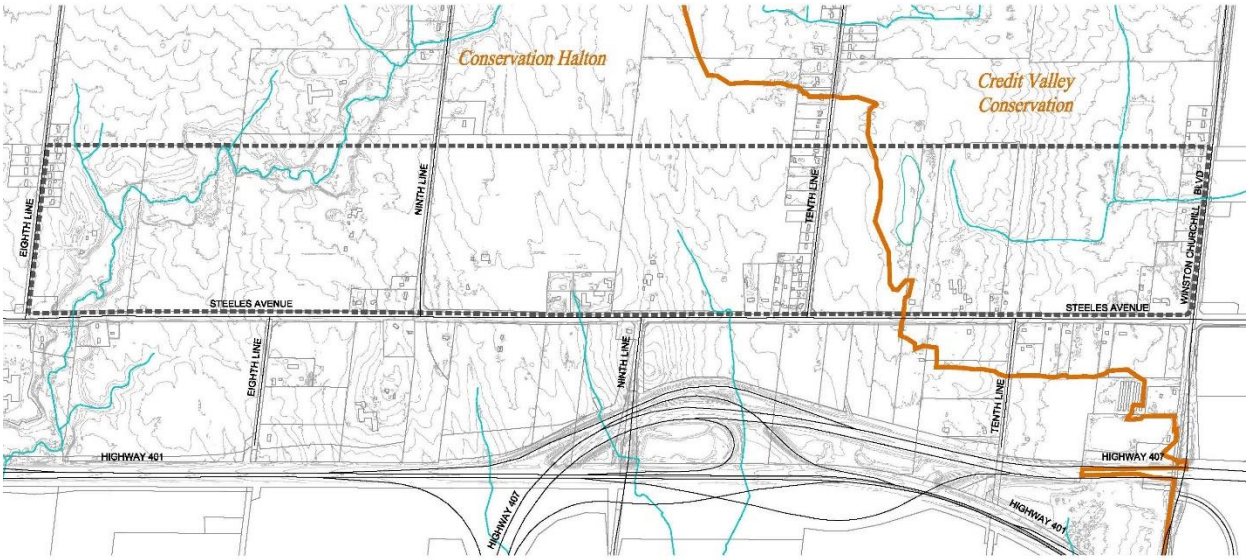
Town of Halton Hills

Premier Gateway Scoped Subwatershed Study

Phase 1: Study Area Characterization

November 15, 2023 Final



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Final

Project No.: WW20101004
Date: November 15, 2023

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November 15, 2023

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1 INTRODUCTION

The Premier Gateway Phase 2B Lands have been designated for urban development (principally employment uses) within the Town of Halton Hills and the Region of Halton. In order to support the Town in the planning for this area, a Scoped Subwatershed Study (SWS) has been undertaken to identify important natural features and functions, and ultimately establish a water management approach which protects and preserves these important elements as part of a functioning Natural Heritage System.

The Scoped SWS has been established as a three-phase process, as follows:

Phase 1: Study Area Characterization

Phase 2: Analysis and Management Strategy

Phase 3: Implementation and Monitoring

The Premier Gateway Phase 2B Lands lie at the southern limit of the Town of Halton Hills and are generally bounded by Highway 401 to the south and agricultural lands to the north, between Winston Churchill Boulevard to the east and Eighth Line to the west. The study area straddles the boundary between the Sixteen Mile Creek Watershed in Conservation Halton jurisdiction, and the Mullet Creek Subwatershed of the Credit River Watershed in CVC jurisdiction. The Sixteen Mile Creek Watershed contains three drainage basins (i.e., West branch, Middle and East Branches) and downstream reaches below the confluence of the two upper drainage basins (Gore & Storrie. 1996), encompassing nine subwatersheds. The Credit River Watershed contains 20 subwatersheds, 13 of which are tributary to the Credit River Main Branch.

1.1 Study Overview and Team

In 2020, the Town of Halton Hills initiated the Premier Gateway Phase 2B Employment Area Integrated Planning Project. This Project represents an integrated planning project that involves both secondary planning and scoped subwatershed planning.

