44 native species (Appendix H7).

FOD7-4 (Fresh-Moist Black Walnut Lowland Deciduous Forest Type)

Five Fresh-Moist Walnut Lowland Deciduous Forest Type polygons were surveyed within the South Milton SWS. The canopy layers in these forests were dominated by Black Walnut with an abundance of Box Elder and occasional Sugar Maple and White Willow. The subcanopy layers were also dominated by Black Walnut, and abundant with Hawthorn species. Associates in this layer were Box Elder, Tartarian Honeysuckle, Apple Species, European Buckthorn and White Willow. The shrub layers were a mix of Box Elder, Green Ash, Tartarian Honeysuckle, Choke Cherry, European Buckthorn, Wild Black Currant, Common Red Raspberry, and Black Raspberry. The most abundant species in the ground layers were Sugar Maple seedlings, Awnless Brome, Dame's Rocket, Thicket Creeper, Reed Canary Grass, and Canada Goldenrod. An average of 55 species were documented within these polygons, including 32 native species (Appendix H7).

FOD7-5 (Fresh-Moist Black Maple Lowland Deciduous Forest Type)

Two Fresh-Moist Black Maple Lowland Deciduous Forest Type polygons were surveyed within the South Milton SWS. The canopy layers in this forest type were dominated by Sugar Maple and Black Maple and occasional Bitternut Hickory, Green Ash, Black Walnut and American Basswood. The sublayers were most abundant with Black Maple, with occasional American Basswood and American Elm. Black Maple also dominated the shrub layer, with some Bur Oak and American Basswood. The ground layer was abundant with Garlic Mustard, Trout-lily species, Spotted Jewelweed, and Reed Canary Grass. An average of 56 species were documented across these two polygons, including 39 native species (Appendix H7).

FOD9-1 (Fresh-Moist Oak-Sugar Maple Deciduous Forest Type)

One Fresh-Moist Oak-Sugar Maple Deciduous Forest Type polygon was surveyed within the South Milton SWS. The canopy layer within this forest was dominated by Sugar Maple and Bur Oak. In the subcanopy, European Alder was abundant, with occasional Eastern Hop-hornbeam. The shrub layers were abundant with Gray Dogwood, Choke Cherry, and European Buckthorn, with associates including Honeysuckle species and Cranberry Viburnum (*Viburnum opulus ssp. opulus).* The most abundant species in the ground layer were Canada Anemone and Wild Strawberry. A total of 77 species were documented within this polygon, including 45 (77%) native species (Appendix H7).

FOD9-4 (Fresh-Moist Shagbark Hickory Deciduous Forest Type)

Two Fresh-Moist Shagbark Hickory Deciduous Forest Type polygons were surveyed within the South Milton SWS. The canopy layers in the Fresh-Moist Shagbark Hickory Deciduous Forests were typically dominated by Shagbark Hickory and Freeman Maple, with associates including Box Elder, Paper Birch, and American Basswood. In the understory, Shagbark Hickory and Sugar Maple dominated, with occasional Box Elder, Paper Birch, Bitternut Hickory, American Beech, Eastern Hop-hornbeam, American Basswood, and American Elm. Green Ash, Choke Cherry, and European Buckthorn dominated the shrub layer, with associates including Sugar Maple, Blue-Beech, Shagbark Hickory, Gray Dogwood, Hawthorn species, Honeysuckle species, Black Cherry, Black Raspberry, Eastern Hop-hornbeam, and Cranberry Viburnum. The ground layer was abundant with Jack-in-the-pulpit, Awnless Brome, Woodland Sedge, Shagbark Hickory, Broad-leaved Enchanter's Nightshade, Avens species, Fowl Mannagrass, Virginia Smartweed, Kentucky Bluegrass, Zigzag Goldenrod, Common Dandelion, and White Trillium (*Trillium grandiflorum)*. An average of 84 species were documented across these two polygons, including 55 native species (Appendix H7).

Mixed Forest

Mixed Forests make up approximately 101 ha (7%) of the natural areas within the Primary and Supplemental Study Areas (Table 4.8.1). A total of 46 mixed forest polygons were classified within the study areas. The majority of these features were confined to the lower study area within the west and lower middle branch of the Sixteen Mile Creek, where they were one of the dominant community series (Map T2). Several smaller polygons also made up a large portion of the forest cover in the southern portion of the east branch and northern portion of the lower middle tributary subwatersheds east of Trafalgar Road and North of Britannia Road.

The mixed forests within the South Milton SWS by 4 vegetation types across 3 different Ecosites. Descriptions of these vegetation communities are provided below.

FOM2-1 (Dry-Fresh White Pine-Oak Mixed Forest Type)

One Dry-Fresh White Pine-Oak Mixed Forest Type polygon is mapped within the South Milton SWS. This feature was surveyed from a nearby road, so the groundcover species could not be observed. The dominant species in the canopy and understory layers within this forest type included White Pine, Bur Oak, Red Oak, Norway Spruce, White Ash and Box Elder.

FOM2-2 (Dry-Fresh White Pine-Sugar Maple Mixed Forest Type)

Four Dry-Fresh White Pine-Sugar Maple Mixed Forest Type polygons are mapped within the South Milton SWS. The canopy layers for this forest type were dominated by White Pine and White Spruce, with an abundance of Sugar Maple, Bur Oak, American Basswood and Eastern Hemlock. The understory was a mixture of Sugar Maple, White Ash, and White Pine. Black Raspberry and White Ash were abundant in the shrub layer, with associates including Sugar Maple and Black Cherry. The ground layer was dominated by Sugar Maple and White Ash seedlings, with occasional Garlic Mustard, Broad-leaved Enchanter's Nightshade, Running Strawberry Bush, and Black Raspberry. An average of 17 species were documented across these four polygons, including 14 native species (Appendix H7).

FOM3-2 (Dry-Fresh Sugar Maple-Hemlock Mixed Forest Type)

One Dry-Fresh Sugar Maple-Hemlock Mixed Forest Type polygon is mapped within the South Milton SWS. The canopy layer in this forest was dominated by Sugar Maple and Eastern Hemlock, with some White Ash, Red Pine and White Pine. The understory and shrub layer was also dominated by Sugar Maple, with occasional American Beech, Choke Cherry and American Basswood in the shrub layers. Sugar Maple seedlings were abundant on the forest floor, along with occasional Broad-leaved Enchanter's Nightshade and American Beech. A total of 27 species were documented within this polygon, including 21 (81%) native species (Appendix H7).

FOM6-1 (Fresh-Moist Sugar Maple-Hemlock Mixed Forest Type)

Four Fresh-Moist Sugar Maple-Hemlock Mixed Forest Type polygons are mapped within the South Milton SWS. The canopy layers of this forest type were typically dominated by Eastern Hemlock and Sugar Maple, followed by American Beech, with associates including Eastern Hop-hornbeam, White Pine, Red Oak, American Basswood, and American Elm. Sugar Maple dominated in the understory layers, with abundant American Beech and some Paper Birch, White Pine and Eastern Hemlock, while American Beech was most abundant in the shrub layers. The forest floor was abundant with Garlic Mustard, Running Strawberry Bush, Herb Robert, and Common Speedwell (*Veronica officinalis)*. Other ground layer associates included Canada Goldenrod, Intermediate Fern, Spinulose Wood Fern (*Dryopteris carthusiana)*, Marginal Wood Fern (*Dryopteris marginalis)*, Woodland Strawberry, Climbing Nightshade and Blue-stemmed

Goldenrod. An average of 23 species were documented across these four polygons, including 14 native species (Appendix H7).

Wetland

Wetlands account for approximately 304 ha or 20% of the natural areas within the Primary and Supplemental Study Areas (Table 4.8.1). A total of 248 wetland polygons are mapped within the study area, as shown on Map T2. Marshes are most common on the tablelands in small patches within agricultural areas and along small watercourses, but also line the bottomlands of both branches of the Sixteen Mile Creek. Swamps forests and thicket swamps, in contrast, are more restricted in their distribution, consisting of larger blocks in the lower Sixteen Mile Creek in the Supplemental Study Area, as well as in the northern portion of the Lower Middle Branch subwatershed and western edge of the East Branch subwatershed along the Sixteen Mile Creek.

Meadow Marsh

Meadow Marsh communities make up approximately 179 ha (12%) of the natural areas within the Primary and Supplemental Study Areas (Table 4.8.1). A total of 149 polygons of this type are mapped. These features are widely distributed throughout the study area on both the tablelands and valleylands of each branch of the Sixteen Mile Creek (Map T2). On the tablelands, these communities most often border headwater streams and small open aquatic features within agricultural areas but also line the bottomlands within all branches of the Sixteen Mile Creek. The largest Meadow Marsh features were within the Middle Branch and Middle East Branch subwatersheds within the northern portion of the South Milton SWS.

The Meadow Marshes within the South Milton SWS are represented by 2 Vegetation Types within the the Mineral Meadow Marsh (MAM2) Ecosite. Descriptions of these vegetation communities are provided below.

MAM2 (Mineral Meadow Marsh)

Nine Mineral Meadow Marsh polygons are mapped within the South Milton SWS. These features were typically dominated by Reed Canary Grass (Table 4.8.1). Other abundant species included Garlic Mustard, Sedge species (*Carex* sp), Erysimum Species, Spotted Jewelweed, Kentucky Bluegrass, Eastern Late Goldenrod, Panicled Aster, and Tufted Vetch (*Vicia cracca).* Average species richness across the polygons surveyed was 32 species, including 20 native species (Appendix H7).

MAM2-2 (Reed-canary Grass Mineral Meadow Marsh Type)

Twenty-six (26) Reed-canary Grass Mineral Meadow Marsh Type polygons are mapped within the Primary and Supplemental Study Areas (Table 4.8.1). This meadow marsh type was dominated by Reed Canary Grass and Canada Goldenrod. Other abundant species included European Reed (*Phragmites australis ssp. australis)*, Common Dandelion and Narrow-leaved Cattail. On average, species richness was 28 across the polygons surveyed, including an average of 14 native species (Appendix H7).

MAM2-10 (Forb Mineral Meadow Marsh Type)

Thirteen (13) Forb Mineral Meadow Marsh Type polygons are mapped within the Primary and Supplemental Study Areas (Table 4.8.1). The Forb Mineral Meadow Marshes within the study area were typically dominated by Canada Goldenrod and Narrow-leaved Cattail (*Typha angustifolia)*. Other abundant species include Reed Canary Grass, Marsh Bedstraw (*Galium palustre)*, Purple Loosestrife, Smooth Goldenrod (*Solidago gigantea),* Panicled Aster, Gray Dogwood, and Riverbank Grape. On average, species richness was 38 across the polygons surveyed, including an average of 20 native species (Appendix H7).

Shallow Marsh

Shallow Marsh communities make up approximately 11 ha (<1%) of the natural areas within the South Milton SWS, with a total of 29 polygons of this type classified (Table 4.8.1). These features are located primarily within agricultural lands and golf courses within the central portion of the South Milton SWS (Map T2) and are generally small features less than 1 ha in size (Appendix H7).

The Shallow Marshes within the South Milton SWS were represented by three Vegetation Types within the Mineral Shallow Marsh (MAS2) Ecosite. Descriptions of these vegetation communities are provided below.

MAS2 (Mineral Shallow Marsh Ecosite)

Two (2) Mineral Shallow Marsh Ecosite polygons are mapped within the South Milton SWS (Table 4.8.1). These features were co-dominated by Reed-canary Grass and Goldenrods, with Narrow-leaved and Broad-leaved Cattails, Redtop, and Common reed being abundant associates. The average species richness across these two polygons was 39, with only 13 native species (Appendix H7).

MAS2-1 (Cattail Mineral Shallow Marsh)

Seventeen (17) Cattail Mineral Shallow Marsh Type polygons are mapped within the Primary and Supplemental Study Areas (Table 4.8.1). These features were dominated by Broad-leaved Cattail or Narrow-leaved Cattail, or a combination of these two species, with Canada Goldenrod and Common Reed as abundant associates. The average species richness across these polygons was roughly 7 species, including only 3 native species (Appendix H7).

MAS2-9 (Forb Mineral Shallow Marsh Type)

One Forb Mineral Shallow Marsh Type was documented in the data provided by Savanta (Table 4.8.1). As only the community type was provided, details regarding the species composition and other characteristics will be provided in a future update to the characterization report.

Deciduous Swamp

Deciduous Swamp communities make up approximately 73 ha (5%) of the natural areas within the Primary and Supplemental Study Areas (Table 4.8.1). A total of 55 polygons of this type are mapped. These features are most common in tableland areas and along the east and middle branches of the Sixteen Mile Creek where relatively large patches were present. The largest Meadow Marsh features are within the Middle Branch and Middle East Branch subwatersheds within the northern portion of the South Milton SWS.

The Deciduous Swamps within the South Milton SWS are represented by 5 Vegetation Types across 4 Ecosites. Descriptions of these vegetation communities are provided below.

SWD1-2 (Bur Oak Mineral Deciduous Swamp)

Two Bur Oak Mineral Deciduous Swamp Type polygons are mapped within the South Milton SWS (Table 4.8.1). These features were dominated by Bur Oak in the canopy, with Shagbark Hickory an abundant associate and Silver Maple and American Basswood less common. The subcanopy and understory consisted of the same species, along with Common Buckthorn and Gray Dogwood. Ground cover species included Canada and Tall Goldenrod, Reed Canary Grass, Panicled Aster, Fox sedge (*Carex vulpinoidea*), Hop Sedge (*Carex lupulina*), and Blunt Broom Sedge (*Carex tribuloides*). An average of 22 species were observed across these polygons, with an average of 13 native species (Appendix H7).

SWD2-2 (Green Ash Mineral Deciduous Swamp)

Eight (8) Green Ash Mineral Deciduous Swamp polygons were surveyed within the South Milton SWS (Table 4.8.1). The canopy and subcanopy of these features were dominated by Green Ash with occasional Crack Willow, while the understory layers contained occasional Sandbar Willow (*Salix interio*r), Gray Dogwood, and Tatarian Honeysuckle. Common species include Reed-canary Grass, Dame's Rocket, New England Aster, and Canada Anemone (*Anemone canadensis*), and Purple Loosestrife. On average, 26 species were observed within these polygons, including 16 native species (Appendix H7).

SWD3-2 (Silver maple Mineral Deciduous Swamp Type)

Three (3) Silver Maple Mineral Deciduous Swamp Type polygons were surveyed within the South Milton SWS (Table 4.8.1). These canopy layer of these features were dominated by Silver Maple, with Green Ash, White Willow, and American Basswood being occasional associates, whereas the subcanopy layers were often had Manitoba Maple, Trembling Aspen, and American Elm. Abundant understory trees and shrubs included Green Ash, Silver Maple, Common Buckthorn, Swamp Red Current (*Ribes triste*), and Poison Ivy (*Toxicodendron radicans*). The groundcover layers were abundant with Reed Canary Grass, Asters (Symphyotrichum sp), Spotted Jewelweed, and Goldenrods. Less common associates included Canada Anemone, Field Horsetail (*Equisetum arvense*), Wild Strawberry, and Cattails. On average, 15 species were observed in these polygons, including 11 native species (Appendix H7).

SWD3-3 (Swamp Maple Mineral Deciduous Swamp Type)

Four Swamp Maple Mineral Deciduous Swamp Type polygons are mapped within the South Milton SWS (Table 4.8.1). These features were dominated by Freeman's Maple in the canopy and subcanopy, and also contained American Elm and Green Ash in the understory. The ground cover was abundant with Poison Ivy, Clear Weed, and Enchanter's nightshade. Species richness for the one polygon surveyed by D&A was 24, including 15 (71%) native species (Appendix H7).

SWD4-1 (Willow Mineral Deciduous Swamp Type)

Five Willow Mineral Deciduous Swamp Type polygons were surveyed within the South Milton SWS (Table 4.8.1). The canopy and subcanopy of these features were dominated by non-native willows (e.g. White Willow), along with Manitoba Maple, Green Ash, and Bur Oak as less common associates. Understory species included Red-osier Dogwood, Common Buckthorn, Riverbank Grape, and American Elm, while the groundcover consisted of Canada Goldenrod, Purple Loosestrife, and Reed Canary Grass. On average, 24 species were observed in these polygons, including 13 native species (Appendix H7).

Mixed Swamp

Mixed Swamp communities make up approximately 4 ha (<1%) of the natural areas within the South Milton SWS (Table 4.8.1). This community type is restricted to one feature at the southern edge of the West Branch subwatershed of the Sixteen Mile Creek within the Supplemental Study Area (Map T2). No field investigation was conducted for this feature; it was mapped based on background information and interpretation of orthoimagery only.

Thicket Swamp

Thicket swamp communities make up approximately 38 ha (2.6%) of the natural areas within the South Milton SWS (Table 4.8.1). A total of 13 polygons of this type mapped. These features were clustered in the northern portion of the South Milton SWS within the middle and middle east branches, as well as the southern edge of the South Milton SWS along the east Sixteen Mile Creek (Map T2).

The Meadow Marshes within the South Milton SWS were represented by 2 Vegetation Types within theMineral Thicket Swamp (SWT2) Ecosite. Descriptions of these vegetation communities are provided below.

SWT2 (Mineral Thicket Swamp Ecosite)

One Mineral Thicket Swamp Ecosite was surveyed within the South Milton SWS (Table 4.8.1). This feature was dominated by Black Walnut, with occasional Sugar Maple in the canopy and understory layers. Black Walnut was most abundant in the shrub layer, and the ground layer contained occasional Garlic Mustard, Colt's-foot and Riverbank Grape. A total of 8 species were observed in this polygon, including 4 (50%) native species (Appendix H7).

SWT2-2 (Willow Mineral Thicket Swamp Type)

Three Willow Mineral Thicket Swamp Type polygons were surveyed within the South Milton SWS (Table 4.8.1). These features were dominated by Heart-leaved Willow (*Salix eriocephala).* Occasional ground layer associates included Spotted Jewelweed, Purple Loosestrife, Reed Canary Grass, and Hybrid Cattail (*Typha x glauca)*. On average, 7 species were observed across these polygons, including 4 native species (Appendix H7).

SWT2-9 (Gray Dogwood Mineral Thicket Swamp Type)

Two Gray Dogwood Mineral Thicket Swamp Type polygons were surveyed within the South Milton SWS (Table 4.8.1). These features were dominated by Black Maple and Sugar Maple in the canopy layers, with abundant Black Walnut and occasional associates including Box Elder, Freeman Maple, Green Ash, American Basswood, and American Elm. Black Maple, Sugar Maple, and Hawthorn species dominated the understory, with occasional Green Ash, Choke Cherry, Bur Oak, American Basswood and American Elm. In the shrub layers, Gray Dogwood and Hawthorn species were the most abundant, along with occasional Green Ash, Staghorn Sumac, Common Red Raspberry and Riverbank Grape. Black Maple seedlings and Common Scouring-rush were the most abundant species on the ground layer, followed by Sugar Maple seedlings, Woodland Sedge, Yellow Trout-lily and Dame's Rocket. On average, 89 species were observed across these polygons, including 51 native species (Appendix H7).

Aquatic

Aquatic communities make up the smallest portion of the South Milton SWS at approximately 50 ha in total or 3.33% of all the natural areas within the Primary and Supplemental Study Areas (Table 4.8.1). A total of 139 polygons are mapped, which are primarily small (< 0.5 ha) features in agricultural or anthropogenic areas (Map T2). Many of the aquatic features, including the largest, are concentrated within the Rattlesnake Point Golf Club, Wyldewood Golf and Country Club, and Oakville Executive Golf Course.

Open Aquatic

One hundred and seven (107) Open Aquatic polygons making up approximately 44 ha (3%) of the natural areas were identified within the Primary and Supplemental Study Areas (Table 4.8.1). These communities were distributed throughout the South Milton SWS, but were concentrated within the golf courses and along the upper East Sixteen Mile Creek (Map T2). Smaller open aquatic features were also scattered among agricultural lands.

OAO (Open Aquatic)

These communities were typically abundant with Narrow-leaved Cattail and Thicket Creeper, with occasional European Reed, Poison Ivy, Broad-leaved Cattail, and Red Fescue (*Festuca rubra ssp. rubra)* along shoreline areas.

Shallow Water

Twenty-three (23) Shallow Water polygons were surveyed within the South Milton SWS, making up approximately 3 ha (<1%) of the natural areas (Table 4.8.1). These features were most common in the southeastern portion of the South Milton SWS within agricultural areas, golf courses, and occasionally along the east branch of the Sixteen Mile Creek (Map T2).

One shallow water polygon was surveyed within the South Milton SWS. This community was dominated by Duckweed species (*Lemna sp).* A total of 21 species were observed in this polygon, including 13 (65%) native species.

Floating-leaved Shallow Aquatic

Four Floating-leaved Shallow Aquatic polygons making up less than 1 ha (<1%) of the natural areas within the South Milton SWS were identified (Table 4.8.1). These features were all small (<0.5 ha), and are isolated within the lower middle branch subwatershed. The largest feature, located north of Derry Road along the western edge of the primary study area, is part of a larger complex of wetland features within the corridor of the middle branch of the Sixteen Mile Creek. One Vegetation Type was identified within this community series and is described below.

SAF1-3 (Duckweed Floating-leaved Shallow Aquatic Type)
Two Duckweed Floating-leaved Shallow Aquatic Type polygons were surveyed within the South Milton SWS (Map T2). These features were dominated by Lesser Duckweed, Purple Loosestrife, Reed Canary Grass, Broad-leaved Cattail, and had occasional Crack Willow (*Salix x fragilis).*

Submerged Shallow Aquatic

Six (6) Submerged Shallow Aquatic polygons making up approximately 2 ha (0.15%) of the natural areas were identified within the South Milton SWS (Table 4.8.1). These communities were all located within the Wyldewood Golf and Country Club (Map T2). These features were dominated by Reed Canary Grass and Narrow-leaved Cattail.