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

1. Study Area Characterization
2. Impact Assessment
3. Preferred Management Measures and Requirements for Future Studies

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

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

Aaron Farrell (HDR, legacy WSP): Project Manager and Water Resources Lead

Allison Zhang (legacy Wood): Hydrology / Hydraulics and Water Quality

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1.2 Environmental Assessment Act Requirements

The Scoped Subwatershed Study component of the Integrated Planning Project incorporates the fundamental principles of the Municipal Engineers Association (MEA) Class Environmental Assessment process. The information developed through the subwatershed planning process satisfies Phases 1 and 2 of the MEA Class Environmental Assessment process. The Work Plan for the Scoped Subwatershed Study has included consultation with regulators, area landowners, and the general public. Consideration of other technical disciplines (i.e., area servicing, transportation, etc.) is fully integrated with the overall land use planning study. The Scoped SWS has served as the natural systems and water resources background technical document to facilitate the evaluation and assessment of servicing and transportation alternatives leading to a preferred plan for land use and servicing matters. In addition, the Scoped SWS has been undertaken to address requirements per the Terms of Reference (ref. Appendix A), and the applicable Federal, Provincial, Regional, Municipal and Conservation Authority policies and legislation as identified in the Terms of Reference.

1.3 Report Overview

This Phase 1: Study Area Characterization report summarizes the methodologies and results of the Study Area Characterization component of the Scoped Subwatershed Study. The information presented in **Section 2** of this report provides the detailed methodologies and findings, and has been organized and presented according to the following core study disciplines:

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

Section 3 of this report provides an overview of the study findings and their integration, primarily with respect to the Study Area Characterization, as well as the general process to be applied in establishing the preliminary management plan.

2 BASELINE INVENTORY

The following sections provides the detailed assessments completed to characterize the existing conditions within the Premier Gateway Phase 2B Area. Where appropriate, the characterization has been extended beyond the limits of the study area, to provide context for the study area features and systems in the context of the subwatershed. The characterization has been organized by study discipline as noted above and provides details regarding the scope and importance of the assessment, the information referenced and used for the characterization, details of the fieldwork methods and findings, analytical methods applied including details for developing numerical models, and a summary of the key findings and results.

2.1 Hydrogeology

2.1.1 Scope Overview

The overall objective of the groundwater component of the Scoped Subwatershed study is to characterize the groundwater flow system by identifying and characterizing:

- Recharge and discharge areas, and groundwater flow directions
- Hydrostratigraphic units and hydraulic properties
- Water quality and quantity constraints on development
- Groundwater recharge and discharge function in supporting ecological and hydrologic function of wetlands and streams.

The characterization provides the information needed to develop management strategies as part of the next phase of the Scoped Subwatershed Study, to maintain the ecological and groundwater function of wetlands and streams during and following the development of the landscape.

A background review of reports and datasets has been conducted and those sources of information that are most relevant are listed in **Section 2.1.2**. The groundwater component of this study includes a field component to carry out spot baseflow measurements at select sites within the study area to assess potential groundwater contributions. This data was also integrated with groundwater discharge / seepage observations from the other technical disciplines.

2.1.2 Background Information Review

The following key reports and data sources were reviewed to obtain background hydrogeologic data and interpretations:

- Premier Gateway Phase 1B project (AFW 2020) – this study provides data and interpretations for the adjacent Study Area including descriptions of local hydrostratigraphy, bedrock topography, and groundwater flow mapping
- South Milton Urban Expansion Area Subwatershed Study - Draft Final (Amec Foster Wheeler, May 2020), general hydrostratigraphy and hydrogeologic parameters
- The Ministry of Environment, Conservation, and Parks (MECP) Water Well Information System (WWIS) and Permits to Take Water (PTTW) – provides lithology data, water level data, and water taking data for the Study Area
- Draft Scoped Subwatershed Study, Northeast Corner Steeles Avenue and 8th Line (JLA et al. 2020) – provides site-scale hydrogeological characterization including additional lithology and water level data
- Assessment reports for the Credit Valley Source Protection Area (CTCSPC 2015) and Halton Region Source Protection Area (HHSPC 2017) – these provide regional characterization data as well as mapping generated through the Source Water Protection program, including Highly Vulnerable Aquifers (HVAs), Significant Groundwater Recharge Areas (SGRAs), and thermal regimes
- Ontario Geological Survey (OGS) – provides mapping of surficial geology, bedrock geology, and top of bedrock
- Halton Aquifer Management Plan (RMOH 1995) – the Phase 1 Report (Background Hydrogeology) describes potential minor and major aquifers and hydrogeological sensitivity
- Oak Ridges Moraine Groundwater Program (ORMGP 2018) - provides mapping of potential groundwater discharge areas, bedrock valley thalwegs, and flowing wells surrounding the Study Area
- 401 Corridor Integrated Planning Project, Town of Halton Hills – Scoped Subwatershed Plan (Dillon Consulting 2000) – this report provides characterization (including hydrogeology characterization) and recommendations for how water resources and ecological functions should be maintained as a result of changing land use associated with the 401 corridor
- Hydrogeological Investigation for the Rural Community of Hornby (Hydrology Consultants 1983) and Private Well Monitoring Report Steeles Avenue Project

Halton Hills (Terraprobe Ltd. 2006) – among other things, these reports provided background groundwater quality information for the Premier Gateway Phase 1B project located adjacent to the current Study Area

2.1.3 Field Reconnaissance

A scoped field investigation was carried out for the groundwater component including spot baseflow observations recorded in the summer (i.e., September 10, 2020), fall (i.e., November 9, 2020), and spring (i.e., May 11, 2021) seasons at 12 locations within the Study Area (ref. Figure GW-11; attached). The spot baseflow measurements were collected to observe the seasonal and spatial variability of baseflow along watercourses. Baseflow conditions are present during periods when overland flow to a watercourse is absent and the watercourse has returned to its 'dry' weather level. It is during these conditions that areas of potential groundwater discharge and recharge along the length of a watercourse can be evaluated. Dry weather conditions supporting baseflow conditions were considered to occur following a period of at least three consecutive days with less than 5 mm of cumulative rainfall.

Baseflow monitoring locations were selected at road crossings along watercourses and ditches associated with Mullet Creek and East Sixteen Mile Creek, both within and along the boundary of the Study Area (Figure GW-11). Spot baseflow 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, flow velocity and water temperature to produce a final discharge value for the stream at each location. Where streamflow was insufficient to measure using the ADV, baseflow was estimated visually (e.g., less than 0.5 L/s). Spot baseflow measurements are presented in Table GW-1 (ref. Appendix C) and **Figure GW-11** and are discussed further in **Section 2.1.4** as part of the evaluation of potential groundwater discharge.

2.1.4 Characterization and Analysis

2.1.4.1 Physiography

The physiographic description of an area commonly includes summaries of topography, landform, drainage and the occurrence of surface soil types along with an overview of the depositional and erosional history that created the landform. Geologic descriptions commonly detail the overburden and bedrock composition and form below the surface as well as the relationship of the geology to the physiography of that area. Together these two descriptions are used to characterize the physical setting of a study area and form the basis of any groundwater interpretation. Within the Study Area, the

physiography and geology are so closely related that for the purposes of this study, the physical setting overview provides a synthesis of both characteristics.

The project Study Area (Figure GW-1) is situated completely within the Peel Plain physiographic region (Chapman and Putnam, 1984) and is characterized by a gently sloping glacial till plain. Ground surface generally slopes from the northwest, just northwest of the Study Area at an elevation of approximately 220 metres above sea level (m asl), to the southwest towards East Sixteen Mile Creek (minimum elevation of 201 m asl in the Study Area) and to the east towards Mullet Creek (minimum elevation of 204 m asl in the Study Area; **Figure GW-1**; MNRF 2021). Ground surface is incised locally in the southwestern portion of the Study Area, associated with erosion caused by East Sixteen Mile Creek, and to a lesser extent along Mullet Creek as it leaves the Study Area in the northeast. The next closest physiographic region, the South Slope region, is located approximately 2 km to the northwest of the Study Area.

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 Wisconsin Glaciation and was accompanied by various meltwater lakes and channels. The last glacial retreat ended between 10,000 and 20,000 years ago, blanketing the area in glacial sediments.

2.1.4.2 Geology

2.1.4.2.1 Bedrock Geology and Bedrock Topography

The Paleozoic bedrock underlying the Study Area is the Queenston Formation. This bedrock unit is known for its characteristic soft red shale, which allows small streams to easily erode into it where it is exposed at surface. This unit is described as a calcareous shale interbedded with dense grey to green limestones and silty limestones (Bond et. al. 1976).

The bedrock topography is shown on **Figure GW-2** and was created using well record data from the MECP Water Well Information System (WWIS; MECP 2020) and interpolated to a resolution of 5 m. This mapping is in good agreement with regional bedrock topography mapping (approximately 415 m resolution) available from the OGS (MRD 207; Gao et al., 2006). The bedrock surface represents a regional erosional unconformity and its surface elevation ranges from approximately 200 m asl along the central part of the northwestern boundary of the Study Area, to a local minimum of 188 m asl in the southwestern portion of the Study Area and 192 m asl in the northeastern portion of the Study Area. Two minor bedrock valley systems and a larger

bedrock valley along Hornby Road were interpreted within the Premier Gateway Phase 1B study area located west of the current Study Area (AFW 2020). The Oak Ridges Moraine Groundwater Program also provides mapping of bedrock valley thalwegs, which were interpreted approximately 2.5 km southwest and 1.5 km northeast of the Study Area boundary (ORMGP 2018). These bedrock valleys contain thicker sequences of overburden sediments and, where connected, these valleys can act as preferential pathways for groundwater flow and also be associated with conditions of upward hydraulic gradients and artesian conditions. However, no bedrock valleys are interpreted within the current Study Area. Depth to bedrock is interpreted to range from approximately 15 to 20 m across the majority of the Study Area, to a minimum of approximately 3 m under part of East Sixteen Mile Creek (Figure GW-3). Depth to bedrock / overburden thickness mapping was created by subtracting the bedrock topography surface from a 5 m digital elevation model (DEM) of ground surface (MNRF 2021).