4.8.3.2 Botanical Inventories

Methods

An inventory of vascular plant species growing within each ELC polygon was conducted at the same time as the Ecological Land Classification Surveys (Appendix H4). The data from these surveys were supplemented with additional species observations made during other surveys (e.g. reptiles, breeding bird surveys, etc). This information was added to the ELC database to facilitate data management, QA/QC, analysis, and mapping. The taxonomy, nomenclature and provincial ranks for each of the species are consistent with the Natural Heritage Information Centre (NHIC 2014). Regional ranks follow Varga et al. (2005) for the Greater Toronto Area and Crins et al. (2006) for Halton Region.

Analysis

Background Review Results

Data from eight (8) background resources were reviewed in order to compile a comprehensive list of species that are known to occur within the Primary or Supplemental Study Areas or natural features that are contiguous with the South Milton SWS (i.e. Sixteen Mile Creek). These resources included:

- Britannia Road Transportation Corridor Improvements: Environmental Study Report

(North-South Environmental 2011 & 2013)

- Sixteen Mile Creek Subwatershed Update Study/Functional Stormwater and Environmental Management Studies (AMEC Environment & Infrastructure et al., 2013);
- Milton Phase 2 Holistic Monitoring Study (D&A 2010 – 2014);
- Milton Phase 3 Monitoring (D&A 2016)
- North Oakville Creeks Subwatershed Study;
- Premier Gateway Subwatershed Study;
- 401 Corridor Integrated Planning Project, Town of Halton Hills: Scoped Subwatershed Plan (Dillon 2000);
- Element Occurrence Data for Provincially tracked species, plant communities and wildlife concentration areas query (NHIC 2016);
- Consultation with Aurora District MNRF for Species at Risk (SAR) records (via an Information Request);
- Great Lakes Conservation Blueprint for Terrestrial Biodiversity (Henson & Brodribb 2005)
- Conservation Halton Element Occurrence Data (Conservation Halton, 2016)

The review of background studies and data returned records for a total of 493 vascular plant species occurring within and/or adjacent to the Primary and Supplemental Study Areas. Of these, 371 (75%) are native to Ontario. A complete list of the species compiled from all of the background resources reviewed is provided in Appendix H1.

Field Investigation Results

A total of 730 vascular plant species were documented in the South Milton SWS area as part of the botanical inventories conducted by Savanta and D&A. This included 455 species from the properties surveyed by Savanta and 604 from the lands surveyed by D&A. Of the 730 records, 631 were confirmed to the species level; the remaining 99 were identified to genus due to lack of diagnostic characteristics (e.g. flowers, fruit). Of those identified to species, 240 (38%) species are not native to Ontario, including 61 (10%) ornamental species, and 13 (2%) agricultural species.

In terms of growth form, the majority of species observed, 333 (56%), were forbs, including 205 (32%) native species and 149 (24%) non-native species. Trees made up the second richest group, with 84 (13%) species including 55 (9%) native and 29 (5%) non-native species. Shrubs were represented by 58 (9%) species, of which 37 (6%) are native, and 21 (3%) are non-native. Grasses represented 9% (56 species) of the flora, with more non-native species than native species (32 species vs. 24 species), and 50 (8%) sedge species were recorded for the South Milton SWS, including one non-native species. Finally, 14 (2%) native fern species were observed, and 16 (3%) vines, including 10 (2%) native and 6 (1%) non-native vines.

In terms of Coefficients of Conservatism (CC), 319 of the 730 species observed (44%) are taxa that are typically associated with a wide variety of plant communities and disturbance regimes (CC = 0 - 3; Appendix H8). Only 216 (30%) species are typically associated with specific habitat types but have a moderate tolerance to disturbance (CC= 4 - 6), and only 59 (8%) are species of late-successional and low-disturbance plant communities (CC = 7,8) or with a high fidelity to communities with a narrow range of environmental conditions (CC = 9,10). Finally, 136 (%) of the species observed have no CC values assigned, which are typically non-native species. Average CC for the native species observed was 3.5.

Obligate upland species were the most numerous group and represented 29% of all species included in this analysis, whereas obligate wetland species represent only 15%. Overall, the flora of the South Milton SWS is dominated by species favoring upland conditions, with 325 species having CW >0 versus 212 species with CW <0 Appendix H8. An additional 58 species are equally likely to occur in wetland and upland habitats (CW = 0). Overall, average CW for the species observed was 0.8.

4.8.3.3 Breeding Birds

Methods

An extensive survey effort was conducted across the South Milton SWS area for breeding birds. Savanta staff conducted surveys on 18 different days (85.4 person hours) during 2015 and D&A staff conducted surveys on 22 different days (97.5 person hours) during 2016 (Appendix H5). Data was collected using point counts (roadside and off-road), area search transects, and incidental observations. Point count and area search transect survey locations were conducted primarily in the Primary study area on a subset of properties in the South Milton SWS where access had been provided; additionally, sites were chosen in an attempt provide representative coverage of the various habitat types within the study area. (Map T3-2) shows the locations of bird point count stations and features sampled using area search transects. A total of 105 point count stations and additional area search transects were conducted across the South Milton SWS.

Surveys generally followed the guidelines outlined in the Ontario Breeding Bird Atlas (Cadman *et al.*, 2007): surveys were conducted within the recommended time period of May 24th to July 12th (Appendix H5); however, some surveys were conducted beyond the recommended 10:00 am end-time (Appendix H5). This was done to maximize the coverage over a relative narrow survey window. Open habitats and agricultural areas were targeted for surveys that extended past 10:00 a.m.; generally, birds that use these habitats sing more regularly later in the day, unlike birds that use forested habitats that are more active earlier in the morning. Repeat surveys for each point count location and area search transect were completed at least one week apart and during appropriate weather conditions (*i.e.* with light winds and no heavy rain). Point count surveys were conducted for five minutes for roadside stations, and 10 minutes non-roadside surveys. The reduced survey effort for roadside surveys was conducted to allow increased coverage of agricultural habitats, and that we expected the community of bird species to be similar among survey locations. Additional details regarding survey visits are presented in Appendix H5.

Analysis

Background Review Results

During the 2001 to 2005 Ontario Breeding Bird Atlas, 105 breeding bird species were reported from the two 10 x 10 km squares (17NJ91 and 17NJ92) that encompass the vast majority of the primary and Supplemental Study Areas within the South Milton Subwatershed Study lands between 2001 and 2005 (Cadman *et al*. 2007).

Field Investigation Results

In total, 117 bird species were reported within and adjacent to the Primary and Supplemental Study Areas within the South Milton SWS (Appendix H5). Appendix H2 provides a summary of species records by source.

Of the 117 species, 16 species were considered migrants, including: Black-bellied Plover (*Pluvialis squatarola*), Semipalmated Plover (*Charadrius semipalmatus*), Least Flycatcher (*Empidonax minimus*), Ruby-crowned Kinglet (*Regulus calendula*), Swainson's Thrush (*Catharus ustulatus),* Pine Siskin (*Spinus pinus*), Tennessee Warbler (*Oreothlypis peregrina*), Magnolia Warbler (*Setophaga magnolia*), Bay-breasted Warbler (*Setophaga castanea*), Blackpoll Warbler (*Setophaga striata*), Palm Warbler (*Setophaga palmarum*), Black-throated Green Warbler (*Setophaga virens*), Canada Warbler (*Cardellina canadensis*), Wilson's Warbler (*Cardellina pusilla*), White-throated Sparrow (*Zonotrichia albicollis*), and White-crowned Sparrow (*Zonotrichia leucophrys*).

An additional six species were observed during the site investigations, but were not considered to be breeding within the study areas (e.g. were flying overhead and/or foraging but not breeding) including: Ring-billed Gull (*Larus delawarensis*), Herring Gull (*Larus argentatus*), Caspian Tern (*Hydroprogne caspia*), Double-crested Cormorant (*Phalacrocorax auritus*), Bald Eagle (*Haliaeetus leucocephalus*) and, Peregrine Falcon (*Falco peregrinus*).

Five of the species were not native to Ontario: Mute Swan (*Cygnus olor*), Rock Pigeon (*Patagioena livia*), European Starling (*Sturnus vulgaris*), House Sparrow (*Passer domesticus*), and House Finch (*Haemorhous mexicanus*).

Breeding birds are also described according to habitats that they normally associate with. To help understand these relationships, all of the breeding bird species documented within the South Milton SWS lands were grouped according using the Habitat Association lists contained within Appendix 3 of the Atlas of the Breeding Birds of Ontario (Cadman et al. 2007). Five major habitat associations were recognized: (1) Woods and Forests; (2) Grassland, Agricultural, Open; (3) Shrub and Early Succession; (4) Wetlands; and (5) Urban and Suburban. A sixth, Unassigned, only applied to one species, Turkey Vulture (Cathartes aura).

The breakdown of breeding bird species present within the South Milton SWS lands is as follows:

30 - Woods and Forests
20 - Grassland/Agricultural/Open
19 - Shrub and Early Succession
15 - Wetlands
10 - Urban
1 - Unassigned

Typical breeding bird species documented from the South Milton SWS from each group included the following:

Woods and Forests: Downy Woodpecker, Eastern Wood-Pewee, Great Crested Flycatcher, Red-eyed Vireo, and White-breasted Nuthatch.

Grassland/Agricultural/Open: Killdeer, Horned Lark, Barn Swallow, Vesper Sparrow, Savannah Sparrow, and Common Grackle.

Shrub and Early Succession: Willow Flycatcher, Gray Catbird, Cedar Waxwing, Song Sparrow, and Northern Cardinal.

Wetlands: Canada Goose, Mallard, Great Blue Heron, Swamp Sparrow, and Red-winged Blackbird.

Urban: Mourning Dove, Blue Jay, American Crow, Black-capped Chickadee, and American Robin.

All five of the habitat guilds of birds appeared to be widely distributed across the Primary and Supplemental Study Areas within the South Milton SWS lands. This is not surprising as these five habitat associations are also widely distributed. After all, the study area can be generally described as an agricultural landscape bisected by various branches and tributaries of Sixteen Mile Creek. Scattered throughout this landscape are a number of remnant woodland and wetland habitats, again mostly associated with the Sixteen Mile Creek Valley. Also mixed throughout are successional habitats transitioning from open habitats to woodland habitats, as well as numerous rural residences, plant nurseries and golf courses.

4.8.3.4 Anurans (Frogs and Toads)

Methods

Nocturnal amphibian call surveys were conducted at a total of 120 locations for the South Milton SWS area; this included 30 properties surveyed by Savanta during 2015 and 80 locations across the Primary study area by D&A. D&A also conducted surveys at 17 amphibian monitoring stations within or adjacent to the South Milton SWS as part of the Milton Phase 3 Subwatershed Study monitoring program during 2016. Survey results from all three sources have been amalgamated for the South Milton SWS characterization (Map T3-1).

Amphibian call surveys were completed according to the protocol outlined in the Marsh Monitoring Program (MMP) (BSC, 2009), including seasonal timing and weather conditions. During each visit, surveyors documented amphibian calls for a 6-minute duration at each of the monitoring stations. The duration of each point count was extended from the standard 3-minute recommendation to 6 minutes to help ensure that all species present were documented and that calling intensity was accurately recorded given that moderate to loud ambient background noise was present across much of the study area. Survey locations are shown on Map T3-1, and survey information is provided in Appendix H5**.**

Analysis

Background Review Results

The studies reviewed for background information identified eight (8) anuran species that potentially occur within and adjacent to the Primary study area:

- American Bullfrog (*Lithobates catesbeianus*);
- American Toad (*Anaxyrus americanus*);
- Gray Treefrog (*Hyla versicolor*);
- Green Frog (*Lithobates clamitans*);
- Northern Leopard Frog (*Lithobates pipiens*);
- Spring Peeper (*Pseudacris crucifer*);
- Western Chorus Frog - Great Lakes population (*Pseudacris triseriata*); and
- Wood Frog (*Lithobates sylvaticus*).

Full choruses were heard from American Toad, Gray Treefrog, and Spring Peeper. Green Frog and Northern Leopard Frog were recorded throughout the Primary study area. American Bullfrog and Western Chorus Frog were only heard in a couple of locationsSouth Milton SWS while Wood Frog was not heard within the Primary study area but was recorded slightly west. Ontario Nature Herpetological Atlas query (squares 17NJ91, listed the same eight species. Details and references of each record can be found in Appendix H2.

Field Investigation Results

As noted in the methods, characterization of calling amphibians present in the South Milton SWS area is based on a consolidation of field data collected by Savanta in 2015 and D&A in 2016. Savanta completed Nocturnal Amphibian Call Surveys at 53 point count locations across 25 properties in 2015, resulting in 79 species records. Savanta surveys were all completed within the Primary study area on participating landowner properties and are depicted on Map T3-1. D&A Milton Phase 3 Monitoring was completed during the spring and early summer of 2016 at 17 point count stations of which 2 are within the Primary study area, 4 within the Supplemental Study Area, and 11 are northwest of the study areas (Map T3-1). The surveys resulted in 42 species records. Details of all species records can be found in Appendix H5.

Within the primary and Supplemental Study Area, a total of seven (7) anuran species were documented. Species documented included:

- American Bullfrog (*Lithobates catesbeianus*);
- American Toad (*Anaxyrus americanus*);
- Gray Treefrog (*Hyla versicolor*);
- Green Frog (*Lithobates clamitans*);
- Northern Leopard Frog (*Lithobates pipiens*);

- Spring Peeper (*Pseudacris crucifer*); and
- Western Chorus Frog - Great Lakes population (*Pseudacris triseriata*)

Of the species observed, American Bullfrog is the most dependent on permanent aquatic habitat. They tend to be found in habitats ranging from large lakes to ornamental ponds including vernal pools, and along streams and creeks (Dodd, 2013), but prefer forested habitats. American Bullfrogs require waterbodies that are large, open-canopied, and permanent or almost permanent including but not limited to lakes, oxbows, both natural and manmade ponds, and slow moving watercourses (Babbitt *et al.* 2003). Sites with shallow water and significant emergent and submergent vegetation are preferred for oviposition (Dodd, 2013). They are classified as area-sensitive (OMNR, 2000) and are often one of the first species to disappear with increased urbanization of the landscape.

American Toads are habitat generalists as they occur in a wide range of habitats ranging from forests to manicured lawn but tends to prefer open deciduous forests and grasslands as foraging habitat (Dodd, 2013). American Toads will migrate several hundred meters to breeding habitat (Dodd, 2013) that include shallow warm ponds, shallow streams, river margins, and more degraded habitat, including large puddles and roadside ditches (Crowley, 2016).

Gray Treefrogs inhabit wooded and thicket communities that are located near permanent water, as they don't tend to travel far from breeding locations (Dodd, 2013). Breeding habitat for Gray Treefrogs includes small wetlands located adjacent to woodlands and woodland ponds which can range from intermediate (greater than four months) to long hydroperiods (permanent). Prime habitats have shrubs, trees, floating vegetation, or other vegetation surrounding water to be used as calling perches (Dodd, 2013). They will use more disturbed habitat including ditches and pasture ponds.

Green Frog are also habitat generalists as they will inhabit anything from a large lake to a small pond; woodland pools and streams; seeps and springs; streamside riparian communities (Dodd, 2013). They are ubiquitous throughout southwestern Ontario; a study completed by Hecnar and M'Closkey (1996) found them in 104 of 117 sites they surveyed in ponds including Essex Plain, Stratford Plain, and the Grey-Bruce Uplands. Although they are a generalist, they prefer habitat that is relatively unaffected by urbanization and agriculture but will still inhabit wetlands adjacent to farm fields (Dodd, 2013). They do not tend to migrate far from breeding sites as they tend to stay near water throughout the year. Therefore, they prefer wetlands with long hydroperiods. They commonly breed in lakes, ponds, and slow-moving watercourses including stormwater management ponds, canals, and ditches as long as they have permanent water. They will also utilize small woodland ponds (Dodd, 2013).

Northern Leopard Frog prefers open habitat of varying sized connected wetlands with remnant forest features (Dodd, 2013). They also utilize wet meadows, marshes, and open forest habitat as feeding sites away from breeding ponds (Sutton, 2004). Preferred breeding sites have clear water range in both size and quality. They are known to use ponds smaller than 0.4 ha, protected sections of a lake, as well as golf course ponds (Dodd, 2013). Their ideal breeding habitat includes shallow ponds that warm up quickly with significant cover of emergent and submerged vegetation particularly on the shoreline (Dodd, 2013). They use the vegetation as cover from predation, as well as a place to attach their egg masses.

Spring Peeper inhabit largely hardwood and mix-hardwood forests and, less commonly, coniferous forests (Dodd, 2013). In more urban settings they will inhabit riparian forests. Terrestrial foraging habitat can range from 100 to 1,000 m away from breeding sites (Herrmann *et al.* 2005). Breeding sites can be very small and can vary greatly including but not limited to lakes shores, stormwater management ponds and manmade ponds, bogs, marshes, ditches, seepage swamps, and floodplain forests. Breeding sites may range in hydroperiods, but they prefer hydroperiods of greater than four months that are not permanent (Babbitt *et al.* 2003). Habitat connectivity between breeding habitat and forest habitat is key for this species as it relies on both marsh and wetland habitats as well as terrestrial forests.

Western Chorus Frog (great lakes population) prefer areas that provide a mix of complementary habitats including, but not limited to, deciduous forests mixed with nearby open meadow habitats and ponds (Dodd, 2013). They can also found in woodland pools with an open canopy during the winter and spring seasons as well as along the shoreline of the Great Lakes where the shoreline has significant emergent vegetation and a greater shoreline perimeter to flooded area ratio (Price *et al.* 2004). Terrestrial foraging areas and breeding habitat are usually within approximately 100m but have been found up to 200m away (Kramer, 1973). Breeding habitat typically includes grassy marshes, ditches, small swamps, woodland pools, and have been known to breed in shallow wetlands on golf courses (Dodd, 2013). Breeding sites are water bodies can include temporary and/or permanent, shallow, fishless, abundant emergent vegetation with an open canopy (Dodd, 2013).

Western Catchments: West Branch, and Main Branch

A total of five (5) anuran species were documented within the western catchments within the study area. Species detected included:

- American Toad;
- Gray Treefrog;
- Green Frog
- Spring Peeper; and
- Northern Leopard Frog

The surveys completed within the western catchments resulted in very few species records. Between the three data sources, there is a total of six point count locations within the South Milton SWS area and ten additional sites to the north and west of the study areas.

The main tributary of Sixteen Mile Creek is contained within a valley that has a complex of deciduous and mixed forest communities with a thin meadow marsh community along the watercourse. No frogs were recorded along this watercourse within the study area, but American Toads and Spring Peepers were heard upstream in low abundance. There were no call stations located within the floodplain of this watercourse although it is not likely to provide significant breed habitat. There are several farm ponds east of this watercourse that provide breeding habitat for American Toad, Gray Treefrog, Green Frog, Northern Leopard Frog, and Spring Peepers. There were full choruses for both American Toad and Spring Peeper. These species tend to like more open marsh wetland for breeding and tend to be able to breed in degraded habitat.

Outside the study area to the northwest were records of Western Chorus frog (Great Lakes population) in a high abundance indicate that there is likely breeding habitat. There is also records of Wood Frog in two forests, but this species was not detected within the study area.

Central Catchments: Middle Branch, Middle East Branch, and Lower Middle Branch

A total of five (5) anuran species were documented within the western catchments. Species detected included:

- American Toad;
- Gray Treefrog;
- Green Frog
- Spring Peeper; and
- Northern Leopard Frog

The north end of the Middle Sixteen Mile Creek, between the north Study area boundary and just south of Derry Rd, contains floodplain forests adjacent to meadow marsh and shallow marsh communities with pockets of swamp. American Toads were found to be calling throughout this corridor in both small wet spots in agricultural fields, meadow marshes, and shallow marshes, and within the riparian woodlands. This indicates that there is a significant area of breeding habitat available to American Toads in this corridor. Green Frog was heard calling in the meadow marsh/shallow marsh complex located west of Sixth Ln and north of the Railway tracks. Spring peeper was also heard calling from this location from several wet pockets. Both Spring Peeper and Green Frog were also heard calling along the same tributary but south of Derry Rd. Northern Leopard frog was heard calling in low abundance along this tributary where there was minimal tree cover. The survey results indicate that this reach of the Middle Sixteen Mile Creek contains abundant breeding habitat for American Toad, Green Frog, and Spring Peeper and minimal breeding habitat for Northern Leopard frog.

Middle Sixteen Mile Creek flows through two golf courses south where the natural features surrounding the watercourse become forested. The golf courses also contain several large open ponds with thin emergent vegetation shores. The most abundant species in this area was green frog followed by Northern Leopard Frog and Spring Peeper. There was one record for Gray Tree Frog in one of the ponds with six individuals calling. This indicates that the golf courses provide breeding habitat for the four species.

North of Britannia Road, Middle Sixteen Mile Creek confluences with East Sixteen Mile Creek. The floodplain at this location becomes wider and more open with patches of thicket and forested valley slopes. South of Britannia there are records for American Toad, Gray Treefrog, Green Frog, and Spring Peeper calling. There are two permanent ponds located south of the watercourse that likely provides breeding habitat for the four species listed above.

Eastern Catchments: East Branch and Lower Middle Tributary

A total of seven (7) anuran species were documented within the western catchments. Species detected included:

- American Toad;
- Gray Treefrog;
- Green Frog;
- Spring Peeper;
- Northern Leopard Frog; and
- Western Chorus Frog

There were no point count stations located north of the railway tracks in the eastern catchment. The habitat appears to have minimal tree cover and is significantly cultural. Green Frog was observed in this area as an incidental record during odonate surveys.

South of the railway tracks west of Eighth Line, there are several small isolated wetlands that are providing breeding habitat for American Toad, Green Frog, Northern Leopard Frog, and Spring Peepers. Despite the isolated nature of the wetlands and the lack of complementary woodland habitat, the features in this area provided one of the higher diversity locations for amphibians within the study area based on the number of species and relative abundance.

South of Derry Rd. west of Eighth Line, an isolated mid-block woodlot provided breeding habitat for Spring Peepers and Gray Treefrog. The woodlot is relatively small but has a mix of upland woodland, meadow, and wetland habitats present.

Further south and closer to Britannia Road, there was a high diversity and abundance of calling amphibians. The wetlands, swamp, meadows, and upland forests in this area provide a mix of breeding and foraging habitats that support a high diversity and abundance of amphibian habitat in the Primary study area South Milton SWS. All seven frog and toad species recorded within the South Milton SWS were documented in this general area. American Toad, Gray Treefrog, Green Frog, Northern Leopard Frog, and Spring Peeper had the highest abundance; the adjacent area (to southeast) was also the only location in the South Milton SWS where Western Chorus Frog was recorded. As well, American Bullfrog was recorded in a small pond that is connected to the East Sixteen Mile Creek tributary southwest of Britannia Road. Additionally, this area had one of the highest abundances of Gray Treefrog in the South Milton SWS; only one other location within the Primary Study Area had a full chorus of this species during 2016 surveys.

The golf course east of Trafalgar contains fewer ponds and wetland features than the golf courses in the central catchment. Northern Leopard Frog, Spring Peeper, and Gray Treefrog were heard calling in high abundance from the natural feature north of the golf course and within the ponds. American Toad was also heard calling along some of the creeks and are likely breeding there. A single American Bullfrog was heard by Savanta in 2015 in one of the ponds at station P12-F. The ponds within this property are some of the largest ponds within the study areas and may provide enough habitat for them to breed.

Of the eight species recorded in background studies and Ontario Nature Herpetological Atlas; seven were recorded within the South Milton SWS. Despite the number of surveys conducted, and the coverage across the South Milton SWS, it is somewhat surprising that Wood Frog was not detected. The lack of detection does not rule out the possibility that it is present in some of the higher quality wetland and woodland areas, but it does confirm that Wood Frog is rare. Its calling window tends to be much shorter than other amphibians, and can be hard to predict as the can start breeding while there is still ice on the ponds (Dodd, 2013). Therefore future surveys should consider this, and potentially adjust the timing of call surveys to increase the likelihood of detecting this species.

4.8.3.5 Salamanders

Methods

Salamander surveys were conducted by D&A and Savanta at ponds located in the northern and northeastern portion of Drumquin Woods during early spring 2016 (Map T3-1). The primary objective of the surveys was to determine if Jefferson Salamander (*Ambystoma jeffersonianum*) and/or the Jefferson Salamander dependent unisexual polyploid types are present within Drumquin Woods. The trapping survey period was selected to coincide with adult Ambystomid seasonal migrations to breeding ponds (Stebbins and Cohen, 1995; JSRT, 2009; COSEWIC, 2010). Trapping was conducted in two ponds located in the northeastern corner of Drumquin woods over six nights in 2016 and checked on the mornings of April 8, 9, 11, 13, 14, and 17 (Appendix H5) (Map T4). A total of fourteen (14) traps were used, including nine (9) in the western pond and five (5) in the eastern pond.

Savanta staff conducted additional trapping in nine (9) other locations across two properties on March 10 and March 28 2016. The properties they visited were located in the north end of Drumquin Woods, and in a separate 4.75ha woodlot located approximately 400m north of Drumquin woods. Savanta also conducted a movement survey on March 15th in the north section of Drumquin Wods. In addition, Savanta set 46 salamander cover boards in 2015 in the South Milton SWS area. All trapping and cover board locations are provided on Map T4-5 Salamander Survey Locations (see Savanta 2016 Terrestrial Data spreadsheet for coordinates of traps, and 2015 data for cover board locations).

Prior to fieldwork, Wildlife Animal Care Committee Research Protocol (WACCRP), Wildlife Scientific Collector's Authorization (WSCA) and Endangered Species Act (ESA) permits were obtained.

The following documents were reviewed prior to fieldwork, and their recommendations were followed where applicable:

- Canadian Council on Animal Care Species-specific Recommendations on Amphibians &

Reptiles

- Canadian Council on Animal Care Guidelines on The Care and Use of Wildlife
- USGS National Wildlife Health Center Restraint & Handling of Live Amphibians
- In addition, although toe-clipping was not performed, the USGS National Wildlife Health Centre Toe-Clipping of Frogs and Toads (also covers salamanders) was reviewed for general insights

The protocol for trapping in the 2016 season was undertaken to minimize the length of time that captured specimens spent in traps. This lessened the potential of trapped specimens becoming fatigued and/or oxygen deprived.

Analysis

Background Review Results

The Ontario Nature Reptile and Amphibian Atlas was reviewed for species found within the atlas squares 17NJ91, 17NJ92, 17PJ01 and 17PJ02. This source provided observations of six (6) species of salamanders, including:

- Mudpuppy (*Necturus maculosus)*
- Red-spotted Newt (*Notophthalmus viridescens viridescens)*
- Jefferson Salamander (*Ambystoma jeffersonianum)*
- Jefferson Salamander Complex - unidentified member
- Spotted Salamander (*Ambystoma maculatum)*
- Eastern Red-backed Salamander (*Pseudotriton ruber)*

In addition, field surveys during the Boyne SIS Areas 5a, 5b and 6 studies completed in 2016 (DSEL) detected two (2) additional species records:

- Eastern Tiger Salamander (*Ambystoma tigrinum)*
- Eastern Red-backed Salamander (*Pseudotriton ruber)*

Field Investigation Results

During D&A and Savanta's trapping investigations in April 2016, several minnows, tadpoles, and predacious diving beetles were observed. No adult anurans or salamander species were detected in traps.

During Savanta's salamander trapping, one (1) species, Spotted Salamander (Ambystoma maculatum) was detected near the northwestern corner of Drumquin Woods (in the Lower Middle Tributary Catchment) on March 28th 2016 (see Map T3-1). Spotted Salamanders typically prefer mature deciduous forests with vernal pooling, but local populations can also inhabit mixed and coniferous woods (Petranka, 2010). Additional salamander trapping in Drumquin Woods and the further north 4.75ha woodlot is planned for Spring 2017, depending on property access. D&A received the required permits from the MNRF on March 9th 2017. Reptiles (Snakes & Turtles)

Methods

Snake and turtle surveys within the South Milton SWS were conducted in targeted areas that had been identified based on desktop assessment and, in some cases based on knowledge that sites may provide suitable habitat. D&A conducted targeted reptile surveys across five properties under appropriate weather conditions, and also recorded incidental reptile observations during other surveys for ELC, odonates and breeding birds. Savanta conducted nine (9) targeted snake transects over nine properties and deployed twenty-seven (27) snake cover boards across seven (7) properties in 2015. Savanta also conducted turtle nesting surveys at 13 stations located across seven (7) properties and turtle basking surveys at twenty-five (25) points across nineteen (19) properties. Roadside mortality surveys were also conducted by Savanta in 2015 using twelve (12) transects. Survey information is provided in Appendix H5, and survey locations are shown on Map T3-3.

Snake surveys were conducted using area searches throughout suitable habitat types within the study area, such as field/forest edges, pond and wetland edges, and upland forest areas adjacent to ponds. In addition to these targeted surveys, area searches and incidental observations were recorded for snakes and turtles during other field investigations such as breeding bird surveys and vegetation surveys. Targeted surveys that had originally been recommended for Eastern Milksnake (*Lampropeltis triangulum)* were not carried out, as it was down-listed from Special Concern to Not at Risk in Ontario (OMNRF, 2016).

Targeted turtle basking and nesting surveys were conducted at the same time as targeted snake surveys. Specific information regarding surveys are presented in Appendix H5. Directed searches were conducted in suitable habitat on selected properties; the approach involved searching for basking turtles along shorelines and open water of ponds and other watercourses, as well as potential nesting sites in landscapes with loose sand or gravel close-by to waterbodies. Binoculars and spotting scopes were used for surveys at a distance. In addition to these targeted surveys, turtles and potential nesting sites observed during other field investigations such as Breeding Bird Surveys and ELC surveys were noted as incidental records.

Analysis

Background Review Results

Review of historical and recent data sources (Appendix H2) identified records for two (2) species, including:

- Eastern Gartersnake (*Thamnophis sirtalis sirtalis)*
- Snapping Turtle (*Chelydra serpentina)*

The Reptile and Amphibian Atlas of Ontario (Ontario Nature 2015) provided an additional twelve (12) species records for the grid squares 17NJ91, 17NJ92, 17PJ01 and 17PJ02. These species include:

- Blanding's Turtle (*Emydoidea blandingii)*

- Pond Slider (*Trachemys scripta)*
- Snapping Turtle (*Chelydra serpentina)*
- Midland Painted Turtle (*Chrysemys picta marginata)*
- Northern Map Turtle (*Graptemys geographica)*
- Eastern Gartersnake (*Thamnophis sirtalis sirtalis)*
- Eastern Milksnake (*Lampropeltis t. triangulum)*
- DeKay's Brownsnake (*Storeria dekayi)*
- Northern Red-bellied Snake (*Storeria o. occipitomaculata)*
- Northern Ring-necked Snake (*Diadophis punctatus edwardsii)*
- Northern Watersnake (*Nerodia sipedon sipedon)*
- Smooth Greensnake (*Opheodrys vernalis)*

Field Investigation Results

A total of four (4) reptile species were detected in the primary and Supplemental Study Areas during targeted reptile surveys and incidentally from the combined field effort of Savanta (2015 and 2016) and D&A (2016a and 2016b). These species include Midland Painted Turtle, Snapping Turtle, Eastern Milksnake, and Eastern Gartersnake. In total, D&A and Savanta made 71 species observations, including two (2) Eastern Gartersnakes, one (1) Eastern Milksnake, forty-eight (48) Midland Painted Turtles, seventeen (17) Snapping Turtles, and three (3) unidentified turtle species. The majority of these species occurrences (59.2%) were located in the Lower Middle Branch catchment, as summarized in Table 4.8.2. Savanta also reported three (3) dead Eastern Gartersnakes, ten (10) dead Midland Painted Turtles, one (1) dead Snapping Turtle, and one (1) dead unidentified turtle species during road mortality surveys.

Table 4.8.2 Summary of Reptile observations based on subwatershed within the South Milton SWS

Common Name	Scientific Name	West Branch	Middle Branch	Lower Middle Branch	Lower Middle Trib	East Branch
Eastern Gartersnake	*Thamnophis sirtalis sirtalis*			2		
Eastern Milksnake	*Lampropeltis triangulum*			1		
Midland Painted Turtle	*Chrysemys picta marginata*	4	4	30		10
Snapping Turtle	*Chelydra serpentina*		4	8	2	3
Unidentified turtle species			2	1		

Typically, the turtle observations were concentrated in and around golf course ponds. For example, sixteen (16) Midland Painted Turtles, and one unidentified turtle species were observed on the Royal Ontario Golf Club property, and an additional four (4) Midland Painted Turtles, one (1) Snapping Turtle and one (1) unidentified turtle species were observed on the adjoining

Wyldewood Golf Course property to the south. These occurrences were all located within or directly beside the ponds on the properties.

Both of the Eastern Gartersnakes were detected in the Lower Middle Branch, one next to a hedgerow bordering an agricultural field, and the other in a small cultural thicket adjacent to a small pond. The Eastern Milksnake was observed beside a small pond in an agricultural field in the Lower Middle Branch catchment just west of Fifth Line.

4.8.3.6 Odonates

Methods

Odonate (*i.e*. damselflies and dragonflies) surveys were conducted by D&A from the primary study area in July 2016 over five (5) days, under suitable weather conditions (*i.e.* mostly sunny, warm/hot and not too windy). These surveys covered nine (9) areas totaling 26.5 hours (see Figure T3-3). The areas visited were selected by examining available aerial photography using Google Earth and choosing what appeared to represent a good selection of breeding habitats. Property access was the other major determining factor when selecting sites. Also, all the sites surveyed ended being within the provincial Greenbelt and the Region of Halton's Natural Heritage System. The surveys consisted of walking within and along the perimeter of suitable breeding locations. Survey locations and times are summarized in Appendix H5 and presented on Map T3-3. Species were identified by sight or with the assistance of binoculars, as well as using an aerial insect net and 16x magnification hand lens. Confirmation of trickier identifications in the field utilized Jones et al. (2008) and Lam (2004) as references. Many of the locally rare and uncommon species were photographed for documentation purposes.

Savanta also collected odonate data from 33 locations within the South Milton SWS in 2015. Although most data was collected incidentally in conjunction with breeding bird surveys, a number of locations with more suitable breeding habitats were subject to targeted odonate surveys. Survey locations and times are summarized in Appendix H5 and presented on Map T3-3. One of the targeted surveys involved searches for Rapids Clubtail (*Gomphus quadricolor*), which is designated Endangered in Ontario (OMNR 2016) and Canada (COSEWIC 2016). Searches were conducted by Peter Burke in late May (for exuviae) and early to mid-June (for adults) 2015 at two locations within the Supplemental Study Area (Burke, pers. comm., March 2016). The first area was along Sixteen Mile Creek, south of Lower Base Line. The second was also along Sixteen Mile Creek, a one kilometre stretch upstream and downstream of Fourth Line.

Analysis

Background Review Results

A total of 46 species of damselflies and dragonflies (*i.e.* odonates) are on file with the Atlas of Ontario Odonata (Colin Jones, pers. comm., 2016). Appendix H2 provides a complete list of odonate species recorded by background source.

Field Investigation Results

In total, 50 odonate species were recorded within and adjacent to the South Milton SWS lands (Appendix H9). The number of damselflies and dragonflies documented were approximately the same, with 27 damselfly species documented versus 23 dragonfly species.

4.8.3.7 Lepidoptera

Methods

A total of four days, totaling 18 hours, of butterfly surveys were conducted in the 2016 field season by D&A in locations that were pre-determined based on air photo interpretation of the study area. A total of seven sites were visited, based on accessibility and natural habitat being present (see Map T3-3).

The seven locations where butterfly surveys were undertaken in 2016 included:

- In the forest edges and riparian habitat along the eastern side of Sixteen Mile Creek, from Britannia Road to approximately 600 metres southward;
- Along the last 250 metres of Thompson Road South (south of Britannia Road);
- A one kilometre stretch of riparian areas and forested habitat, north, and south of Britannia Road West, immediately west of Trafalgar Road;
- Open areas and forested habitat in and around Drumquin Park;
- Open areas and forested habitat in and around the Royal Ontario Golf Club;
- Open areas west of Sixth Line, approximately 1.2 km north of Derry Road East; and
- Open areas and riparian habitats east of Sixth Line, approximately 1.2 km north of Derry Road East.

The surveys involved doing general area searches for butterflies using binoculars; surveys were conducted during warm, sunny weather, between 8:00 a.m. and 4:00 p.m. (Appendix H5). Incidental observations of butterflies were also recorded during other field surveys.

Savanta also observed a number of lepidopteran species during 2015 Breeding Bird Surveys, across 26 properties in the South Milton SWS. Details of these surveys are provided in Appendix H5.

Analysis

Background Review Results

Records of 72 species of butterfly were found within the four 10x10 km squares (Toronto Entomologists' Association, 2015) that incorporate the primary and Supplemental Study Areas (Appendix H9).

Field Investigation Results

A total of 33 species of butterfly were observed during D&A's 2016 field investigations, and Savanta documented a total of 40 species during 2015 surveys (Appendix H9).

4.8.3.8 Winter Wildlife

Methods

Savanta conducted winter wildlife surveys in 2013 and 2015 at fourteen (14) properties in 2013 and thirteen (13) properties in 2015, as well as ten (10) roadside transects. Map T3-3 shows the locations of these transects.

While D&A was unable to conduct winter wildlife surveys in winter 2016, due to the timing of when this study commenced, winter wildlife surveys for raptors and owls have been completed in winter 2017. Locations have been targeted for properties that have the highest potential for supporting raptor and owl wintering habitat. Updates from these field investigations will be provided as part of the next iteration of reporting and evaluation of significance.

Analysis

Background Review Results

The background studies reviewed for the South Milton SWS did not provide results for dedicated winter wildlife surveys. Therefore, characterization of the study area is based on results from field investigations conducted Sin the Primary and Supplemental Study Areas.

Field Investigation Results

Savanta conducted winter wildlife surveys in 2013 and 2015 on the South Milton SWS lands. The following species were observed:

2013 species observed include:

- Gray Squirrel (*Sciurus carolinensis)*
- Deer Mouse *(Peromyscus maniculatus)*
- White-Tailed Deer (*Odocoileus virginianus)*
- Coyote (*Canis latrans)*
- Red fox (*Vulpes vulpes)*
- Raccoon (*Procyon lotor)*
- Eastern Cottontail (*Sylvilagus floridanus)*
- Ermine (*Mustela erminea)*
- Long-tailed Weasel (*Mustela frenata)*

2015 observations include:

- White-tailed Deer (*Odocoileus virginianus)*
- Coyote (*Canis latrans)*

- Eastern Cottontail (*Sylvilagus floridanus)*
- Gray Squirrel (*Sciurus carolinensis)*
- Red Squirrel (*Tamiasciurus hudsonicus)*

- Red Fox (*Vulpes vulpes)*
- Deer Mouse (*Peromyscus maniculatus)*
- Meadow Vole (*Microtus pennsylvanicus)*
- Muskrat (*Ondatra zibethicus)*
- Northern Short-tailed Shrew (*Blarina brevicauda)*
- Raccoon (*Procyon lotor)*
- Long-tailed Weasel (*Mustela frenata)*
- Short-tailed (Least) Weasel (*Mustela nivalis)*
- Porcupine (*Erethizon dorsatum)*

Additional winter surveys will be conducted during 2017 and will target open country habitat with adjacent forested habitat. Sites will be prioritized based on those that are most consistent with SWH criteria.

4.8.3.9 Other Wildlife

Methods

Non-target wildlife species observed during the various field surveys, including mammals, were recorded based on occurrences documented in the background reports, and as incidental observations during field investigations during 2016.

Analysis

Background Review Results

A total of 36 mammal species had records within the four 10 x 10 km grid squares surrounding the Primary and Supplemental Study Areas (Atlas squares: 17NJ91, 17NJ92, 17PJ01, 17PJ02) (Appendix H2).

Field Investigation

A total of 12 species of mammal were detected during 2016 field observations, including:

i. Beaver (*Castor canadensis)*
ii. Coyote (*Canis latrans)*
iii. Eastern Chipmunk (*Tamias striatus)*
iv. Eastern Cottontail (*Sylvilagus floridanus)*
v. Gray Squirrel (*Sciurus carolinensis)*
vi. Mink (*Neovison vison)*
vii. Muskrat (*Ondatra zibethicus)*
viii. Red Squirrel (*Tamiasciurus hudsonicus)*
ix. Virginia Opossum (*Didelphis virginiana)*
x. White-tailed Deer (*Odocoileus virginianus)*
xi. Unidentified Bat Species
xii. Unidentified *Peromyscus* mouse species

4.8.4 Interpretation / Key Findings

4.8.4.1 Ecological Land Classification

Field Investigation Key Findings

Extensive ELC coverage for the South Milton Subwatershed Study was developed using background data from previous studies undertaken by D&A, Conservation Halton data, and ground-truthed seasonal investigations during 2015 and 2016 by Savanta and D&A.

Overall, the South Milton SWS Primary and Supplemental Study Areas are dominated by agricultural lands. However, the natural areas within Primary and Supplemental Study Areas contain a diverse range of vegetation communities ranging from Open Aquatic to Dry-Fresh Deciduous Forests. A total of 52 different ELC Vegetation Types across 27 Ecosites and 19 Communities Series were mapped. Treed communities, such as forests and swamps, dominate the corridors and valleys of both branches of the Sixteen Mile Creek, whereas the tablelands are dominated by agricultural features with only scattered and small natural areas. Overall, the natural areas tended to be more diverse in terms of both the total number of species, as well as the proportion of native species present in comparison to agricultural and anthropogenic areas.