2.1.4.2.2 Surficial and Overburden Geology and Thickness

The surficial geology in the Study Area, as mapped by the OGS (OGS 2010) consists primarily of fine-grained sediments characterized by the sandy silt to clayey silt till (Halton Till) and glaciolacustrine silts and clays (Figure GW-4). This characterization is consistent with well records reviewed for this study. Modern alluvium consisting of clay to gravel is mapped along East Sixteen Mile Creek. The coarsest deposit mapped at surface within the Study Area is a small portion of an ice-contact gravel deposit located near the intersection of Steeles Ave. and the southern extension of 9th Line (Figure GW-4).

Geologic mapping prepared by the Ontario Geological Survey (OGS; OGS 2010), water well records from the MECP, and additional hydrostratigraphic interpretation from the Phase 1B study (AFW 2016) were reviewed to develop a conceptual model of the hydrostratigraphy and identify potential aquifers in the Study Area. A total of 281 MECP water well records within 1 km of the Study Area were utilized and are listed, with their associated well record details, in **Appendix C** (Table GW-2). The water well records closest to the Study Area are illustrated in **Figure GW-4**.

Four geological / hydrostratigraphic cross-sections were developed (Figure GW-4) using the available data that align with Steeles Ave. (Figure GW-5; Cross-Section AA'), 8th Line (Figure GW-6; Cross-Section BB'),10th Line (Figure GW-7; Cross-Section CC'), and Winston Churchill Boulevard (Figure GW-8; Cross-Section DD').

As described previously, and as shown on **Figure GW-3** and **Figures GW-5** to **GW-8**, the thickness of overburden / depth to bedrock within the Study Area varies from

approximately 15 to 20 m across the majority of the Study Area, to a local minimum of approximately 3 m under a portion of East Sixteen Mile Creek.

The cross-sections demonstrate the following significant overburden characteristics:

— A significant thick sequence of fine-grained material extending from ground surface.

— Discontinuous sand lenses within this fine-grained sequence.

— A discontinuous basal sand and gravelly unit at the bedrock / overburden interface.

— A thicker, coarser, and more continuous channelized basal sand / gravel deposit along 10th Line (Cross-Section BB'; Figure GW-6)

Unlike the Premier Gateway Phase 1B study area to the southwest, a bedrock valley infilled with coarser sediments was not interpreted in the current Study Area.

2.1.4.3 Hydrogeology

2.1.4.3.1 Conceptual Groundwater Flow

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

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

Hydrostratigraphic units are developed by lumping or splitting stratigraphic units based on their hydrogeologic properties. The delineation of hydrostratigraphic units is completed using knowledge of the regional and local understanding of the spatial distribution of stratigraphic units where higher quality data is available and carrying this interpretation outwards using lower quality data. Permeable geologic materials that can transmit significant quantities of water are known as aquifers. Aquifers are "water bearing" formations, meaning that water can be easily extracted from these units. The less permeable units are known as aquitards, and although water can move through these units, it moves slowly and it is difficult to extract water from these units. How

these aquifers are connected within a hydrogeologic setting is what controls much of the movement of groundwater.

The delineation of the flow system will identify where groundwater originates, where it discharges, and the most prominent paths it travels between these points (e.g., pathways through aquifers 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.

2.1.4.3.2 Hydraulic Conductivity

As mentioned, hydrostratigraphic units are developed by lumping or splitting stratigraphic units based on their hydrogeologic properties. Hydraulic conductivity is the main property of a stratigraphic unit that describes how easily water can move through it. Stratigraphic units are considered aquifers where the hydraulic conductivity is relatively high. Conversely, they are considered aquitards where the hydraulic conductivity is relatively low. Aquifer units are defined solely on the basis of the estimated ability of the unit to yield water and do not consider water quality or vulnerability to surficial sources of contamination.

The hydraulic conductivities of the overburden units will correlate with the grainsize, with coarser grained sediments having a higher hydraulic conductivity. Where these coarse-grained sediments are sufficiently thick and connected, they may be sufficient aquifers to produce water for human use. Within the Study Area, the sand lenses within the larger fine-grained till package will act as limited aquifers, but to a lesser extent if they are more discrete. The basal sands and gravels will act as the primary aquifer in the area, as well as the underlying shale bedrock where it is weathered and fractured (e.g., within several metres of the bedrock surface). These hydrogeologic units are present on the cross-sections (Figures GW-5 to GW-8).

Estimates of hydraulic conductivity from single well response testing of monitoring wells located in the southwestern portion of the Study Area were calculated for units described as “sandy silt to silty sand till” and “silty sand to sandy silt till” as part of the Draft Scoped Subwatershed Study, Northeast Corner Steeles Avenue and 8th Line (JLA et al. 2020). Estimates of hydraulic conductivity ranged from 8.2 x 10^{-8} to 2.0 x 10^{-6} m/s. The hydraulic conductivity of the upper weathered Queenston shale in the regional area was recorded to be as high as 10^{-6} m/s (RMOH 1995).

2.1.4.3.3 Groundwater Levels and Groundwater Flow

Shallow overburden (ref. Figure GW-9) and bedrock (ref. Figure GW-10) groundwater levels and flow directions were mapped using available water level data from water well records from the MECP WWIS (MECP 2020) and water level data compiled for the Premier Gateway Phase 1B study (AFW 2020). When used together for mapping, these data provide average water level surfaces because water levels from the WWIS may be collected in different years, different seasons, and in some cases, may represent recovering water levels where a well was just drilled. As such, the actual groundwater levels may be +/- 3 m from those illustrated in **Figures GW-9** and **GW-10**. For the shallow overburden (ref. Figure GW-9), a water level surface was created using water level data from overburden wells completed at a depth of less than or equal to 20 m of ground surface and using inferred perennial surface water levels along the main channel of East Sixteen Mile Creek and within water bodies using the available DEM (MNRF 2021). Observation of baseflow at East Sixteen Mile Creek during all three seasonal spot baseflow measurements in 2020 and 2021 suggests some level of sustained groundwater discharge contribution (ref. Figure GW-11). Shallow overburden groundwater flows mimic ground surface topography (ref. Figure GW-1), with horizontal flow originating from the northwest and water levels declining toward the east (Mullet Creek subwatershed), as well as the southeast and southwest (East Sixteen Mile Creek subwatershed) within the Study Area. Shallow flow is directed towards East Sixteen Mile Creek, which was similarly interpreted and mapped locally by JLA et al. (2020). The interpolated shallow overburden water level surface ranges from between 214 and 201 m asl across the Study Area. Depth to water table at shallow overburden wells within the Study Area range from 0.9 to 6.1 m bgs.

Overburden water levels were monitored transiently in five wells in the southwest portion of the Study Area between April 2019 to April 2020 as part of the Scoped Subwatershed Study conducted at the northeast corner of Steeles Ave. and 8th Line (JLA et al. 2020; Figure GW-9). Shallow overburden groundwater levels declined to a seasonal low during late summer and early fall and rose to a seasonal maximum during the winter and spring. Groundwater levels ranged in elevation from 202.7 to 209.7 m asl over the monitoring period and varied seasonally anywhere from approximately 0.9 to 3 m, depending on the well. These observations are similar to other study areas where water levels within the Halton Till show a 1 to 2 m seasonal variation (AMEC Earth and Environmental 2011, R.J. Burnside & Associates, 2016).

A potentiometric water level surface was also developed for wells completed within the shale bedrock and is found on **Figure GW-10**. Horizontal bedrock flow originates from the northwest and declines both toward the northeast (Mullet Creek subwatershed) and

southwest (East Sixteen Mile Creek subwatershed) within the Study Area and has a strong correlation with the bedrock topography shown on **Figure GW-2**.

A line showing the interpreted groundwater flow divide in both the shallow (overburden) and deep (bedrock) groundwater flow systems should be added to future groundwater flow maps during future planning stages when sufficient high quality groundwater level data is available. The addition of a line would support cross-watershed boundary water management efforts where groundwater is flowing from one watershed to another.

In general, as reported in the Halton Region Aquifer Management Plan (RMOH 1995), vertical hydraulic gradients are interpreted to be largely downward over much of the Peel Plain and can be much stronger than the lateral gradients. Groundwater is interpreted to move vertically downward through the Halton Till until reaching a sand lens or the basal sand / upper fractured bedrock, where groundwater would migrate laterally toward streams or southward in the direction of the regional hydraulic gradient (RMOH 1995).