Several provincially rare vegetation communities were encountered within the Primary and Supplemental Study Areas (Appendix H6). These include:

- FOD6-2 (Fresh-Moist Sugar Maple-Black Maple Deciduous Forest Type) - S3?
- FOD7-4 (Fresh-Moist Black Walnut Lowland Deciduous Forest Type) - S2S3
- FOM3-2 (Dry-Fresh Sugar Maple-Hemlock Mixed Forest Type) - S3S5
- SWD1-2 (Bur Oak Mineral Deciduous Swamp) - S3
- SWT2-2 (Willow Mineral Thicket Swamp Type) - S3S5

Fresh-Moist Sugar Maple-Black Maple Deciduous Forest was found in one polygon within the Lower Middle Branch Subwatershed. Fresh-Moist Black Walnut Lowland Deciduous Forests were found in 7 polygons along the floodplains of the Mid East Branch and East Branches of the Sixteen Mile creek. Dry-Fresh Sugar Maple-Hemlock Mixed Forests were observed in 5 polygons across the Primary and Supplemental Study Areas. Four of these polygons were found along north and west facing slopes within the West Branch and East Branches of the Sixteen Mile Creek, in the southern portion of the South Milton SWS. One additional polygon was observed in a headwater area in the lower East Branch subwatershed. Bur Oak Mineral Deciduous Swamp is found in two very small polygons (<1 ha); one along the southern edge of the Middle Branch subwatershed, and the other an isolated woodland along a hedgerow within the Lower Middle branch subwatershed north of Britannia Road. Lastly, Willow Mineral Thicket Swamps were found among 3 polygons in the South Milton SWS; one in the Middle Branch subwatershed, one in the East Branch subwatershed, and one along the north edge of Drumquin Wetland in the Lower Middle Tributary subwatershed.

Areas and/or polygons with notable vegetation communities were also observed throughout the South Milton SWS. These features and general areas include:

Mature forests: 18 polygons were identified with indicators of mature forest, including numerous large-diameter trees (>50 cm dbh) or numerous large-diameter dead trees (snags). These features are generally located within the Sixteen Mile Creek corridor in the lower study area, but several features are located within the corridor of the east Sixteen Mile Creek in the middle northern portion of the South Milton SWS within the Wyldewood Golf and Country Club as well as in the Middle East Branch of the Sixteen Mile Creek.

High biodiversity features: Numerous polygons were identified that contain many species and a high proportion of native species. These areas are generally located within the lower sections of the Sixteen Mile Creek valleys, deciduous forests south of Britannia Road between 5th Line and Trafalgar Road, within Drumquin Wetland, and in the deciduous forest along the Middle Sixteen Mile Creek north of the rail line and east of 5th Line. Since some areas have not been surveyed extensively during all seasons, more high-biodiversity areas are expected to be identified during further field investigations.

Habitat for provincially or regionally significant species: Provincially or regionally significant (SAR, Rare, or Uncommon) species were identified in at least 191 polygons within the Primary and Supplemental Study Areas. These polygons are located throughout the study area but are generally associated with the Sixteen Mile Creek branches and adjacent lands.

Seeps and springs: Seepage areas were noted in the field where obvious, and the plant lists for each polygon were also screened for species that can indicate seepage, including Red Baneberry (*Actaea rubra*), Canada Yew (*Taxus canadensis*), and Speckled Alder (*Alnus rugosa*) (Ringius and Sims 1997). Seepage areas typically occur along steep slopes where bedrock is close to the surface, as well as on coarse, permeable soils. Seepage areas were observed along lower slopes and gullies within the West Sixteen Mile Creek valley and lower East Sixteen Mile Creek valley where soils overlay limestone bedrock. Indicator species, in particular, Baneberry and Speckled Alder, were also noted throughout the central portion of the East Sixteen Mile Creek corridor and adjacent areas in forests, swamps, woodlands, and meadows, as well as Drumquin Wetland. Many of these areas are also associated with coarse textured soil (Chapman and Putnam, 1984), which may allow for seepage and/or groundwater upwelling.

Key natural features will be evaluated during the Phase 2 assessment process. This will include identifying and evaluating features features that include the following:

- Wetland features following Ontario Wetland Evaluation System protocols
- Woodlands following guidelines in the Natural Heritage Reference Manual and the Region's criteria for significant woodlands
- Significant Valleylands following guidelines in the Natural Heritage Reference Manual
- Significant Wildlife Habitat for areas that support rare vegetation community types
- Habitats that support provincially Endangered or Threatened species

4.8.4.2 *Botanical Inventories*

Background Review Key Findings

In total, records for 193 significant species were identified from the background studies. Significant species were considered to be those that are listed federally or provincially as Species at Risk (Endangered, Threatened, Special Concern), and/or uncommon or rare globally (Grank), nationally (Nrank), provincially (Srank) and/or locally (regionally) (Ecodistrict 7E-4, Regional Municipality of Halton). All of the 193 species are native to Ontario and the Regional Municipality of Halton.

A total of five (5) federally and provincially listed species at risk species were identified in the review of background data. These included: American Ginseng (*Panax quinquefolius*), Butternut (*Juglans nigra*), White Prairie Gentian (*Gentiana alba*), and Few-flowered Club-rush (*Trichophorum planifolium*), which are designated as Endangered and Dense Blazing Star (*Liatris spicata*), which is designated as Threatened.

Fifteen (15) species that are considered Critically Imperiled (N1), Imperiled (N2), and Vulnerable (N3) in Canada were also reported in these background studies; including, Cooper's Milkvetch (*Astragalus neglectus*), Smooth Yellow False Foxglove (*Aureolaria flava*), Carey's Sedge (*Carex caryana*), Northern Hawthorn (*Crataegus pruinosa var. dissona*), Eastern Burning Bush (*Euonymus atropurpureus*), White Prairie Gentian (*Gentiana alba*), Honey-locust (*Gleditsia triacanthos*), Dense Blazing Star (*Liatris spicata*), Woodland Flax (*Linum virginianum*), American Gromwell (*Lithospermum latifolium*), Virginia Bluebells (*Mertensia virginica*), American Ginseng (*Panax quinquefolius)*, Moss Phlox (*Phlox subulata*), Pitch Pine (*Pinus rigida*), Few-flowered Club-rush (*Trichophorum planifolium*). An additional three (2) species have numeric range ranks (e.g. N3N5) which indicate uncertainty over their status; these include Butternut and Bearded Shorthusk (*Brachyelytrum erectum*). Pitch Pine is restricted to eastern Ontario, so this record may be a misidentification or was planted.

At the provincial level, nineteen (19) rare species (S1-S3) were noted. These include all of the above species with the exception of Large Toothwort (*Cardamine maxima*) and New England Violet (*Viola novae-angliae*).

At the regional and local levels, 149 of the 493 species detected in the background data are considered rare or uncommon in Ecodistrict 7E-4, while 140 are rare or uncommon in the Regional Municipality of Halton (Varga et al. 2005). Based on the Halton NAI (Crins et al. 2006) assessment), 138 of these species are considered rare or uncommon in Halton. These species are too extensive to summarize here but are included in Appendix H1.

The specific locations of several significant species were confirmed through a data request to Conservation Halton (CH, 2017). The species that are known to occur within the primary or Supplemental Study Areas based on this data include:

- Saskatoon Berry (*Amelanchier alnifolia*)

- Poke Milkweed (*Asclepias exaltata*)
- Tall Bellflower (*Campanula americana*)
- Giant Blue Cohosh (*Caulophyllum giganteum*)
- Blue Cohosh (*Caulophyllum thalictroides*)
- New Jersey Tea (*Ceanothus americanus*)
- Hawthorn (*Crataegus coccinioides* syn. *C. conspecta*)
- Eastern Burning Bush (*Euonymus atropurpurea*)
- Butternut (*Juglans cinerea*)
- Virginia Bluebells (*Mertensia virginica*)
- Common Evening Primrose (*Oenothera biennis*)
- Red Pine (*Pinus resinosa*)
- Swamp White Oak (*Quercus bicolor*)
- Red-sheathed Bulrush (*Scirpus microcarpus*)
- Lowbush Blueberry (*Vaccinium angustifolium*)
- Early Sweet Blueberry (*Vaccinium pallidum*)

Additional significant species with records from within 1km of the Supplemental Study Area within the Sixteen Mile Creek Valley include Big Bluestem (*Andropogon gerardii*), Bearded Shorthusk (*Brachyelytrum erectum*), Richardson's Sedge (Carex richardsonii), Buttonbush (*Ceanothus americanus*), Slender Wheat Grass (*Elymus trachycaulus ssp. trachycaulus*), Stiff Marsh Bedstraw (*Galium tinctorium*), Eastern Manna Grass (*Glyceria septentrionalis*), Woodland Sunflower (*Helianthus divaricatus*), Winterberry (*Ilex verticillata*), Twinleaf (*Jeffersonia diphylla*), Sycamore (*Platanus occidentalis*), Seneca Snakeroot (*Polygala senega*), Pennsylvania Smartweed (*Persicaria pensylvanica*), Pasture Rose (*Rosa carolina*), Soapberry (*Shepherdia canadensis*), White Goldenrod (*Solidago bicolor*), Sqaurrose Goldenrod (*Solidago squarrosa*), Yellow Pimpernel (*Taenidia integerrima*), and Marsh Speedwell (*Veronica scutellata*).

The locations of these records are primarily from the lower west Sixteen and Central Sixteen Mile creek valleys in the Supplemental Study Area. Virginia Bluebells is also known from one isolated location west of 6th Line in the lower middle branch of the Sixteen Mile Creek, at the west edge of the primary and Supplemental Study Areas. Butternut is also known from the Milton Boyne (Phase 3) study area which is directly northwest of the primary and Supplemental Study Areas.

The majority of significant species records are listed in Appendix H1, in particular species at risk, and provincially rare species were obtained from the Sixteen Mile Creek ANSI report (MNRF, 2014). The area encompassed by that study was primarily outside of the Supplemental Study Area in the southern portion of the Sixteen Mile Creek valley. These species also typically occur within specific habitats (e.g. tallgrass prairie) that have not been identified within the Primary or Supplemental Study Areas and therefore are unlikely to occur within the South Milton SWS. However, these records are included in this study because of the contiguity of the Sixteen Mile Creek system with the South Milton SWS.

Field Investigation Key Findings

In total, 172 significant species were observed within the Primary and Supplemental Study Areas during field investigations by D&A and Savanta Inc. This included species that are listed federally or provincially as a Species at Risk (Endangered, Threatened, Special Concern), or is uncommon or rare at the global (Grank), national (Nrank), provincial (Srank) or regional/local level (Ecodistrict 7E-4, Regional Municipality of Halton). These species are indicated in Appendix H8, and a summary of these species is provided below in Table 4.8.3 along with a comparison to the findings from the background resources.

Only one of the five species at risk from the background review, Butternut (*Juglans nigra*), was observed in the South Milton SWS (Appendix H8). In addition to Butternut, the provincially imperiled (S2) Honey Locust (*Gleditsia triacanthos*), was also found. The Honey Locust were observed in several locations throughout the properties survey by D&A but were all planted rather than naturally occurring.

The number of species observed during field investigations that are uncommon or rare within Ecodistrict 7E-4 totaled 126, including 57 of the 148 species that were detected in the background review. One notable species is Fragile Fern (*Cystopteris fragilis*), which is considered to be extirpated from this Ecodistrict by Varga et al. (2005). A voucher specimen for this species was collected to ensure proper identification; the species was observed in a seepage area at the base of a slope in a mixed Sugar Maple-Hemlock forest, which is similar habitat to where this species has been observed by D&A elsewhere in southern Ontario.

Of the plant species observed 108 are uncommon or rare within Halton based on Varga et al. (2005), including 50 that were not detected in the review of background information. Similarly, 53 species were observed that are uncommon are rare in Halton according to Crins et al. (2006); all of which were recorded in the background studies that were reviewed.

Table 4.8.3 Occurrence of significant plant species based on background documents and field inventory in the South Milton SWS area.

Level of Significance	Number of Species Observed During Field Investigations (Dougan 2016a and b, Savanta 2015)	Number of Species Records in Background Resources
National (COSEWIC 2016)	1	5
Provincial (MNRF 2015)	1	5
Regional (Ecodistrict 7E-4; Varga et al. 2005)	126	148
Local (Halton; Varga et al. 2005)	108	138
Halton NAI (Crins et al. 2006)	53	136

Areas that support vegetation species of conservation concern will be evaluated during the Phase 2 assessment process. This will generally include identifying and evaluating features that support:

- Provincially rare plant species
- Regionally rare plant species
- Provincially Endangered or Threatened plant species

4.8.4.3 Breeding Birds

Background Review Key Findings

Of the 105 species documented in the background review, 30 are considered to be significant, based on national, provincial, regional and local status rankings, and area sensitivity. Nine species are ranked designated Threatened nationally by COSEWIC, including Bank Swallow (*Riparia riparia*), Barn Swallow (*Hirundo rustica*), Bobolink (*Dolichonyx oryzivorus*), Chimney Swift (Chaetura pelagica), Common Nighthawk (*Chordeiles minor*), Eastern Meadowlark (*Sturnella magna*), Eastern Whip-poor-will (*Antrostomus vociferus*), Red-headed Woodpecker (*Melanerpes erythrocephalus*), and Wood Thrush (*Hylocichla mustelina*) (COSEWIC 2016). Two additional species are ranked designated Special Concern by COSEWIC, including Eastern Wood-Pewee (*Contopus virens*) and Grasshopper Sparrow (*Ammodramus savannarum*).

Of the 105 breeding bird species, eight (8) species have been designated Threatened in Ontario, including Bank Swallow, Barn Swallow, Bobolink, Eastern Meadowlark, Eastern Wood-Pewee, Grasshopper Sparrow, Peregrine Falcon (*Falco peregrinus anatum*) and Wood Thrush (OMNRF 2016). Provincially, all 105 species have provincial conservation ranks (*i.e*. S-ranks) of S5 and S4, indicating that their populations are secure or apparently secure in Ontario (NHIC 2016). A total of eight species have been designated Threatened in Ontario by the Ministry of Natural Resources and Forestry, including Bank Swallow, Barn Swallow, Bobolink, Eastern Meadowlark, Eastern Wood-Pewee, Grasshopper Sparrow, Peregrine Falcon and Wood Thrush. Twenty-three species (23) are considered area-sensitive (OMNR 2000).

Eight (8) species are considered to be locally rare in Halton Region, including Carolina Wren (*Thryothorus ludovicianus*), Common Nighthawk, Eastern Whip-poor-will, Long-eared Owl (*Asio otus*), Orchard Oriole (*Icterus spurius*), Red-headed Woodpecker, Upland Sandpiper (*Bartramia longicauda*), and Yellow-billed Cuckoo (*Coccyzus americanus*) (McIlveen 2006). In addition, 31 species are regionally uncommon in Halton Region (McIlveen 2006). Many of these species, such as Common Nighthawk, Eastern Whip-poor-will, and Peregrine Falcon were reported within one or both of the squares (17NJ91 and 17NJ92).

Field Investigation Key Findings

Of the 90 native breeding bird species during field investigation, nine (9) are recognized as Species at Risk. That is, they are designated Special Concern, Threatened or Endangered in Canada (COSEWIC 2016) or Ontario (OMNRF 2016). Species designated Threatened or Endangered in Canada receive protection under the federal Species at Risk Act (2002)

(Government of Canada 2002). Similarly, species designated Threatened or Endangered in Ontario receive protection under the provincial Endangered Species Act (2007) (Government of Ontario 2007). Special Concern Species receive protection as Significant Wildlife Habitat (OMNR 2000; OMNRF 2015) under the 2014 Provincial Policy Statement (PPS) (OMMAH 2014) under the provincial Planning Act (Government of Ontario 1990). The nine species and their associated status are depicted in Appendix H9. They include the following:

i. Common Nighthawk (*Chordeiles minor*)
ii. Chimney Swift (*Chaetura pelagica*)
iii. Eastern Wood-Pewee (*Contopus virens*)
iv. Bank Swallow (*Riparia riparia*)
v. Barn Swallow (*Hirundo rustica*)
vi. Wood Thrush (*Hylocichla mustelina*)
vii. Grasshopper Sparrow (*Ammodramus savannarum*)
viii. Bobolink (*Dolichonyx oryzivorus*)
ix. Eastern Meadowlark (*Sturnella magna*)

Thirty-one (31) of the 90 native breeding species are considered locally rare or uncommon (McIlveen 2006) (Appendix H9). This includes the following six locally rare species:

i. Yellow-billed Cuckoo (*Coccyzus americanus*)
ii. Common Nighthawk (*Chordeiles minor*)
iii. Osprey (*Pandion haliaetus*)
iv. Common Raven (*Corvus corax*)
v. Orchard Oriole (*Icterus spurius*)
vi. Clay-colored Sparrow (*Spizella pallida*)

Clay-coloured Sparrow was included as locally rare or uncommon as the Halton Natural Areas Inventory (NAI) described its status as casual local summer resident (McIlveen 2006), which suggests its relative abundance status is ambiguous. As it is listed as rare in Hamilton (Smith 2014; Curry and Hamilton Naturalists' Club, 2006) and the Toronto Region (TRCA 2013), and according to Ontario Breeding Bird Atlas data (Cadman *et al.* 2007), its appears to be more poorly distributed in Halton Region compared to neighbouring areas, we interpreted its status to be rare in Halton Region.

Twenty-five (25) of the species are considered locally uncommon. This includes:

i. Hooded Merganser (*Lophodytes cucullatus*)
ii. Wild Turkey (*Meleagris gallopavo*)
iii. Black-billed Cuckoo (*Coccyzus erythropthalmus*)
iv. Chimney Swift (*Chaetura pelagica*)
v. Green Heron (*Butorides virescens*)
vi. Northern Harrier (*Circus cyaneus*)
vii. Sharp-shinned Hawk (*Accipiter striatus*)

viii. Cooper's Hawk (*Accipiter cooperii*)
ix. Red-bellied Woodpecker (*Melanerpes carolinus*)
x. Pileated Woodpecker (*Dryocopus pileatus*)
xi. Willow Flycatcher (*Empidonax traillii*)
xii. Horned Lark (*Eremophila alpestris*)
xiii. Purple Martin (*Progne subis*)
xiv. Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)
xv. Red-breasted Nuthatch (*Sitta canadensis*)
xvi. Marsh Wren (*Cistothorus palustris*)
xvii. Blue-gray Gnatcatcher (*Polioptila caerulea*)
xviii. Eastern Bluebird (*Sialia sialis*)
xix. Northern Mockingbird (*Mimus polyglottos*)
xx. Mourning Warbler (*Geothlypis philadelphia*)
xxi. Chestnut-sided Warbler (*Setophaga pensylvanica*)
xxii. Pine Warbler (*Setophaga pinus*)
xxiii. Eastern Towhee (*Pipilo erythrophthalmus*)
xxiv. Vesper Sparrow (*Pooecetes gramineus*)
xxv. Grasshopper Sparrow (*Ammodramus savannarum*)

Fifteen (15) of the 90 native breeding bird species are considered to be area-sensitive, meaning that they require large areas of suitable habitat to maintain a viable population (OMNR 2000) (see Appendix H9). Two-thirds (10) of the species are normally associated with forested habitats, four others are associated with various open habitats, including agricultural lands, and one is typically associated with wetlands. The fifteen species include:

i. Northern Harrier (*Circus cyaneus*)
ii. Sharp-shinned Hawk (*Accipiter striatus*)
iii. Cooper's Hawk (*Accipiter cooperii*)
iv. Hairy Woodpecker (*Picoides villosus*)
v. Pileated Woodpecker (*Dryocopus pileatus*)
vi. Red-breasted Nuthatch (*Sitta canadensis*)
vii. White-breasted Nuthatch (*Sitta carolinensis*)
viii. Blue-gray Gnatcatcher (*Polioptila caerulea*)
ix. Ovenbird (*Seiurus aurocapilla*)
x. American Redstart (*Setophaga ruticilla*)
xi. Pine Warbler (*Setophaga pinus*)
xii. Savannah Sparrow (*Passerculus sandwichensis*)
xiii. Grasshopper Sparrow (*Ammodramus savannarum*)
xiv. Bobolink (*Dolichonyx oryzivorus*)
xv. Eastern Meadowlark (*Sturnella magna*)

Distribution of significant breeding bird species based on subwatershed areas in the Primary and Supplemental Study Areas is summarized in Table 4.8.4.

Table 4.8.4 Summary of significant breeding birds based on subwatershed within the South Milton SWS area.

Status Categories	West Branch	Lower Middle Branch	Middle Branch	Mid East Branch	East Branch	Lower Middle Trib
National & Provincial SAR *(Total No. = 9)*	4	7	3	2	7	7
Priority Species in BCR 13 *(Total No. = 31)*	17	27	17	12	25	24
Locally Rare Species *(Total No. = 6)*	2	4	2	1	3	2
Locally Uncommon Species *(Total No. = 25)*	12	18	8	7	15	12
Area Sensitive Species *(Total No. = 15)*	9	11	5	2	8	8

4.8.4.4 Anurans (Frogs and Toads)

Field Investigation Key Findings

Within the primary and Supplemental Study Area, a total of seven (7) anuran species were documented; of those species, only Western Chorus Frog (Great Lakes population) is considered a Vulnerable (S3) provincially. One Western Chorus Frog was recorded at NACS station 63 located west of Eighth Ln and north of Britannia and may using the treed areas on the Renaissance property, as that is the closest suitable breeding and foraging habitat on the landscape. Western Chorus Frog was also recorded west of the study areas as a part of the Milton Phase 3 monitoring in 2016. In 2008, As a part of the Derry Green Subwatershed Study (2014), Savanta recorded 3 calling individuals in a small marsh located on a property northwest of the intersection of 5th Line and Main St E. approximately 200 m away from the Primary study area. Breeding habitat for this species would be considered candidate Significant Wildlife Habitat - Species of Conservation Concern. Therefore, it will be important to further document the occurrence of this species, particularly with regard to habitat associated with the Renaissance Lands and adjacent properties.

American Bullfrog is classified as uncommon in Halton Region (Curry, 2006) and is area-sensitive (OMNR, 2000). American Bullfrog was found in an online pond associated with East Sixteen Mile Creek north of Britannia and calling from a pond on the Piper's Heath Golf Club. Given the local rarity status of this species and that its occurrence is a trigger for SWH, locations where it is confirmed will be considered for evaluation as SWH.

4.8.4.5 Salamanders

Field Investigation Key Findings

Jefferson Salamander or Jefferson Salamander-dependent polyploids were not detected during surveys conducted in 2016. Salamander surveys will continue during 2017, with additional trapping surveys conducted in Drumquin Woods and surrounding areas. Findings from these surveys will be incorporated with existing data and used to evaluate the significance of the features present, and the habitat functions provided with regard to Significant Wildlife Habitat, and/or Jefferson Salamander habitat.

4.8.4.6 Reptiles (Snakes and Turtles)

Background Review Key Findings

Of the twelve reptiles recorded in the broader area, 7 species are considered to have National, Provincial, or local significance.

Nationally, Blanding's Turtle is considered Endangered (COSEWIC 2015). Three additional species (Northern Map Turtle, Snapping Turtle, and Eastern Milksnake) are listed as Special Concern by COSEWIC.

Provincially, three species have S-rankings of S2 or S3, indicating that their populations are vulnerable or imperiled, respectively. These species include Blanding's Turtle (S3), Northern Map Turtle (S3) and Snapping Turtle (S3). In addition, three species are designated Special Concern provincially by the MNRF, including Northern Map Turtle, Snapping Turtle, and Eastern Milksnake, while Blanding's Turtle is listed as Threatened.

Locally, Northern Watersnake is considered to be uncommon in Halton Region, and an additional four species are considered rare. This includes Blanding's Turtle, Northern Map Turtle, Smooth Greensnake, and Northern Ring-necked Snake. Northern Map Turtle is also listed as area-sensitive species. Appendix H2 provides a summary of species records by background source.

Blanding's Turtle (*Emydoidea blandingii)* was identified by the Ontario Reptile and Amphibian Atlas (Ontario Nature 2015) as having several records within the grid squares covering the study area.

Field Investigation Key Findings

Midland Painted Turtle, Eastern Gartersnake, and Eastern Milksnake are considered to have secure populations, nationally and provincially. Snapping Turtles, however, are designated as Special Concern federally and provincially, and have a provincial S-ranking of S3, indicating that their populations are vulnerable. The majority of Snapping Turtle observations were located in the Lower Middle Branch and Middle Branch and were typically adjacent to or within the creek or nearby ponds. Snapping Turtles are a Special Concern species in Ontario, and as such, loss of habitat and habitat fragmentation is a major threat to their resilience as a species. Typically, Snapping Turtles thrive in habitat containing slow-moving water such as ponds, river edges and slow streams with dense aquatic vegetation and a soft mud bottom (COSEWIC 2008).

Finally, the specific locations for element occurrence records for Blanding's Turtle were provided by the NHIC in early 2017. One of the element occurrence records results in Category 2 and 3 habitats for Blanding's Turtle overlapping with portions of the southwest Supplemental Study Area area with (MNRF 2013). This includes wetlands and areas adjacent to wetlands within 2km of a confirmed Blanding's Turtle observation. Surveys may be required in these areas to determine if Blanding's Turtle is using ponds within 2 km of the confirmed observation.

4.8.4.7 Odonates

Background Review Key Findings

Only one of the 46 species documented in the background review, Rapids Clubtail (*Gomphus quadricolor*), is a Species at Risk at the national or provincial level. It is designated Endangered in Canada (COSEWIC 2016) and Ontario (OMNRF 2016), and has a provincial conservation rank of S1, indicating its Ontario population is critically imperiled (NHIC 2016). Three other species have subnational conservation ranks (*i.e*. S-ranks) of S2 or S3 indicating populations that are vulnerable or imperiled, including River Bluet (*Enallagma anna*) (S2), Unicorn Clubtail (*Arigomphus villosipes*) (S2S3), and Lilypad Clubtail (*Arigomphus furcifer*) (S3) (NHIC 2016).

Locally, eight (8) of the 46 species reported are listed as rare in Halton Region (Van Ryswyk, pers. Comm., February 2016). This includes:

- Aurora Damsel (*Chromagrion conditum*)
- Eastern Red Damsel (*Amphiagrion saucium*)
- Hagen's Bluet (*Enallagma hageni*)
- Midland Clubtail (*Gomphus fraternus*)
- Northern Spreadwing (*Lestes disjunctus*)
- Rainbow Bluet (*Enallagma antennatum*)
- River Bluet (*Enallagma anna*)
- Rusty Snaketail (*Ophiogomphus rupinsulensis*)

An additional 16 species are considered uncommon in Halton Region (Van Ryswyk, pers. Comm., February 2016), including:

- American Rubyspot (*Hetaerina americana*)
- Autumn Meadowhawk (*Sympetrum vicinum*)
- Band-winged Meadowhawk (*Sympetrum semicinctum*)
- Canada Darner (*Aeshna canadensis*)
- Fawn Darner (*Boyeria vinosa*)
- Fragile Forktail (*Ischnura posita*)
- Halloween Pennant (*Celithemis eponina*)
- Lilypad Clubtail (*Arigomphus furcifer*)
- Powdered Dancer (*Argia moesta*)
- Prince Baskettail (*Epitheca princeps*)
- River Jewelwing (*Enallagma anna*)

- Springtime Darner (*Basiaeschna janata*)
- Stream Bluet (*Enallagma exsulans*)
- Sweetflag Spreadwing (*Lestes forcipatus*)
- Taiga Bluet (*Coenagrion resolutum*)
- Unicorn Clubtail (*Arigomphus villosipes*)

Field Investigation Key Findings

Of the 50 species documented by Savanta and Dougan & Associates between 2012 and 2016, 44 are considered “secure” or “apparently secure” in Ontario (NHIC 2016); the remaining six had S-ranks of S1 to S3, meaning their provincial conservation status varied from “critically imperiled” to “vulnerable”. Azure Bluet (*Enallagma aspersum*) and Double-striped Bluet (*Enallagma basidens*) are ranked “vulnerable” (S3); River Bluet (*Enallagma anna*) and Painted Skimmer (*Libellula semifasciata*) are ranked “imperiled” (S2); Unicorn Clubtail (*Arigomphus villosipes*) is ranked as “vulnerable/imperiled” (S2S3); and Slender Bluet (*Enallagma traviatum*) is considered “critically imperiled” (S1) (NHIC 2016). It is worth noting however, that Azure Bluet, Double-striped Bluet, River Bluet and Slender Bluet are considered to be expanding their range in southern Ontario. In fact, Double-striped Bluet, River Bluet and Slender Bluet were not even on record for Halton Region at the time of the Natural Areas Inventory (Rothfels 2006). Status of Azure Bluet in Halton Region has also increased from rare to uncommon during the last decade, although it isn’t clear if that is a reflection of greater survey coverage or an actual increase in abundance and distribution. The Sixteen Mile Creek subwatersheds that the six provincially significant species were documented in are shown in Table 4.8.5. Four of the six provincially significant species were observed in the Lower Middle Branch Sixteen Mile Creek subwatershed.

In addition, 28 of the 50 species documented between 2012 and 2016 are locally significant. That is, they are considered rare or uncommon in Halton Region (Van Ryswyk, pers. comm., Feb 2016). Although Rothfels (2006) was the original source for the status of odonata in Halton Region, Brenda Van Ryswyk, local odonate expert and Natural Heritage Ecologist at Conservation Halton, recently updated the local status ranks in 2016 to better reflect current knowledge in the Region. The 28 locally rare and uncommon species are listed in Table 4.8.5.

Almost 86% of the locally significant species (*i.e.* 24 of 28) were documented within the Lower Middle Branch subwatershed of Sixteen Mile Creek. Since the Lower Middle Branch subwatershed occupies the largest amount of land of all the subwatersheds within the primary and Supplemental Study Area, this total isn’t surprising.

Table 4.8.5 Summary of significant Odonates based on subwatershed within the South Milton SWS area.

	Common Name	Scientific Name	West Branch	Lower Middle Branch	Middle Branch	Mid East Branch	East Branch	Lower Middle Trib
Provincially Significant in Ontario *(NHIC 2016)*								
1	River Bluet	*Enallagma anna*	✓		✓			
2	Azure Bluet	*Enallagma aspersum*	✓					
3	Double-striped Bluet	*Enallagma basidens*		✓				
4	Slender Bluet	*Enallagma traviatum*		✓				
5	Unicorn Clubtail	*Arigomphus villosipes*		✓				
6	Painted Skimmer	*Libellula semifasciata*		✓				
		Total	2	4	1	0	0	0
Rare in Halton Region *(Van Ryswyk, pers. comm., February 2016)*								
1	Elegant Spreadwing	*Lestes inaequalis*		✓				
2	Blue-fronted Dancer	*Argia apicalis*		✓			✓	
3	River Bluet	*Enallagma anna*	✓		✓			
4	Double-striped Bluet	*Enallagma basidens*		✓				
5	Slender Bluet	*Enallagma traviatum*		✓				
6	Rusty Snaketail	*Ophiogomphus rupinsulensis*	✓					
7	Painted Skimmer	*Libellula semifasciata*		✓				
		Total	2	5	1	0	1	0
Uncommon in Halton Region *(Van Ryswyk, pers. comm., February 2016)*								
1	River Jewelwing	*Calopteryx aequabilis*		✓	✓			
2	American Rubyspot	*Hetaerina americana*	✓	✓	✓			✓
3	Spotted Spreadwing	*Lestes congener*	✓	✓				
4	Northern Spreadwing	*Lestes disjunctus*	✓	✓				
5	Sweetflag Spreadwing	*Lestes forcipatus*		✓	✓			
6	Swamp Spreadwing	*Lestes vigilax*		✓				
7	Powdered Dancer	*Argia moesta*	✓	✓				
8	Rainbow Bluet	*Enallagma antennatum*	✓	✓		x	✓	✓
9	Azure Bluet	*Enallagma aspersum*	✓					
10	Stream Bluet	*Enallagma exsulans*	✓	✓	✓	✓	✓	✓
11	Skimming Bluet	*Enallagma geminatum*	✓	✓			✓	✓
12	Orange Bluet	*Enallagma signatum*		✓			✓	✓
13	Fragile Forktail	*Ischnura posita*		✓		✓	✓	✓
14	Sedge Sprite	*Nehalennia irene*		✓				
15	Shadow Darner	*Aeshna umbrosa*		✓			✓	✓
16	Unicorn Clubtail	*Arigomphus villosipes*		✓				
17	Common Baskettail	*Epitheca cynosura*		✓				
18	Halloween Pennant	*Celithemis eponina*	✓	✓				
19	Eastern Amberwing	*Perithemis tenera*		✓	✓	✓		✓
20	Band-winged Meadowhawk	*Sympetrum semicinctum*				✓	✓	✓
21	Autumn Meadowhawk	*Sympetrum vicinum*		✓				
		Total	9	19	5	5	7	9

All of the significant odonate species documented in 2015 and 2016, with the exception of Azure Bluet, Slender Bluet and Band-winged Meadowhawk (*Sympetrum semicinctum*), have been recorded along, or regularly inhabit creeks or their margins, although some prefer slower stretches of moving water (Catling & Brownell 2000; Lam 2004; Jones *et al*. 2008; Paulson 2011). As such, and assuming that the breeding habitats and water quality remain the same, these species should be able to persist across the South Milton SWS riparian system into the future.

The total number of odonates recorded within the last five years from within and adjacent to the South Milton SWS lands is greater than what is on file at the Ontario Odonata Atlas (OOA). Fifty (50) species were recently recorded, compared to 46 species on file with the OOA (for all years up to and including 2016). The fact that only two years of survey effort, from a 'relatively' small area surveyed, resulted in a list of species larger than what was on file with the OOA for the four 10 x 10 km squares that encompass the study areas (*i.e.* 40,000 ha), suggests that relatively little field survey work had been completed and reported to the OOA prior to these recent studies. Nevertheless, this 2012 – 2016 survey work is likely a reasonable reflection of the species present in the habitats available within the South Milton Subwatershed Study lands. However, it is also likely additional field survey work, spread out over a wider period of time and across a wider number of natural habitats, would round out the list of species present in the landscape.

The following 15 species were recorded from the study area but are not on file for the area in the OOA.

i. Spotted Spreadwing (*Lestes congener*)
ii. Elegant Spreadwing (*Lestes inaequalis*)
iii. Swamp Spreadwing (*Lestes vigilax*)
iv. Blue-fronted Dancer (*Argia apicalis*)
v. Azure Bluet (*Enallagma aspersum*)
vi. Double-striped Bluet (*Enallagma basidens*)
vii. Skimming Bluet (*Enallagma geminatum*)
viii. Orange Bluet (*Enallagma signatum*)
ix. Slender Bluet (*Enallagma traviatum*)
x. Sedge Sprite (*Nehalennia irene*)
xi. Shadow Darner (*Aeshna umbrosa*)
xii. Common Baskettail (*Epitheca cynosura*)
xiii. Calico Pennant (*Celithemis elisa*)
xiv. Painted Skimmer (*Libellula semifasciata*)
xv. Eastern Amberwing (*Perithemis tenera*)

Conversely, the following 11 species have been documented from the surrounding 10 x 10 km OOA atlas squares but were not recorded within the primary or Supplemental Study Areas.

i. Eastern Red Damsel (Amphiagrion saucium)
ii. Aurora Damsel (Chromagrion conditum)
iii. Taiga Bluet (Coenagrion resolutum)
iv. Hagen's Bluet (Enallagma hageni)
v. Canada Darner (Aeshna canadensis)

vi. Springtime Darner (Basiaeschna janata)
vii. Fawn Darner (Boyeria vinosa)
viii. Lilypad Clubtail (Arigomphus furcifer)
ix. Midland Clubtail (Gomphus fraternus)
x. Rapids Clubtail (Gomphus quadricolor)
xi. Prince Baskettail (Epitheca princeps)

4.8.4.8 Lepidoptera

Background Review Key Findings

Of the 72 species of butterfly that were documented in the background review, two species are considered Federally significant: Monarch (*Danaus plexippus)* and Mottled Duskywing - great lakes pop. (*Erynnis martialis)* (COSEWIC 2016). Provincially, Monarch is ranked Special Concern, and Mottled Duskywing is considered Endangered. A total of seven species have provincial S-rankings of S3 or S2, indicating that their populations are vulnerable or imperiled, respectively (NHIC 2015). These species include: Common Sootywing (*Pholisora catullus)* (S3), Dion Skipper (*Euphyes dion)* (S3), Giant Swallowtail (*Papilio cresphontes)* (S3), Hickory Hairstreak (*Satyrium caryaevorum)* (S3), West Virginia White (*Pieris virginiensis)*(S3), Monarch (S2N), and Mottled Duskywing (S2).

In Halton Region, 23 species are considered to be rare or uncommon immigrants or residents. American Snout (*Libtheana carinenta)* and Giant Swallowtail are both rare immigrants. Common Buckeye (*Junonia coenia)*, Fiery Skipper (*Hylephila phyleus)*, and Pipevine Swallowtail (*Battus philenor)* are rare immigrants and seasonal colonists. Six species, including Columbine Duskywing (*Erynnis lucilius)*, Common Sootywing (*Pholisora catullus)*, Edwards' Hairstreak (*Satyrium edwardsii)*, Milbert's Tortoiseshell (*Nymphalis milberti),* Mottled Duskywing - great lakes pop. (*Erynnis martialis)*, and Wild Indigo Duskywing (*Erynnis baptisiae*) are rare permanent residents and Painted Lady (*Vanessa cardui)* is considered a rare to common immigrant and seasonal colonist. An additional 11 species are considered uncommon permanent residents in Halton Region.

Field Investigation Key Findings

Of the 33 species documented during site investigation, Monarch is significant federally and provincially. Federally, it is considered to be Endangered (COSEWIC 2015), and it is assessed as being Special Concern by both the federal Species at Risk Act and provincially by the MNRF (2015). Monarch also has a provincial S-ranking of S2N, S4B, indicating that its non-breeding populations are imperiled while its breeding populations are apparently secure (NHIC 2015). Additionally, the Hickory Hairstreak and Large Marble are both ranked S3, indicating vulnerable populations (NHIC 2015). In addition, Wild Indigo Duskywing is considered Locally Significant in Halton Region. However, it should be noted that this species has very recently expanded its range substantially in southern Ontario, including both Hamilton and Halton Regions; its present status in Halton Region is unknown, but it is likely more widespread and common than it was during the last NAI (Wormington 2006). As shown in Table 4.8.6, the majority of the significant species were observed along the Lower Middle Branch.

In comparison to 2016 field investigation results, the Ontario Butterfly Atlas reports are nearly double the number of species observed by D&A and Savanta. Of the 74 species records, two species reported are federally or provincially significant: the Mottled Duskywing (Great Lakes pop.), which is Endangered federally (COSEWIC 2016) and provincially (MNRF 2015), and the West Virginia White which is Special Concern at the provincial level (MNRF 2015). In addition, 17 species were reported by the Atlas that are considered to be Locally Significant in Halton Region, while D&A only observed two. Expanding on the Lepidoptera surveys that were conducted during 2016 by including additional habitats, over a greater time span (April to September), it is likely that the number of species observed would be higher. For example, habitat-specific surveys in early May at some woodlots containing Toothwort may reveal additional records of West Virginia White; at present, this species is mainly known in Halton Region from large wooded sites along the Niagara Escarpment. Mottled Duskywing, which requires sandy soils and large stands of New Jersey Tea, is known from Halton Region only along the Niagara Escarpment; as such, it is unlikely to occur in the present study area

Table 4.8.6 Summary of significant Lepidoptera occurrences within the Sixteen Mile Creek subwatersheds

Common Name	Scientific Name	West Branch	Middle Branch	Lower Middle Branch	Lower Middle Trib	East Branch
Provincially Significant in Ontario (NHIC 2016)						
Hickory Hairstreak	*Satyrium caryaevorum*	1		1		1
Large Marble	*Euchloe ausonides*			1		
Monarch	*Danaus plexippus*	1	1	1	1	
Total		2	1	3	1	1
Rare in Halton Region						
Common Buckeye	*Junonia coenia*			1		
Common Sooty Wing	*Pholisora catullus*			1		
Leonard's Skipper	*Hesperia leonardus*			1		
Painted Lady	*Vanessa cardui*		1	1		
Pipevine Swallowtail	*Battus philenor*			1		
Two-spotted Skipper	*Euphyes bimacula*			1	1	
Wild Indigo Duskywing	*Erynnis baptisiae*		1			
Total			2	6	1	
Uncommon in Halton Region						
Acadian Hairstreak	*Satyrium acadica*			1		1
Total				1		1

4.8.4.9 Winter Wildlife

Field Investigation Key Findings

All of the species documented by Savanta during winter wildlife surveys are common and widespread in Ontario and Halton Region. Surveys conducted by D&A during winter 2017 will provide an evaluation of potential raptor and owl overwintering areas within the Primary and Supplemental Study Areas.

4.8.4.10 Other Wildlife

Background Review Key Findings

While the majority of the species documented in the background review are common and widespread in Ontario and Canada, a few are considered significant, including three species of endangered bats including Little Brown Myotis (*Myotis lucifugus)*, Northern Myotis (*Myotis septentrionalis)*, and Tricolored Bat (*Perimyotis subflavus)*, as well as the rare, likely extirpated Snowshoe Hare. Species records are summarized in Appendix H2. While targeted Maternal Roost Surveys were not carried out for bats as part of this study, in a smaller-scale Impact Assessment capacity once development plans are proposed, these surveys should be conducted as per the Aurora District Bat Survey Protocol, if forests and certain swamps communities are to be impacted (Aurora District MNRF, 2016). As per the protocol, these surveys would involve flagging the appropriate ELC communities that have been determined as having high snag densities (>10 snags/ha), and conducting acoustic monitoring over a minimum of 10 nights between June 1 and June 30.

Field Investigation Key Findings

All of these species observed during field investigations are considered to be common and widespread, with stable populations both in Canada (COSEWIC 2016) and Ontario (OMNRF 2016; NHIC 2016).

4.9 Synopsis of Discipline Findings

4.9.1 Hydrogeology (Groundwater)

A significant amount of detailed groundwater information exists within, and adjacent to, the Primary Study Area. Based on the groundwater team's local knowledge base, the preliminary background review, hydrogeological data from the landowners ongoing hydrogeological investigation and groundwater related discussions with the TAC the scope of field work and analysis for the groundwater component was finalized to further characterize the hydrogeological setting.

The Primary study Area is situated within the Peel Plain physiographic region which is characterized by a glacial till plain that generally slopes from northwest to southeast and has local areas of incised slopes adjacent to more major water courses.

The surficial geology within the Primary and Supplemental Study Areas consist primarily of fine grained sediments characterized by the glaciolacustrine silt and clay and glaciolacustrine derived silty to clayey till (Halton Till). Areas of glaciolacustrine sand and gravel occur in the eastern portion of the Primary Study Area. Additional drilling confirmed this setting but also indicated there were areas mapped as coarse grained that were fine grained sediments.

The underlying bedrock within the study area is comprised of the Upper Ordovician Queenston Formation characterized by red shale. The shale is generally extensively weathered at the surface (bedrock/overburden contact) and is more competent with depth.

A major component of the current study's field work was to assess the bedrock topography and confirm and refine the extent and depth of an existing buried valley through the drilling program as well as the prevalence of sand and gravel deposits at the base of the buried valley. A bedrock valley in and to the northwest of the Primary Study Area has been recognized through mapping in previous studies. . Two minor bedrock valley systems exist north of Steeles Avenue, enter from the northwest and north of the study area and extend southeast across Steeles Avenue and Highway 401. The current study confirms this northerly connection to the main bedrock valley in the Primary Study Area. The bedrock valley tends to follow the Lower Middle Branch to the Main Branch of Sixteen Mile Creek, as well as a subtle bedrock valley slope to the southeast. The topography within the valley ranges from 190 masl to less than 170 masl.