Within the Study Area, the direction of vertical hydraulic gradients between the bedrock and overburden wells is variable for wells located within approximately 50 m of one another. Out of seven well pairs that fit this criterion, roughly half (4) suggest downward gradients, and half (3) suggest upward gradients. Flowing wells were not observed within the Study Area. The closest flowing wells identified in the MECP WWIS database are located approximately 550 to 740 m south or southwest of the Study Area near Highway 407 and Highway 401. Flowing wells are interpreted to exist to the southwest of the Study Area as described as part of the Premier Gateway Phase 1B project (AFW 2016), as well as near the bedrock valley where a larger, more regional groundwater flow system is interpreted to source the flowing wells.

Groundwater levels, which influence the hydraulic gradient direction, are controlled by the hydraulic conductivity and spatial extent of the hydrostratigraphic unit they are screened in, as well as the temporal nature of groundwater inputs to the specific hydrostratigraphic unit. Where the shallow fractured bedrock and more permeable sand / gravel unit has a potentially more continuous spatial connection, the study area groundwater levels will be influenced by groundwater level trends within the more regional setting (i.e., potentially higher groundwater levels shown in Figure GW-7).

On a more local scale, shallow groundwater may be influenced by fractures within the Halton Till. A significant amount of research has focused on the hydrogeology of fractured glacial tills and was obtained through a literature review carried out for a subwatershed study in northwest Brampton (AMEC Earth and Environmental, 2011).

The following are some of the hydrogeologic factors that potentially relate to fracturing in the till in the Study Area:

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

As presented previously, the local hydrostratigraphy may include more permeable sand lenses. These sand lenses not only provide sources of water for local domestic wells but can also provide extended hydraulic pathways for groundwater movement if they are interconnected. If these interconnections are of a larger scale, they could potentially provide a more direct connection from the lower basal sand / gravel and shallow bedrock unit through the overburden aquitard. This potential larger scale connection through the sand lenses was interpreted southwest of the Study Area, within the study area for the Premier Gateway Phase 1B study.

2.1.4.3.4 Groundwater Recharge

Recharge and recharge rates are governed to a large extent by the surficial geology and associated permeability. Other factors include vegetative cover, topography, spatial and temporal distribution of precipitation events and temperature. A long-term variation in frequency of the low intensity events may affect the overall recharge.

Within the current Study Area, the amount of recharge is limited to a greater extent by the lower permeability of the surficial sediments. Recharge values associated with these

surficial units has been reported to be less than 100 mm/year in this area (Dillon Consulting 2000). This magnitude is similar to the recharge interpreted by the ORMGP using a water budget tool where it extends to the Study Area in the Mullet Creek subwatershed (103 mm/year; ORMGP 2018). The ORMGP considers this estimate to be preliminary and will eventually be verified against other hydrological data (e.g., streamflows and groundwater levels; ORMGP 2018). Recharge values noted in a subwatershed study within Milton south of the study area were in the range of 49 - 170 mm/year (AFW, 2020). Recharge values may be higher or lower depending on the clay and silt content within surficial unit. For example, relatively higher recharge may occur locally in the area of the glaciofluvial sand and gravel deposit mapped at surface near Steeles Ave. and the southern extension of 9th Line (ref. Figure GW-4). Higher depressional focused recharge can also occur in topographic lows. Recharge within the Study Area is expected to provide a local shallow component flow but is likely limited to relatively short distances. Local recharge that does not discharge to local stream reaches will eventually recharge the deeper sand lenses, potentially the basal aquifer and upper bedrock where downward hydraulic gradients persist.

Delineation of Significant Groundwater Recharge Areas (SGRAs) is available in the Assessment Reports for the Halton Region Source Protection Area for East Sixteen Mile Creek (HHSPC 2017) and for the Credit Valley Source Protection Area for Mullet Creek (CTCSPC 2015). SGRAs represent areas of relatively higher groundwater recharge rates that are important for providing groundwater recharge to an aquifer. The only SGRA that is mapped within the Study Area is a small localized SGRA (see Figure 6.12 of HHSPC 2017 for the map of the location). Its location appears to be associated with the ice contact gravels mapped at surface along the southward extent of 9th Line, near its intersection with Steeles Ave., (see Figure GW-4) for the location of the localized surficial deposit of ice contact gravels).

2.1.4.3.5 Groundwater Discharge

As mentioned previously, areas where groundwater moves upward to the water table are known as groundwater discharge areas. These areas can include wetlands and streams and are particularly important where the discharge is critical to maintaining ecological function. Spot baseflow measurements were carried out at various locations to see if there were any trends that would indicate groundwater discharge. The spot baseflow measurements are summarized in Table GW-1 (ref. Appendix C) and **Figure GW-11**.

In general, most of the watercourses at spot baseflow locations were not flowing during the three monitoring events. The greatest amount of baseflow was observed along East Sixteen Mile Creek at Steeles Ave. (ref. Station SA1; Figure GW-11), with baseflow

ranging from 3.6 L/s during summer 2020 to 21.4 L/s during spring 2021. However, JLA et al. (2020) reported no flow conditions at this location in July 2019, suggesting seasonal periods where this part of the creek dries up. The only other baseflows recorded in the Study Area over the three-season monitoring period included:

- Less than 0.5 L/s estimated at a tributary of East Sixteen Mile Creek at 9th Line (Station NL1; Figure GW-11) during spring 2021.
- Less than 0.5 L/s estimated at a tributary of Mullet Creek at 10th Line (Station TL1; Figure GW-11) during spring 2021. However, this may be at least partially supported by a seep with water flowing (less than 0.5 L/s) from a slightly raised gravel / earth embankment on the upstream (west) side of the culvert crossing 10th line. Field staff noted in fall 2020 that this area was recently dredged.
- Less than 0.5 L/s estimated on Mullet Creek at a bridge at Winston Churchill Boulevard. (Station WC1; Figure GW-11) during spring 2021. During the same monitoring event, field staff also observed less than 0.5 L/s from a suspected stormwater culvert located a few metres north of Station WC1 that feeds Mullet Creek just downstream of Station WC1. Sufficient flow was available downstream of the confluence of these two flows for a measurement using the ADV FlowTracker where flow totaled 0.8 L/s. Seepage from the sediments below the suspected stormwater culvert was also observed during the summer and fall 2020 monitoring events.

Field observations made by the Study Team ecologists during this Scoped Subwatershed Study indicate the potential for groundwater discharge in some areas. This includes an apparent discharge zone along East Sixteen Mile Creek, observed as an area of open water on February 2021 where the remainder of the watercourse was frozen (ref. Figure GW-11). Ecology Staff also observed iron staining at five locations along this same reach indicating potential groundwater discharge. Ecology staff did not observe watercress along either East Sixteen Mile Creek or Mullet Creek as an indication of groundwater discharge; however, East Sixteen Mile Creek was interpreted to be a coolwater stream based on water temperature and the observed fish community. This thermal regime suggests that at least some groundwater discharge may be occurring in the area to moderate stream temperatures. Conversely, Ecology staff interpreted Mullet Creek to be a warmwater thermal regime.

Groundwater level monitoring from April 2019 to April 2020 was conducted coincident with surface water level monitoring in the southwest portion of the Study Area as part of the Draft Scoped Subwatershed Study at the northeast corner Steeles Ave. and 8th Line (JLA et al. 2020). Mini-piezometers and mini-piezometer pairs were installed to monitor

shallow groundwater levels, and staff gauges were installed to monitor surface water levels in East Sixteen Mile Creek. Upward gradients and/or potential groundwater discharge are inferred where the water levels of deep piezometers are above those from shallow piezometers and where groundwater levels are above surface water levels. Upward gradients and/or potential groundwater discharge occurred seasonally, largely within winter and spring months, with the rise of the groundwater table at various locations along watercourses associated with East Sixteen Mile Creek. **Figure GW-11** illustrates the locations where upward gradients and/or potential groundwater discharge were inferred periodically as part of the Draft Scoped Subwatershed Study. See JLA et al. (2020; Appendix G) for a more detailed description and hydrographs of the water level trends.

Groundwater discharge may occur in other areas locally where stream reaches incise through the Halton Till and into more permeable sediments, as well as where the till is thin such that the till is sufficiently fractured to be hydraulically active and connected to deeper, coarser sediments or fractured shallow bedrock. However, the stratigraphy available through water well records suggest limited opportunities for this based on the thickness of the till and depth of discontinuous sand / gravel lenses (e.g., Figure GW-5; Cross-Section A-A'). The groundwater discharge potential may be greater along reaches of East Sixteen Mile Creek where the minimum interpreted overburden thickness is approximately 3 m (ref. Figure GW-3; Section 2.1.4.2.2). The local wetlands within the Study Area are currently not considered to have significant functional groundwater discharge associated with them based on the characteristics of overburden flow system.

2.1.4.3.6 Local Groundwater Use

Groundwater supplies in the area are obtained from both non-municipal overburden and bedrock wells. Non-municipal water takings located near the Study Area consist of Permits to Take Water (PTTWs) and non-permitted takings (e.g., domestic takings). While there are no active groundwater or surface water PTTWs within the Study Area itself, there are 13 active takings associated with two PTTWs located within approximately 1.2 km of the Study Area (Figure GW-4). These include the following permits (MECP 2021):

- PTTW # 2458-BVYMW8: This permit for construction dewatering includes two surface water and/or groundwater takings from two ponds located along Highway 407, located approximately 700 m south of the Study Area. Water takings are permitted at a maximum of 4,000 m^3/day from each pond.