The geological stratigraphy and the surface and bedrock topography are the major characteristics which control groundwater flow. The overall stratigraphic characteristics were confirmed and include the following:

- The thickness of the overburden in the study area ranges from about 5 m to more than 30 m in bedrock valleys, but is most often in the 10 m to 15 m range.
- The overburden materials generally consist of low permeable glacial till, silt and clay deposits.
- The majority of the basal sand and gravel within the valley exists north of Britannia Road.
- Discontinuous sand and gravel deposits exist at the bedrock contact at various locations within the Primary Study Area.
- Thin, discontinuous deposits of sand and gravel are evident at various depths within the till.
- The surficial sand and gravel deposits are relatively thin and in some cases not as prevalent as originally mapped.
- There is no apparent continuous stratigraphic connection between the more prevalent basal sand and gravel and ground surface through the till and glaciolacustrine silt and clay.

The following characteristics relate to the domestic wells within the Primary and Supplemental Study Areas:

- Discrete sand/gravel lenses within the overburden and sand and gravel deposits at the bedrock contact provide adequate water supplies.
- The record review for water supply wells found that only about 35% of the wells were completed in overburden deposits and the remainder were completed in the shale bedrock.
- The Queenston shale is generally not considered a good aquifer (for water quality or quantity), but serves as the most significant local aquifer, due to the lack of other aquifers in much of the study area. In particular, the upper portions of the shale, where it is fractured and weathered, can be an important zone of groundwater movement.

There are 17 active permits in the Primary Study Area; however, 16 of these are for construction dewatering and one permit for golf course irrigation. Construction dewatering is usually temporary and golf course dewatering for irrigation is seasonal. The amount of dewatering for construction will depend on the depth and size of the excavation and whether it has intercepted the more permeable sand and gravel deposits or shallow fracture bedrock.

The Highly Vulnerable Aquifer (HVA) mapping provided by Conservation Halton indicates a very small HVA just south of Highway 401 within the study area.

Groundwater level data from monitoring wells indicate the following:

- The depth to groundwater varies across the Primary Study Area with a majority of the wells within the upper 2.5 m.
- Groundwater tends to be closer to ground surface in topographic lows and slightly deeper in topographic highs. Groundwater levels tend to be lower (>4 m) in deeper wells within the till.
- Seasonal trends in the monitoring wells tend to vary in the 1-2 m range.
- All but one of the monitoring well sites show downward gradients. Current data does not indicate any significant upward gradients related to the bedrock valley.

Horizontal groundwater flow enters the Primary Study Area from the west northwest and converges within the West Branch of Sixteen Mile Creek and the Middle Branch of Sixteen Mile Creek. Steeper gradients occur at the confluence of the Main Branch where Sixteen Mile Creek cuts more deeply into the Queenston shale. The groundwater divides for the overburden tend to follow the surface water divides.

It is expected that the groundwater flow directions within the upper fractured bedrock will generally follow the bedrock topography. The overall fractured nature of the upper shale bedrock is expected to be relatively continuous and likely provides a larger-scale connection through the Primary Study Area and beyond. The upper shale bedrock may therefore be connected to recharge areas further upgradient of the Primary Study Area where hydraulic connection through the overburden may be more prevalent.

The amount of recharge is limited to a greater extent by the lower permeability of the surficial sediments. The recharge values may be higher or lower depending the overall clay, silt and sand content within surficial unit. Where the surficial sand exists, higher recharge values will exist. Higher depressional focused recharge can also occur in topographic lows. The Significant Groundwater Recharge Mapping provided by Conservation Halton indicates areas of medium vulnerability that are related to the surficial sands within the Primary Study Area.

Groundwater discharge to stream reaches is very limited throughout the Primary and Supplemental Study Areas. Spot flow measurements and observation indicate that all the tributaries feeding the Lower Middle Branch and the West Branch can be dry at times in the summer months except for those that are fed by stormwater management ponds within Milton. Seepage areas were noted along lower slopes in both West Sixteen Mile Creek and lower East Sixteen Mile Creek where deeper cuts have occurred and valley walls are steep. The groundwater discharge observations for the tributaries within the study area are consistent with historical observations from the previous subwatershed studies.

All of the mini piezometers within wetlands or vernal pools are dry or show downward gradients except 2 mini piezometers. These 2 piezometers go from downward to upward gradients in June and then become dry. The seasonal reversal of hydraulic gradient is likely a result of increased ET and a reduction in the water table as opposed to a larger scale groundwater flow system discharge.

4.9.2 Hydrology and Hydraulics (Surface Water)

The hydrologic and conditions within the Primary and Supplemental Study Areas have been characterized through a desktop review of background information, field reconnaissance, and the development of hydrologic and hydraulic computer models. The Sixteen Mile Creek Watershed has been the subject of study and analysis over the past 20 years as part of various Secondary Planning Studies for the Town of Milton. Although the soils within the area are generally lower permeability material, the agricultural land use conditions and gentle overland slopes provide opportunity for reduced runoff potential during storm events. The hydraulic structures along the regulated watercourses are generally typical of rural drainage systems and historic design standards; relatively frequent overtopping of the roads would thus be anticipated under existing conditions, particularly during formative events in the springtime coinciding with snow accumulation and melt conditions coupled with rainfall.

The study area extends across Subwatersheds 2 and 7 of the Sixteen Mile Creek Watershed, with smaller portions located within Subwatersheds 3, 4, 5 and 6. The HSP-F hydrologic model for the Sixteen Mile Creek Watershed has been refined within the limits of the study area to generate peak return period and Regulatory (Regional) Storm event flows at key locations within the study area. Due to the atypically dry conditions which prevailed through the course of the 2016 monitoring program, the information gathered is considered insufficient for the purpose of model calibration; nevertheless, the HSP-F hydrologic model has been calibrated and validated extensively as part of previous studies conducted over the past 20 years, hence is considered to be representative of the hydrologic conditions within the Watershed and the current study areas.

Floodline mapping has been developed for the regulated watercourses through the Primary and Supplemental Study Areas. The mapping is generally consistent with the current Regulatory floodline mapping for the watercourses.

4.9.3 Stream Morphology

Watercourses and headwater drainage features within the Primary and Supplemental Study Areas were assessed through a combination of desktop analysis and field reconnaissance to characterize channel morphology and dominant processes affecting stability. This has included review of background studies, historic aerial photographs, delineation of meander belt widths, rapid field assessments and detailed field sites.

There are five subwatersheds of Sixteen Mile Creek that are associated with perennial flowing watercourses within the Primary and Supplemental Study Areas, (West Branch, Lower Middle Branch, Middle Branch, Middle East Branch and East Branch). Each subwatershed has numerous additional tributaries and headwater features that contribute discharge and sediment downstream. Through the characterization process of watercourses within the Primary and Supplemental Study Areas, it was determined that:

- Permanent watercourses are generally considered stressed/transitional indicating that channel morphology is within the range of variance of streams of similar hydrographic character but that evidence of instability exists. Dominant processes affecting the stability of the channel vary depending on reach and location within the subwatershed. Processes observed indicated that there is a mixture of aggradation, degradation, widening and planform adjustment occurring.
- Predominantly, only main branch watercourses have year round flow. The majority of tributary watercourses are intermittent and do not support connected flow year round but may have disconnected pools. Tributary watercourses that support year round flow have headwaters within the developed areas of Milton. Depending on the drainage area, these watercourses can either be In Regime or stressed/transitional
- Confined valley tributaries are areas of coarse sediment production. Fine grain material sourced from headwater drainage features are typically carried through the system as wash load or suspended sediment.
- Estimated bankfull hydraulics indicates that the median grainsize is transported at bankfull flows. Should flows (discharge and duration) increase in the future and sediment production remains unchanged, channel degradation will likely increase.

4.9.4 Water Quality

The surface water quality assessment provides a characterization of the aquatic health of the subwatersheds and tributaries with respect to contaminant loadings under existing land use conditions, and establishes a baseline condition which would be used to verify the performance of the recommended stormwater quality management plan as part of subsequent phases of study and monitoring. Statistical analyses have been completed for water quality data provided at two (2) long-term monitoring stations within the Sixteen Mile Creek Watershed, downstream of the Primary and Supplemental Study Areas. The water quality monitoring data indicates that the existing surface water quality along the Sixteen Mile Creek downstream of the study area is generally of relatively higher quality for the rural land use conditions which prevail throughout most of the watershed. Concentrations of organics, nutrients, and TSS are lower than have been reported in other areas of the Watershed for largely agricultural land use conditions, and concentrations of various metals are below values reported elsewhere in the Watershed as well as PWQO's. The lower concentrations are considered potentially attributable to the influence of stormwater management practices within urbanized areas of the Watershed. PWQO exceedances are noted for silver, with some exceedances occurring for cadmium, cobalt, copper, and iron. Although concentrations of lead were noted to be higher at the monitoring stations downstream of the study area compared to other locations in the Watershed, PWQO exceedances were noted to be highly infrequent.

4.9.5 Aquatic Resources

The characterization of the fish and benthic invertebrate communities and their habitats in the permanently flowing branches of Sixteen Mile Creek relied primarily on existing information. The field investigations undertaken as part of this studied focussed on smaller watercourse and headwater drainage features, for which there was less information available.

The aquatic resources in the Primary Study Area can be summarized as follows:

- The Middle Branch, East Middle Branch, and East Branch of Sixteen Mile Creek all originate north-west of the Primary Study Area and are permanently flowing. The groundwater discharge which provides the base flow in these watercourses appears to occur almost exclusively upstream from the Primary Study Area.
- The West Branch of Sixteen Mile Creek also originates north-west of the Primary Study Area. Summer flow in the West Branch is augmented by water released from Kelso Reservoir and the West Branch also receives the discharge from the Milton Wastewater Treatment Plant.
- No areas of groundwater discharge that contribute a significant amount of base flow have been identified within the Primary Study Area.
- The permanently flowing watercourses within the Primary Study Area are warmwater, based on the temperature monitoring conducted by Conservation Halton in 2011. This is consistent with the absence of groundwater discharge.
- More than twenty fish species have been documented within the Primary and/or Supplemental Study Areas in those permanently flowing branches that have been thoroughly sampled. These include species such as Rainbow Darter and Fantail Darter that are generally considered to be indicative of good water quality. This is consistent with the benthic invertebrate communities which rate water quality as unimpaired or possibly impaired. The fish community IBI appears to under-rate the quality of the permanently flowing watercourses.
- Silver shiner, which is considered threatened in Ontario, occurs in the West and Lower Middle Branches of Sixteen Mile Creek.
- Due to the absence of significant groundwater discharge, most of the headwater drainage features that originate within the Primary and Supplemental Study areas are intermittent or ephemeral. The duration of flow has increased in some of the watercourses that receive flow contributions from stormwater management facilities in the Town of Milton, but in drought years, such as 2016, most of these have little or no flow. As a consequence, the streams that originate in the Primary Study Area tend to have simple fish communities composed of species such as Brook Stickleback and Fathead Minnow that can tolerate the harsh conditions that occur in isolated pools and that move upstream to recolonize streams when flow is present.

4.9.6 Terrestrial Resources

Results from the terrestrial characterization have a range of implications for the next steps of the South Milton SWS. This includes, but is not limited to:

- Follow-up studies during 2017 to address gaps
- Integration of results across disciplines to identify supporting functions
- Assessing the significance of features with regard to Provincial, Regional, and Local Natural Heritage Policy
- Assessing the existing Regional NHS with regarding key features, buffers, linkages, and enhancement areas

Based on input from the South Milton SWS TAC and results from 2016 fieldwork, a number of properties within the study area have been identified for follow-up fieldwork during 2017. This includes:

- Properties identified by Conservation and Halton Region
- Additional properties in Drumquin Woods for Jefferson Salamander surveys
- Areas with identified NHS key features or buffers/linkages/enhancement areas that border the Supplemental Study Area boundary
- Properties identified by D&A as requiring additional field investigation

The assessment of natural heritage significance will follow criteria and direction provided in the Natural Heritage Reference Manual, Regional Policies, Town Policies, Ecoregional Criteria for Significant Wildlife Habitat, and the Endangered Species Act to determine the significance and/or candidate significance of the following features:

- Wetlands
- Woodlands
- Significant Wildlife Habitat
- Valleylands
- Habitat for Endangered/Threatened Species

The analysis and assessment of features types listed above will be integrated with an analysis to assess the key features, buffers, linkages, and enhancement areas that make up the Region's Natural Heritage System. The analysis will follow the direction provided in the Natural Heritage System Definition and Implementation Guide (North-South Environmental 2009).

5.0 INTEGRATION – CHARACTERIZING THE SUBWATERSHED

5.1 Integration Approach

The foregoing investigations and discussions of the existing natural systems proceeded on a discipline-specific basis, working toward an integrated characterization and assessment of the features, functions and form related to the existing systems. This integration allows for a fuller understanding of the fundamental environmental components and systems within the study area. An integrated characterization and assessment of each study discipline generally 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 management opportunities and requirements based on future land uses.

Primary environmental elements stemming from the discipline-specific characterization work described in the previous report sections include:

- Natural Heritage (including wetland/woodlot features/areas)
- Watercourses (including headwater drainage features)
- Recharge and Discharge Areas

Each of these elements to varying degrees requires an integrated assessment in order to establish the significance and associated sensitivity of the features, particularly in the context of the proposed urbanizing setting; the following provides some associated guidance in this regard:

i. Natural Heritage Units
    - diversity and significance of species (flora and fauna)
    - potential for corridor linkage and benefits to key biota
    - presence/absence of fluvial unit
    - local catchment area (size and land use)
    - groundwater influence to sustainability of habitats and functions
    - feature size, plant community diversity, and proximity to other features

ii. Watercourses (including headwater drainage features)
    - presence/absence of form/stability
    - baseflow /intermittent/permanent
    - groundwater discharge (reach specific)
    - presence/absence of riparian corridor vegetation
    - bankfull/riparian/flood flows
    - floodplain
    - sediment transport
    - fish habitat (direct/indirect)
    - benthic invertebrates
    - temperature/water quality

iii. Recharge and Discharge Areas
    - rate of infiltration/recharge

- location of functional recharge areas
- functional relationship to watercourse, wetland or terrestrial feature
- quantity of groundwater flux

The foregoing factors/considerations (and others) have been summarized as they relate to the respective environmental units, features and systems. The following sections provide insight regarding these units, features and systems, which will be used in subsequent study stages (Phase 2, 3 and 4 of this SMSWS) to inform the land use and infrastructure (road and services) planning process in an iterative manner.

5.2 Principles of Integration

The fieldwork and accompanying assessments, associated with the subwatershed characterization, has been used to establish various principles, unique to the overall study area. These principles reflect the properties and characteristics of the respective subwatersheds, which depending on their nature, have implications related to future management.

The following sections have been organized by discipline and the integration principle is stated, followed by the management implications, where relevant (italics). It should be noted that by their very nature there are overlaps between the respective disciplines, which essentially lead to the integrated understanding of how the subwatersheds function.

5.2.1 Groundwater Characterization and Functions

i. The fractured nature of the upper till and glaciolacustrine silt/clay, along with macropores, provides the main pathway for infiltration and movement of groundwater, both laterally and to depth throughout the majority of the Primary Study Area. This active hydraulic zone is likely limited to the upper 2 to 3 m. The more permeable sand and gravel deposits in the eastern portion of the Primary Study Area provide a more open shallow hydraulic pathway. A reduction in infiltration can reduce the local groundwater levels and available groundwater for storage and potential discharge where it exists. Infiltration can be reduced through urbanization by increased impervious area and compaction of the shallow till and glaciolacustrine silt/clay.

   Attempt to maintain or enhance infiltration where functionally appropriate and minimize compaction of the shallow overburden.

ii. Reduced water levels may impact terrestrial communities dependent on a high water table and reduce groundwater discharge where it exists in stream reaches and effect aquatic resources.

   Attempt to maintain or enhance infiltration where functionally appropriate. Also implement best management practices for underground servicing to minimize water table lowering.

iii. A reduction in water levels may reduce available water in local water wells.

   Attempt to maintain or enhance infiltration where functionally appropriate and minimize compaction of the shallow overburden.

iv. The fractured nature of the upper till and glaciolacustrine silt/clay, along with macropores, appears to provide an additional capacity to infiltrate and store precipitation when the shallow water levels are sufficiently low, thus buffering runoff for medium intensity rainfall events.

Compaction or removal of the shallow overburden may reduce this buffering capacity

v. Smaller scale depressional topography can focus local shallow groundwater and may increase local recharge.

Efforts should be made to maintain or create where functionally important.

vi. Locally some surficial sand and gravel deposits provide capacity for storm water infiltration.

These areas should be used for enhanced infiltration given due regard to water quality.

vii. Shallow groundwater levels adjacent to terrestrial features may act to buffer the amount of infiltration/recharge out of these features as part of the natural water balance.

Maintaining infiltration within the buffer areas surrounding these features may maintain the natural groundwater levels and local groundwater balance.

viii. The upper fractured Queenston Shale bedrock is considered the most regionally connected groundwater flow system. Installation of various infrastructure within this unit may occur where the overburden is thin and groundwater flow system impacts are possible with respect to the quantity and direction of groundwater flow.

Infrastructure trenches should be designed using best management practices to minimize water table lowering and redirection of shallow flows.

ix. Strong upward hydraulic gradients were not found in the northern portion of the Primary Study Area but the potential for significant dewatering during subsurface infrastructure installation should be considered.

Borehole exploration and groundwater level monitoring specific to this issue is recommended prior to construction.

5.2.2 Surface Water Characterization and Functions

i. The Regional Storm Floodplain along the riverine systems through the SMSWS area is contained within the defined valleys; the floodplains within the headwater systems generally encompass existing agricultural lands.

Flood protection for the SMSWS Area to be integrated with planning of the NHS and management plan for watercourses.

ii. Drainage systems located within or adjacent to terrestrial units to be protected, such as woodlots and wetlands, may contribute overland drainage to the terrestrial units on a frequent basis; therefore, depositing sediments and nutrients is important for sustainability.

Drainage features with floodplains that include woodlots and wetlands should continue to contribute drainage, sediments and nutrients by appropriately managing the existing alignment or by being realigned in a manner that does not impact the terrestrial unit.

iii. Wetlands and woodlots provide temporary flood storage when located within drainage system floodplains.

The flood storage function of the area wetlands and woodlots should be appropriately managed either within the terrestrial units or replicated locally within the drainage system.

iv. If unmitigated, the conversion of agricultural lands to urban land uses will increase the rate and volume of storm runoff locally, and potentially further downstream.

Stormwater management systems should be implemented to manage the increased rate and volume of runoff from future development and no increase water levels within identified downstream Flood Damage Centres.

v. Drainage systems contribute runoff to riparian vegetation along the drainage system corridor, therefore contributing to the formation and sustainability of the riparian vegetation.

Existing drainage systems, whether altered through realignment, form or other alterations, should be appropriately managed to maintain and improve upon existing riparian vegetation communities.

vi. The watercourses within the study area exhibit moderate erosion potential.

The flow regime within the channel system post development should be managed to mitigate potential impacts to the channel system stability. Stormwater management and natural channel design techniques will be required to provide for long-term and sustainable channel stability. Source controls should be implemented on-site to appropriately manage groundwater recharge and work toward replicating pre-development water budget.

vii. Headwater drainage features contribute and convey sediment to the downstream drainage system while also removing contaminants and are, therefore, an integral component of the downstream channel formation process.

The headwater drainage system function of "natural" sediment contribution to downstream systems should be replicated by using innovative drainage systems and BMPs (i.e. replication of lost headwater drainage features within appropriate land uses).

viii. Occupied silver shiner habitat has been identified along the defined riverine systems within the study area.

Stormwater management infrastructure, including Low Impact Development measures and measure to appropriately manage wetland water budgets, may potentially extend flows within the receiving watercourses, augment baseflows, and mitigate thermal impacts from future development, thereby sustaining silver shiner habitat.

5.2.3 Geomorphic Characterization and Functions

i. Land use changes such as the removal of headwater drainage features or vegetation and increases in imperviousness, will increase flow discharges and diminish the development of resisting forces.

Headwater drainage features are critical to maintaining proper flow and sediment conveyance across the landscape. 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. Maintaining appropriate hydrologic and sediment regimes will be necessary to preserve the function of the headwater channels and their role in maintaining stream health in downstream areas.

ii. Channel erosion is a necessary natural process; however anthropogenic pressures such as uncontrolled stormwater runoff, may accelerate and exacerbate natural erosion processes resulting in a loss of property, threats to infrastructure and environmental degradation.

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. Erosion thresholds can be applied to provide insight regarding the capacity of each watercourse system to accommodate an altered land use or flow regime. Application of appropriate thresholds as stormwater best management practice targets should limit rates of erosion to acceptable levels.

iii. The incorporation of the meander belt width and associated setbacks into the stream corridor allows the lateral migration of the channel across its floodplain while also ensuring the maintenance of stream form and function. Through the identification of constraints, mitigation of risk to property or proposed infrastructure is achieved.

The meander belt width and associated setbacks represent a constraint to development and land use planning.

5.2.4 Terrestrial Integration Characterization and Functions

i. Many of the woodland features within the primary and secondary South Milton SWS area are associated with the main valley systems, and they provide large contiguous patches for wildlife that are dependent on woodland habitat for key life history requirements such as breeding, foraging, and dispersal.

Woodland patches that make up Core areas of the NHS and/or provide important ecological functions (e.g. Significant Wildlife Habitat) should be protected, and adjacent areas managed to ensure features and functions are not impacted.

ii. Where mature forests within the study area intersect with headwater features, intermitted streams, and permanent watercourses, erosion has created incised valleys with a range of topographical conditions that support a high variability in understory microhabitats.

Key functions provided by hydrology and fluvial aspects of headwater features, intermittent streams, and permanent watercourses will be identified for these areas to assess management options that may help to maintain and/or enhance the associated topographical and ecological variability where these areas are present.

iii. Some woodlands present on the tablelands are associated with localized catchments and drainage that may be linked to headwater features. For example, localized wetland features within woodlands south of Derry Road that intersect with the Middle Branch and East Branch subwatershed boundary have localized drainage features that are reminiscent of sloughs that typically occur on impervious soils. Despite the small size of these features and the seasonal hydroperiod, they provide important habitat for amphibian species across the primary study area.

   The habitat functionality of these localized drainage features should be effectively maintained and/or restored locally where opportunities exist.

iv. Woodlands and swamps found in lowland areas and on wet soils are generally associated with the floodplain areas of permanent and intermittent watercourses, and therefore linked to the season fluxes in hydrology, soil, and nutrient inputs that result from a range of flooding events. Additionally, some features may be supported by localized linkages to ground water.

   Ecological functions related to hydrological fluxes of permanent and intermittent watercourses should be considered when developing/refining SWM plans. Where features may be supported by local ground water functions, opportunities for recharge should be identified within buffer areas and adjacent lands.

v. Open wetlands such as meadow marsh and shallow marsh features are typically linked to floodplains associated with the main watercourses, and permanent or intermittent tributaries. Additionally, similar wetland features associated with headwater drainage features are generally linked to agricultural land-use practices. Where present, they can provide seasonal or permanent habitat for wildlife species that tend to utilized open habitat, and tolerate human disturbance. Some of these features also provide a linkage function to isolated tableland features.

   Key functions for these wetlands where they're linked to the main watercourses and/or permanent or intermittent streams should be maintained; additionally linkage and habitat characteristics for these features should be maintained and enhanced where possible.

vi. Some of the successional areas (i.e. cultural thickets and meadows) are large enough to support species that tend to be area sensitive. Additionally, Species at Risk that utilize successional habitat and actively managed agricultural lands such as Bobolink, Eastern Meadowlark, and Barn Swallow were present within the agricultural tableland areas across the primary study area.

   Large early successional areas that are known to support area-sensitive species and Species at Risk should be identified, and appropriate management and/or permitting strategies developed consistent with existing provincial and regional policy.

5.2.5 Water Quality Characterization and Functions

i. Existing water quality is generally of higher quality, with lower concentrations of nutrients, microorganisms, TSS, and most metals compared to values reported elsewhere within the

Sixteen Mile Creek Watershed. With the exception of certain metals, the existing surface water quality has demonstrated few PWQO exceedances.

Based on future land use conditions within the study area, stormwater management infrastructure should be designed to maintain and potentially improve the current water quality conditions to the greatest extent possible.

ii. The headwater areas provide a hydrologic function, nutrients, sediment, particulate matter and organics to the downstream aquatic habitat.

The headwater area aquatic habitat support function should be maintained through implementing a drainage system that includes the use of open swales and ditching in a strategic manner.

iii. The main permanently flowing watercourses support diverse fish communities including sensitive species and the Threatened Silver Shiner.

Stormwater management practices that maintain the quality of the permanently flowing watercourses should be implemented within the study area.

5.2.6 Aquatic Characterization and Functions

i. The principal sources of base flow in the permanently flowing main branches of Sixteen Mile Creek (West Branch, Middle Branch, East Middle Branch) are north of the Primary and Supplemental Study Areas.

Land use changes within the Primary and Supplemental study area can be expected to have a relatively small effect on base flow in the main watercourses.

ii. The permanently flowing main branches of Sixteen Mile Creek provide good quality habitats that support diverse fish communities within the Primary Study Area including sensitive darter species and, in the West Branch and Lower Middle Branch, the Threatened Silver Shiner.

The high quality habitats in the main branches should be maintained in order to protect the fish communities that occupy them. Key habitat attributes include flow regimes, water quality and riparian buffers.

iii. Most of the headwater drainage features that originate within the Primary and Supplemental Study Areas are ephemeral. If fish are present, they are typically tolerant species such as Brook Stickleback and Fathead Minnow.

The management focus for ephemeral headwater drainage features that originate within the Primary and Supplemental Study Areas should be on the maintenance of functions that support the high quality habitats that are downstream. This approach will inherently maintain or create habitat for the tolerant species that utilize the intermittent and ephemeral features.

5.3 Applications of Principles

The integration principles outlined in the preceding section will be applied to develop a constraint ranking for the watercourses and headwater drainage features within the study area. Each watercourse will be assessed on a reach-by-reach basis, based upon various environmental factors and considerations, and a "consensus" constraint rating has been developed accordingly. The findings of the assessment will ultimately provide guidance regarding the management opportunities and requirements for each of the surface drainage features within the study area. The following sections summarize the approaches and criteria applied, by discipline, in developing the individual constraint rankings for the area watercourses.

5.3.1 Fisheries

Fish habitat evaluation has been guided using the Credit Valley Conservation and Toronto and Region Conservation document "Evaluation, Classification and Management of Headwater Drainage Features: Guidelines (2014), to establish constraint rankings consistent with the approach applied in the January 2000 Subwatershed Study and the November 2015 Subwatershed Update Study for Sixteen Mile Creek Areas 2 and 7. While the terminology and some of the class boundaries differ somewhat between the two systems, the resulting classification and attendant habitat values and recommended protection strategies, indicate that the change in classification system is not expected to result in major differences between the outcomes of the January 2000 and the November 2015 assessments. The 2014 guidelines are provided below.

i. *Permanent* - Provides direct habitat onsite (e.g. feeding, breeding, and/or migration) as a result of year round groundwater discharge and/or permanent standing surface water within a storage feature (i.e. ponds, wetlands, refuge pools, etc.). Habitat may be either existing or potential (i.e. isolated by a barrier). Permanent habitat also may include critical fish habitat (i.e. habitat that is limited in supply, essential to the fish life cycle, and generally habitat that is not easily duplicated or created). Hydrogeological studies and/or water balance calculations may be required to confirm groundwater contributions, as appropriate, with regard to the scale of the development application(s).
ii. *Seasonal* - Provides limited direct habitat onsite (e.g. feeding, breeding, migration and/or refuge habitat), as a result of seasonally high groundwater discharge or seasonally extended contributions from wetlands or other surface storage areas that support intermittent flow conditions, or rarely ephemeral flow conditions. Occasionally, limited permanent refuge habitat may be identified within seasonal habitat reaches.
iii. *Contributing* - Provides indirect (contributing) habitat to downstream reaches – functions generally increase with flow and/or as flows move downstream with increasing length of channel or channel density (e.g. extent of contributing area). There are two types of contributing habitat:
    a. Complex contributing habitat – generally as a result of intermittent (or less commonly ephemeral) surface flows, can have marginal sorting of substrates – generally well vegetated features that influence flow conveyance, attenuation, storage, infiltration, water quality, sediment, food (invertebrates) and organic matter/nutrients (i.e. there are two types of nutrients, e.g. dissolved nutrients, and course/fine matter). Generally, two structural types: a) defined features with natural bank vegetation consisting of forest, scrubland/thicket or meadow (as

defined in OSAP or ELC); or b) poorly defined features (swales) typically distinguished by hydrophilic vegetation.

b. Simple contributing habitat – generally as a result of ephemeral (or less commonly intermittent) surface flows – generally not well-vegetated features that influence flow conveyance, attenuation, storage, infiltration, water quality and sediment transport. Generally two types: a) defined features characterized by crop cultivation, mowing or no vegetation; or b) poorly defined features (swales) may contain terrestrial vegetation.

iv. Not Fish Habitat - The pre-screened drainage feature has been field verified to confirm that no features and/or functions associated with headwater drainage features is present – generally characterized by no definition or flow, no groundwater seepage or wetland functions, and evidence of cultivation, furrowing, presence of a seasonal crop, lack of natural vegetation, and fine textured soils (i.e. clay and/or silt).

v. Recharge Zone - Coarse-textured soils described as sand and/or gravel have been confirmed through field verification; majority of potential flow will be infiltrated. These features may have ill-defined channels as a relic of past flows; however the key function is groundwater recharge and maintenance of downstream aquatic functions via groundwater connections to streams. No direct fish habitat or indirect contributions through surface flow conveyance, allochthonous or sediment transport provided.

The upstream limit of permanent fish habitat has been determined by direct sampling, or by examining the habitat at the farthest upstream location where fish were collected, and then extending upstream to where that type of habitat changed to something less likely to support fish on a permanent basis. Similarly, the upstream limit of seasonal fish habitat has been determined by examining the habitat at the farthest upstream location where fish were seasonally present, and then extending upstream to where that type of habitat changed to something less likely to support fish for a biologically significant length of time at any time of year.

Broad-Level Constraints

The following general constraint rankings for each class of watercourse aquatic habitat are presented in the *Evaluation, Classification and Management of Headwater Drainage Features: Guidelines* (ref. CVC and TRCA, 2-14). Broad-level constraints (High, Medium, Low) have been assigned to each sub-class of management recommendations to feed into the Integrated Constraint Rating for each watercourse section.

i. Protection – Permanent Fish Habitat, Critical Habitat and Species at Risk (SAR).

Protection 1 ***(High Constraint)*** – permanent, critical fish habitat or habitat associated with species at risk. Generally associated with permanent groundwater discharge or wetland storage – either habitat and/or flow source characteristics may be difficult to replicate or maintain.

Protection 2 ***(High Constraint with rehabilitation potential)*** – permanent fish habitat generally with permanent standing surface water associated with a wetland and/or pond flows.

ii. **Conservation** – Seasonal Fish Habitat.

Conservation 1 ***(Medium Constraint)*** – seasonal fish habitat associated with seasonally high groundwater discharge or seasonally extended contributions from wetlands potential permanent refuge habitat may be provided by a storage feature.

Conservation 2 ***(Medium Constraint)*** – seasonal fish habitat associated with intermittent surface flows.

iii. **Mitigation** – Contributing Fish Habitat

Mitigation 1 ***(Medium Constraint)*** – Complex contributing fish habitat: flows conveyed through natural vegetation communities that support complex, contributing fish habitat i.e. influences water quality, sediment, organic matter, food and nutrients to the downstream habitat.

Mitigation 2 ***(Medium Constraint or Low Constraint)*** – Simple contributing fish habitat: flows that support simple contributing fish habitat, i.e. influences flow conveyance, attenuation and storage to downstream reaches.

iv. **No Management Recommendation Required** ***(Low Constraint)*** – Not Fish Habitat.

v. **Recharge Protection – Recharge Zone -** No direct habitat or indirect habitat providing surface flow, sediment transport, or allochthonous contribution to downstream fish habitat.

Management

A fisheries high constraint relates to perennial watercourses that supports, or has the potential to support, high quality habitat, whereas a medium constraint has been assigned to reaches exhibiting intermittent flow conditions which have been observed to support fish habitat. A low fisheries constraint is assigned to watercourses that are not considered fish habitat, or have little potential to contribute to fish habitat based on the flow regime identified.

All watercourses within the South Milton SWS Primary Study Area have been evaluated with respect to the criteria provided in the document *Evaluation, Classification and Management of Headwater Drainage Features Guidelines* (ref. CVC and TRCA, 2014). This document also provides general management recommendations for each class of watercourse as follows.

1. **Protection** – Permanent Fish Habitat, Critical Habitat and Species at Risk (SAR).

Protection 1 ***(High Constraint)*** – permanent, critical fish habitat or habitat associated with species at risk. Generally associated with permanent groundwater discharge or wetland storage – either habitat and/or flow source characteristics may be difficult to replicate or maintain.

- Preserve the existing drainage feature and groundwater discharge or wetland in-situu, particularly if species at risk are present;

- Maintain external drainage;
- Incorporation of shallow groundwater and base flow protection techniques such as infiltration treatment;
- Use natural channel design techniques or wetland design to restore and enhance existing habitat features, if necessary; realignment not generally permitted;
- Drainage feature must connect to downstream watercourse/habitat;
- Stormwater management (e.g. extended detention outfalls) are to be designed and located to avoid and/or minimize impacts (i.e. sediment, temperature) to fish habitat;
- Examine need to incorporate groundwater flows through infiltration measures (i.e. third pipes, etc.) to ensure no net loss and potential gain.

Protection 2 ***(High Constraint with rehabilitation potential)*** – permanent fish habitat generally with permanent standing surface water associated with a wetland and/or pond flows.

- Preference is to maintain existing surface water source;
- Maintain external drainage or if catchment drainage has been previously removed due to diversion of stormwater management flows, restore lost functions through enhanced lot level controls (i.e. restore original catchment using clean roof drainage) as necessary;
- Replicate on-site surface water sources including wetland creation and incorporating extended detention outlets, if necessary;
- Use natural channel design techniques to replace and enhance existing habitat features only if features are easily replicated;
- Drainage feature must connect to downstream watercourse/habitat;
- Examine need to incorporate groundwater flows through infiltration measures (i.e. third pipes, etc.) to ensure no net loss and potential gain.

2. Conservation – Seasonal Fish Habitat.

Conservation 1 ***(Medium Constraint)*** – seasonal fish habitat associated with seasonally high groundwater discharge or seasonally extended contributions from wetlands potential permanent refuge habitat may be provided by a storage feature.

- Maintain existing seasonal groundwater or wetland surface flows,
- If catchment drainage has been previously removed due to diversion of stormwater management flows, restore lost functions through enhanced lot level controls (i.e. restore original catchment using clean roof drainage), as feasible;
- Replicate on-site seasonal groundwater or surface flows using infiltration measures and/or wetland creation, if necessary;
- Maintain external flows,
- Use natural channel design techniques to replace existing habitat features to maintain overall fish productivity of the reach;
- Drainage feature must connect to downstream habitat.

Conservation 2 ***(Medium Constraint)*** – seasonal fish habitat associated with intermittent surface flows.

- Replicate on-site surface flows;
- Maintain external flows; or if catchment drainage has been removed restore lost functions through enhanced lot level controls, as feasible;
- Use natural channel design techniques to replace existing habitat features to maintain overall fish productivity of the reach;
- Drainage feature must connect to downstream habitat.

3. Mitigation – Contributing Fish Habitat

Mitigation 1 ***(Medium Constraint)*** – Complex contributing fish habitat: flows conveyed through natural vegetation communities that support complex, contributing fish habitat i.e. influences water quality, sediment, organic matter, food and nutrients to the downstream habitat.

- Replicate functions through enhanced lot level conveyance measures, such as well-vegetated swales (herbaceous, shrub and tree material) to mimic online wet vegetation pockets, or replicate through constructed wetland features;
- Replicate on-site flow and outlet flows at the top end of system to maintain feature functions. If catchment drainage has been previously removed due to diversion of stormwater management flows, restore lost functions through enhanced lot level controls (i.e. restore original catchment using clean roof drainage);
- Feature form and flow that connects directly to downstream fish habitat (i.e. direct connection to other drainage features/watercourse or wetlands);

Mitigation 2 ***(Medium Constraint or Low Constraint)*** – Simple contributing fish habitat: flows that support simple contributing fish habitat, i.e. influences flow conveyance, attenuation and storage to downstream reaches.

- Replicate functions by lot level conveyance measures (e.g. vegetated swales) connected to the natural heritage system, as feasible and/or Low Impact Development (LID) stormwater options (refer to TRCA's Water Management Guidelines for details);
- Replicate on-site flows and outlet flows at the top end of vegetated swales, bioswales, etc. to maintain feature functions.

4. No Management Recommendation Required *(Low Constraint)* – Not Fish Habitat.

- The pre-screened drainage feature has been field verified to confirm that no feature and/or functions associated with headwater drainage features are present – generally characterized by evidence of cultivation, furrowing, presence of a seasonal crop, and lack of natural vegetation.

5. **Recharge Protection – Recharge Zone -** No direct habitat or indirect habitat providing surface flow, sediment transport, or allochthonous contribution to downstream fish habitat.

- Maintain overall water balance by providing mitigation measures to infiltrate clean stormwater, unless the area qualifies as a Significant Recharge Area under the Source Water Protection Act. These areas will be subject to specific policies under their respective legislation.

5.3.2 Fluvial Geomorphology

The approach applied to establish fluvial geomorphologic constraint rankings for the area watercourses is summarized in Table 5.3.1.

Table 5.3.1 Summary of Geomorphological Constraints & Management Strategies

Ranking	Definition	Management Strategy
High	Reaches that comprise a defined channel with well-developed channel morphology (i.e., riffle-pool) and/or a well-defined valley. These reaches possess both geomorphological form and function and are high-quality systems that could not be re-located and replicated in a post-development scenario.	Watercourse to be protected/enhanced in current form and location. Modification through enhancement may be acceptable.
Medium	Reaches that may or may not have a well-defined morphology (form) but do maintain geomorphic function and have potential for rehabilitation. In many cases, these reaches may exhibit evidence of geomorphic instability or environmental degradation due to historic modifications and land use practices.	Watercourse to remain open. Enhancement is recommended and relocation/restoration is acceptable, provided maintenance and enhancement of channel functions occurs.
Low	Ephemeral headwater systems that lack defined bed and banks (form) but do perform a geomorphic function through the conveyance of flow and sediment.	Watercourse may be eliminated and drainage incorporated into SWM systems, if not required to meet drainage density targets. Alternatively, watercourse may remain open and realignments would be acceptable, if it is required to meet drainage density targets; no riparian corridor or setbacks required.

Management options for Medium geomorphological constraint streams build upon the fisheries strategies described above (and potentially High constraint streams where modification through enhancement is acceptable) include:

- *Do nothing*: leave the corridors in their present condition and develop outside of their boundaries. It is preferable that streams are not altered. If required from a fisheries management strategy, enhancement to the riparian vegetation may be required.

- *Enhance existing conditions*: maintain the present location of the corridor but enhance existing conditions (e.g. re-establish a meandering planform, connect channel to functioning floodplain, establish a low-flow channel, restore riparian vegetation). Again, this builds upon the fisheries strategy and must address channel functions, such as the effective conveyance of flow and sediment. Instream structures, such as pools and riffles could be added to provide a more diverse form. Care must be taken to ensure the sediment balance is considered (which may in fact result in some local bank erosion).
- *Re-locate and enhance existing conditions*: many of the reaches within the study area have undergone extensive straightening and modification for agricultural drainage purposes. As such, they are not as sensitive to re-location and would benefit from enhancements such as the re-establishment of a meandering planform with functioning floodplain and development of a riffle-pool morphology. In the event that these reaches are re-located, the corridor width associated with each reach must, at a minimum, be maintained.

Management options for Low geomorphological constraint streams include:

- *Do nothing*: leave the drainage feature intact and develop the surrounding lands, with a minimal buffer (a corridor width is not prescribed for these systems).
- *Combination of stormwater management and open conveyance techniques*: the function of headwater streams can be mimicked through the combined implementation of stormwater management techniques with sufficient maintenance of open conveyance systems such as swales to meet drainage density targets. The swales in the post development setting should be part of a public open space and may also include the outlet channel from a SWM facility. A corridor width is not prescribed for these systems.
- *Open conveyance techniques*: the function of the ephemeral swales is replicated entirely through a system of open conveyance techniques. A corridor width is not prescribed for these systems.
- Watercourses may be eliminated and drainage incorporated into SWM systems, if not required to meet drainage density targets. Alternatively, watercourse may remain open and realignments would be acceptable, if it is required to meet drainage density targets; no riparian corridor or setbacks required.

It should be noted that the net constraint rankings in all cases are equivalent or greater than the geomorphological constraint rankings. Therefore the management strategies as described above or better are applicable on a reach basis.

5.3.3 Hydrology

The constraint rankings based upon the hydrologic function afforded by the drainage features has been established primarily based upon the volume of runoff conveyed by the feature, as indicated by the drainage area to the feature. In addition, the physical condition of the feature has been considered in establishing the constraint ranking, as this relates to the anticipated complexity associated with replicating the conveyance function within a reconstructed corridor.

Watercourses within well-defined riverine systems with large contributing drainage areas (i.e. several hundred or several thousand hectares) and defined regulated floodplains have been assigned a high constraint ranking. Watercourses with defined regulated floodplains, but with less defined corridors and relatively smaller drainage areas (i.e. generally greater than 100 hectares) have been assigned a medium constraint ranking. Those watercourses without defined floodplains and with smaller drainage areas (generally less than 100 hectares) have been assigned a low constraint ranking.

5.3.4 Hydrogeology

Constraint rankings based upon groundwater inputs have been assigned based upon the presence/absence of baseflow and the manner in which groundwater contributions support local or downstream aquatic habitat. The groundwater constraint rankings have been established in conjunctions with the aquatic constraint rankings.

5.3.5 Terrestrial

Much of the Terrestrial Integration as it relates to the significance of natural heritage features will be realized through the on-going evaluation of features such as significant woodlands, significant wetlands, and significant wildlife habitat. Much of the primary and secondary study area with woodland habitat, and thus significant woodlands, are captured within the existing Greenbelt lands and the Sustainable Halton NHS. Wetland evaluations will follow the Ontario Wetland Evaluation System, and will be conducted in collaboration with the Ministry of Natural Resources and Forestry. Significant Wildlife Habitat evaluations will follow the process outlined in the *Natural Heritage Reference Manual*, using criteria outlined in the SWH Criteria Schedules for Ecoregion 7E (MNRF 2015).

As part of the integration with other disciplines to identify reach-based constraints for watercourses, the following approach has been applied to identify preliminary constraint rankings based upon terrestrial functions associated with each watercourse reach within the primary and secondary study area:

High – assigned to reaches that flow through or directly adjacent to identified core natural areas and/or provide a linkage function between core natural areas.

Medium- assigned to stream reaches that flow through other existing terrestrial features or provide a terrestrial linkage and enhancement opportunity between terrestrial features.

Low- assigned to stream reaches that do not flow through terrestrial features or provide a linkage opportunity.

5.3.6 Net Watercourse Constraint Rankings

The discipline-specific constraint rankings for the area watercourses will be used to develop preliminary overall constraint rankings for each of the area watercourses. The discipline-specific and overall watercourse constraint rankings will be reviewed with the TAC, and incorporated into the updated Phase 1 report.

5.3.7 Preliminary Working Targets

The following preliminary working targets have been developed based upon the study goals and objectives outlined in Section 3.8. In addition, it is recognized that the objectives/targets and management strategies outlined in the 1996 Watershed Plan for Subwatersheds 2, 3, 4, 5, 6 and 7 (ref. Gore & Storrie Limited and Ecoplans Ltd., February 1996, Tables D.2 to D.7) shall be considered and applied as appropriate in the development of the management strategies; relevant excerpts from the 1996 Watershed Plan are provided in Appendix 'I'. The working targets provided in Table 5.4.1, as well as the requirements outlined in the February 1996 Watershed Plan, will serve to guide the evaluation and development of recommendations to manage and mitigate the impacts of the future development within the South Milton SWS.

Table 5.4.1 Preliminary Working Targets for South Milton Subwatershed Study

Discipline	Goal	Objective/Target	Management Strategies/Actions
	1	To prevent, eliminate or minimize the risks to life and property caused by flooding and erosion hazards and not create new or aggravate existing hazards.	
Natural Hazards		► To ensure new development does not increase the frequency and intensity of flooding, the rate of natural stream erosion or increase slope instability. ► To establish development standards and land use controls that ensure future development is located outside of, and appropriately setback from, flooding and erosion hazards. ► To ensure that new development, including infrastructure, incorporates appropriate mitigation measures in order to avoid adverse impacts to natural features and areas as it relates to natural hazards. ► To consider climate change adaptation measures as part of the development of flooding and erosion management strategies.	► Provide post-to-pre development flood control for all events up to the Regional Storm event, and provide erosion controls to reduce critical flow exceedance at key locations along receiving watercourses. Guidance on future locations and form of flood controls to be generally set by SWS. ► Develop floodline mapping and meander belt widths as part of the SWS to refine hazard limit definition. ► Develop watercourse and stormwater management plan for the future development to mitigate adverse impacts as determined by impact assessment. ► Develop stormwater management plan which incorporates measures to address increased risk due to climate change and/or allows for adaptive management.
	2	To protect, restore or, where appropriate, enhance the biodiversity, connectivity and ecological functions of the natural heritage features and areas throughout the Study Area for the long term..	
Natural Heritage		► To ensure that natural heritage features and areas, associated with a refined NHS, including their ecological and hydrologic functions, are protected from potential adverse impacts of development. ► To ensure that buffers, corridors and linkages between natural features and areas, surface water features and groundwater features are maintained, restored or, where possible, improved through the establishment of the natural heritage system. ► To establish innovative development standards and land use controls that will ensure future development does not negatively impact the NHS.. ► To consider climate change mitigation and adaptation measures as part of the development of natural heritage management strategies.. ► To consider opportunities for maintaining and enhancing the aesthetic and recreational value of the NHS, as part the development of management strategies.	► Build on the recommendations and guidance for the NHS based on the Sustainable Halton Phase 3 Natural Heritage System Definitions and Implementation Guide ► Develop mapping and resources that identify key features and functions associated with Core areas of the NHS, and evaluate key sensitives and constraints associated with proposed secondary plan areas ► Develop mapping and resources that provide conceptual management recommendations for areas within the existing NHS currently identified as Enhancement, Linkage, and/or Buffers ► Integrate the stormwater and watercourse management plan with the natural heritage system ►
	3	To protect, improve or restore the quality and quantity of water resources within, adjacent to and downstream of the Study Area, including their associated ecological and hydrologic / hydrogeologic functions	
Water Resources		► To ensure fluvial processes and stream morphology are maintained or improved to support important habitat attributes (pools, riffles, etc.), dynamic channel form and diversity which will contribute to maintaining a sustainable natural heritage system. ► To prevent nutrient enrichment and contamination of surface and groundwater resources from development and related activities. ► To ensure surface and groundwater features and their hydrologic functions are protected, improved or restored. ► To maintain linkages and related functions among groundwater features, surface water features, hydrologic functions, and natural heritage features and areas. ► To consider climate change mitigation and adaptation measures as part of establishing management strategies. ► To ensure that the riparian rights of downstream landowners is respected.	► Provide erosion controls to maintain critical flow exceedance at critical locations along receiving watercourses as determined by the Subwatershed Study. ► Provide stormwater quality treatment for infiltrated surface water. ► Meet or exceed stormwater quality control requirements for future development in accordance with Provincial (MOECC – TSS based or any updates to MOECC Guidelines) standards. ► Work toward maintaining pre-development groundwater recharge and groundwater discharge at significant surface water and natural heritage features. ► Develop stormwater management plan which incorporates measures to address increased risk due to climate change and/or allows for adaptive management. ► Develop stormwater management and drainage plan which respects the rights of downstream landowners.

Table 5.4.1 Preliminary Working Targets for South Milton Subwatershed Study

Discipline	Goal	Objective/Target	Management Strategies/Actions
	4	To mitigate negative impacts related to the quality and quantity of stormwater within, adjacent to, and downstream of the Study Area.	
Stormwater Management		► To maintain/enhance baseflow to the receiving regulated watercourses. ► To ensure that post- to pre-development peak flow control (as a minimum) achieves flood control objectives for all storm events (2 year to 100 year) and including the Regional Storm event. ► To ensure that stormwater runoff controls maintain or enhance existing flow-duration exceedance characteristics and other erosion indicators in the receiving regulated watercourses. ► To ensure that the treatment of runoff mitigates surface water quality impacts due to development in accordance with Ministry of the Environment and Climate Change guidelines, to an *enhanced* standard. ► To mitigate thermal impacts from stormwater runoff to the extent possible. ► To consider Low Impact Development (LID), Green Infrastructure and Best Management Practices (BMPs) to treat stormwater at its source. ► To consider climate change mitigation and adaptation measures as part of establishing stormwater management strategies. ►	► Work toward maintaining pre-development water budget ► Provide post-to-pre development flood control for all events up to the Regional Storm event. ► Provide erosion controls to reduce critical flow exceedance at key locations along receiving watercourses. ► Meet or exceed stormwater quality control for future development in accordance with Provincial (MOECC – TSS based or any updates to MOECC Guidelines) standards. ► Incorporate stormwater management measures and practices which mitigate thermal enrichment from urban development. ► Develop a stormwater management plan which allows for incorporating LID BMP's into the future development. ► Develop stormwater management plan which incorporates measures to address increased risk due to climate change and/or allows for adaptive management. ► Work toward maintaining pre-development water budget

ACRONYMS

<to be compiled for next round>

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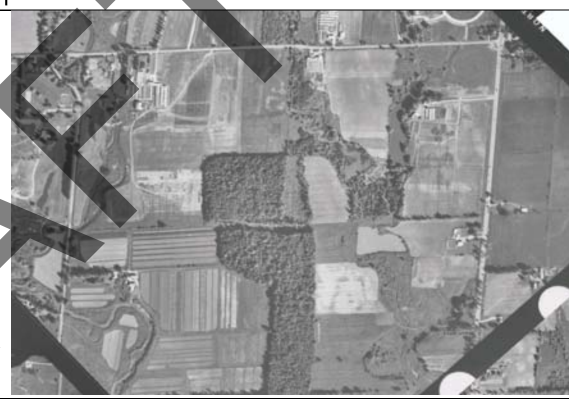
1954: MEMSC(1) flows through riparian corridor adjacent to Sixth Line (centre) with ESMC(11) corridor in the bottom right.	**1978:** Highway 401 and Trafalgar Road boarder image to the top and right. Sixth Line has seen additional residential housing develop as well as a clearing of riparian cover between fields.
	
1954: Derry Road along the top, MSMC(3) flows adjacent/crosses Sixth Line on the left and ESMC(7) and ESMC(6) flow through the centre of the image. Trafalgar Road on the right.	**1978:** Trafalgar Golf and Country Club is in place along Sixth Line. ESMC(7) has been impounded to allow for irrigation practices.
	
1954: MSMC(2) flows through the centre of the image between Sixth Line (right) and Trafalgar Road (left). Channel is impounded behind dam structure.	**1978:** Development around MSMC(2) watercourse. ESMC(3) has been realigned to existing Trafalgar Road crossing. ESMC(4) has been straightened and online pond introduced.

1954: ESMC(1b) and tributaries crossing Lower Base Line Road south of Fifth Line. Surrounding landscape dominated by agriculture.

1978: Confined valley system remains unchanged. Additional rural development and land clearing on tablelands. Lesser tributaries have been afforded a riparian corridor buffer.

1978: SMC(1) and SMC(2) flow through centre of image. Fourth Line on the right.

Figure 4.5.1: 1954 and 1978 Historical Air Photo Interpretations for Primary and Supplemental Study Areas.

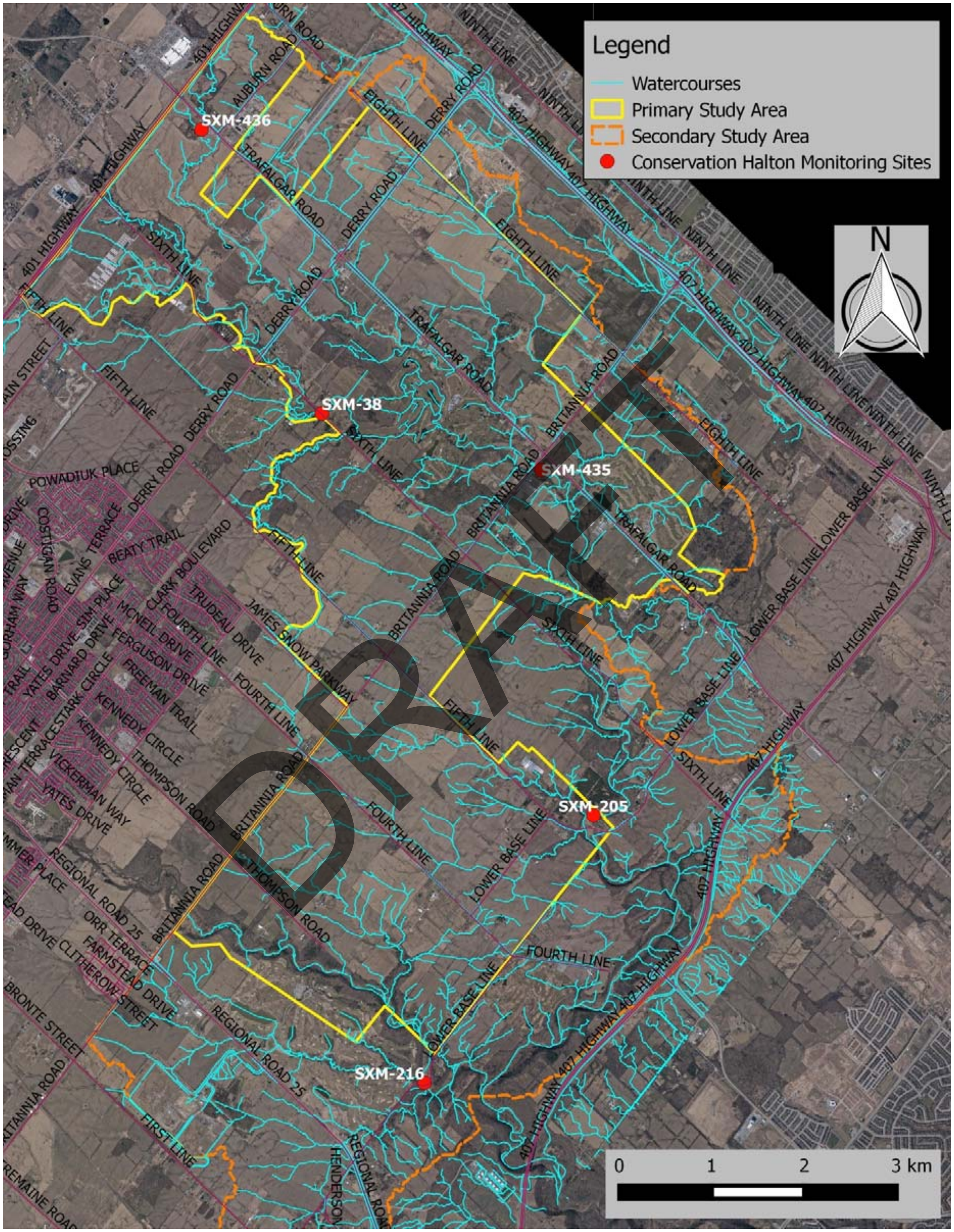


Figure 4.7.2. Conservation Halton's long term environmental monitoring locations that are within the study area. Source: Conservation Halton (2013). Note that the location of SXM-38 is incorrectly displayed in Conservation Halton (2013).

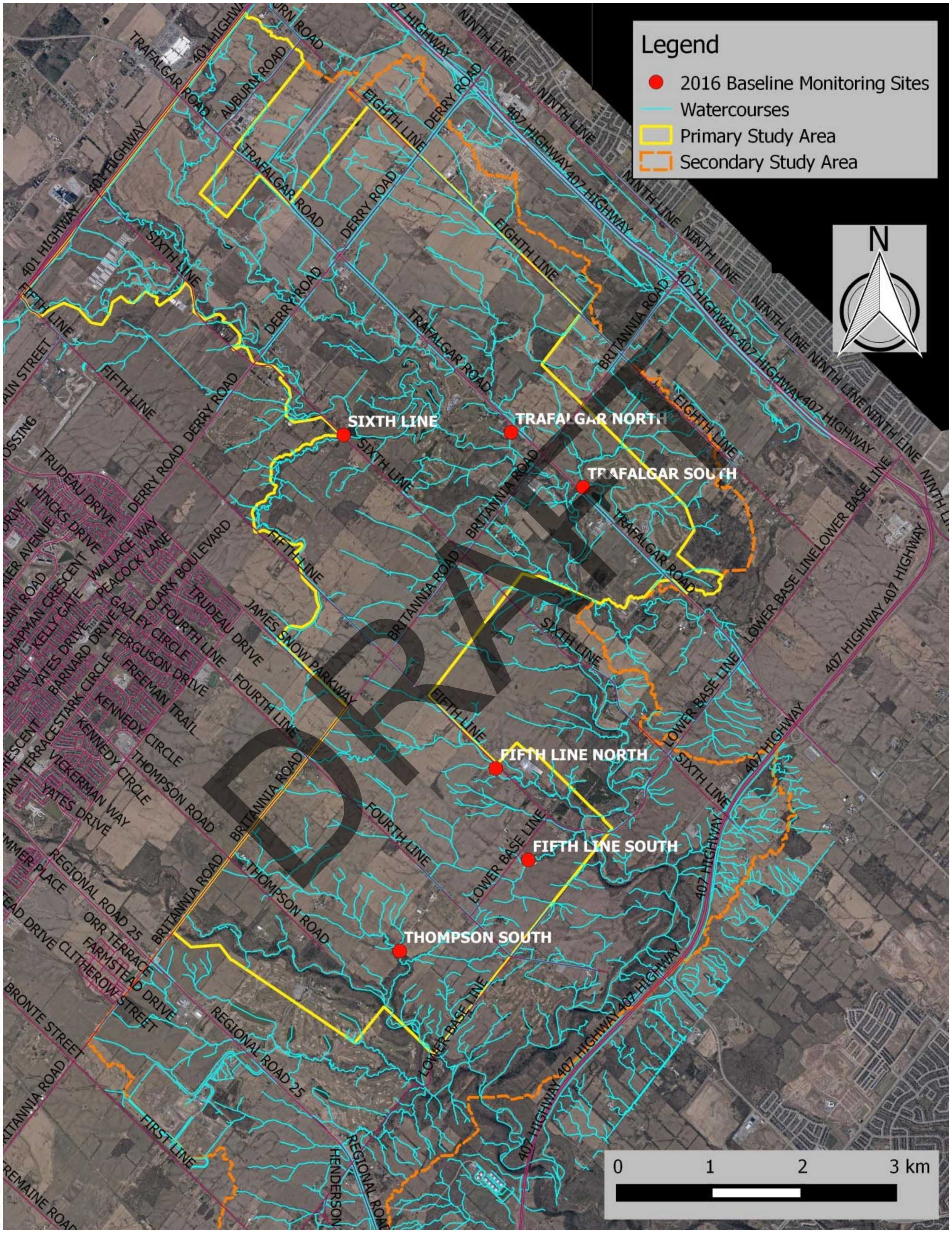


Figure 4.7.3. South Milton subwatershed study baseline monitoring locations.

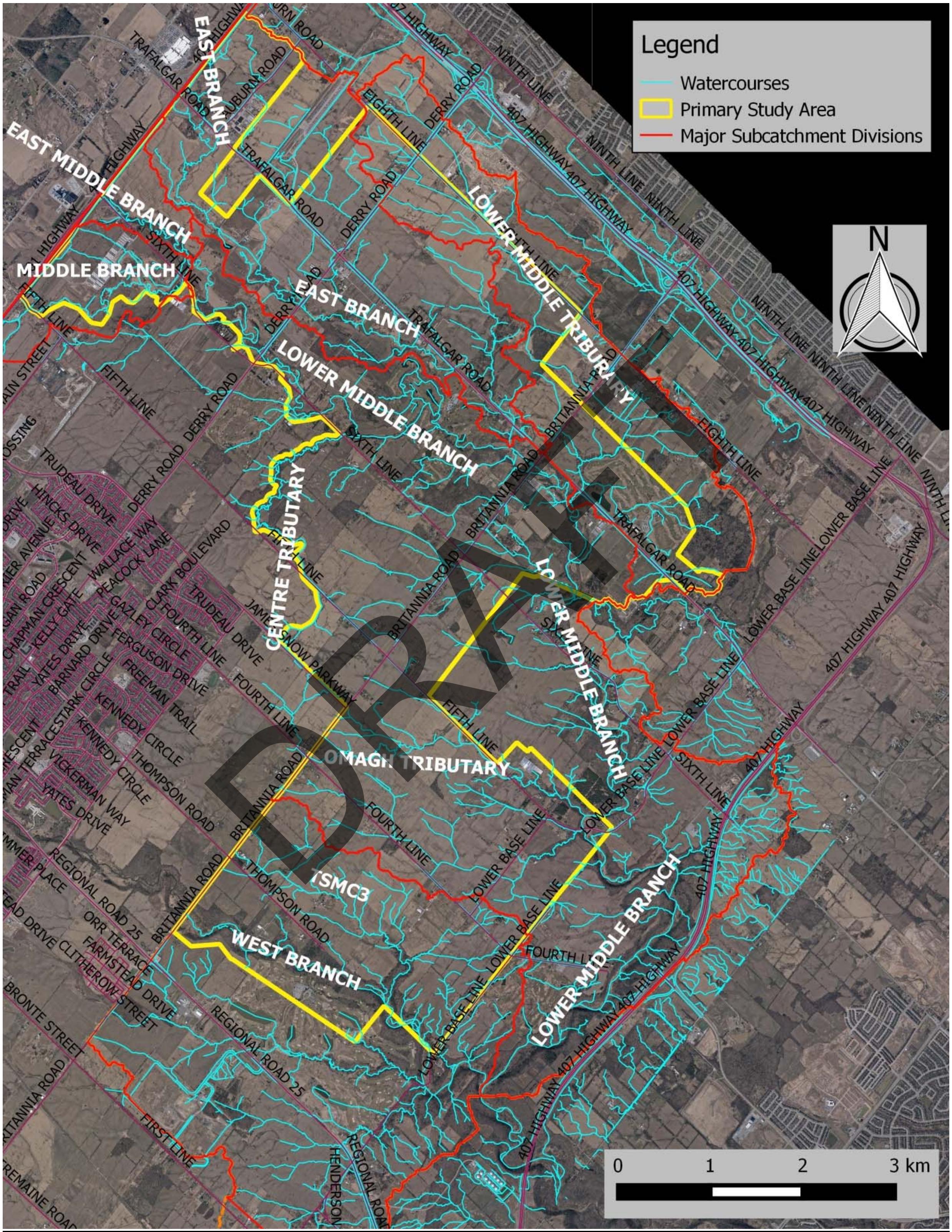


Figure 4.7.7. Location of the major drainage systems that are discussed in Section 4.7.

Appendix A

Background Data / Information / Gap Analysis

Appendix B

Climate

Appendix C

Hydrogeology

Appendix D

Hydrology and Hydraulics

Appendix E

Surface Water Quality

Appendix F

Stream Morphology

Appendix G

Fisheries

Appendix H

Terrestrial

amec foster wheeler

Appendix I

Planning

Appendix J

Approved Work Plan