— PTTW # 8215-BPZ4DY: This permit for construction dewatering includes 11 groundwater takings at various locations along Highway 401, located approximately 600 to 1,180 m south of the Study Area. Maximum permitted takings range from 20 to 720 m^3/day.

Non-municipal, non-permitted takings in the Study Area, such as those for domestic purposes, are inferred through data from the provincial WWIS (ref. Drawing GW-4). There are 33 overburden wells and 12 bedrock wells in the Study Area. The overburden wells are predominantly completed within the more permeable sand lenses or the basal sand and gravel, while the bedrock wells are completed within the shallow weathered / fractured bedrock (ref. Figures GW-5 to GW-8).

The capacity or quantity of water that a well can provide depends on the hydrostratigraphic unit the well is completed in, the nature of the sediments adjacent to the well, the lateral extent and thickness of the unit and the size of the well bore and screen length, among other characteristics. Expected well capacities as estimated through domestic well testing and documented in water well records in the Study Area range from 5.5 to 163.5 m^3/day for overburden wells, and 10.9 to 54.5 m^3/day for bedrock wells.

2.1.4.3.7 Groundwater Quality

The quality of a groundwater sample can inform on the overall potability of the water, and also has the potential to infer the source of that water. The ORMGP maintains an online repository of groundwater quality data associated with the wells in their database. There are two wells with water quality information within the Study Area (Figure GW-4; ORMGP 2018): Well 2803060 (completed within bedrock) and Well 2805235 (completed within a sand interval). Select water quality parameters and concentrations have been extracted from ORMGP (2018) and are summarized in **Table** 2.1.1, along with the Ontario Drinking Water Quality Standard (ODWQS; Government of Ontario 2006). **Table** 2.1.1 also includes water quality results from four overburden wells (MW19-2, MW19-3, MW19-4, and MW19-7) installed into sandy silt / silty sand till as part of the Draft Scoped Subwatershed Study at the northeast corner Steeles Ave. and 8th Line (JLA et al. 2020). The results suggest potentially some anthropogenic influence from road salting with relatively high concentrations of sodium and chloride at overburden well MW19-7 and Well 2805235, as well as at an older (1969), shallow (7.3 m bgs) bedrock well (Well 2803060). Nitrate is elevated at Well 2803060 (3.2 mg/L) and MW19-2 (i.e., 6.7 mg/L; more than half the maximum allowable concentration), possibly suggesting some anthropogenic influence from surface (e.g., septic systems, agriculture, etc..).

Table 2.1.1: Groundwater Quality in Study Area

Parameter	ODWQS[1]	Concentration Range (mg/L)					
		Well 2803060[2]	Well 2805235[2]	MW19-2[3]	MW19-3[3]	MW19-4[3]	MW19-7[3]
		shale bedrock	sand overburden	sandy silt / silty sand overburden			
TDS	500 AO,+	1,502	1,020	n/a	n/a	n/a	n/a
Iron	0.3 AO,+	0.27	n/a	0.05	0.12	1.51	0.03
Calcium	NS	61.5	227	111	95.1	113	154
Chloride	250 AO,+	259.0	219	9.0	26.1	15.1	357
Magnesium	NS	169.7	41	9.9	50.1	42.4	68.3
Nitrate	10 MAC	3.2	0.1	6.7	<0.02	0.55	<0.10
Potassium	NS	6.0	5.3	2.0	3.1	2.5	6.0
Sodium	200 AO,Na,+	68.9	37	6.3	14.4	23.5	126
Sulphate	500 AO,SO4,+	167.1	89	n/a	n/a	n/a	n/a
Total Phosphorus	NS	n/a	n/a	0.0095	0.0094	0.091	0.004
pH	6.5 - 8.5 OG,pH,+	7.35	7.50	7.66	7.81	7.73	7.78

n/a - data not available
NS – not specified
[1] - Ontario Drinking Water Quality Standard. Ontario Regulation 169/03 Ontario Drinking Water Quality Standards (Government of Ontario 2006) - Latest amendment as of Jan, 2018
[2] – from ORMGP (2018)
[3] – from JLA et al. (2020)
AO - Aesthetic Objective
OG – Operational Guideline
Na - the local Medical Officer or Health should be notified when sodium concentrations exceeds 20 mg/L so that this information may be communicated to local physicians for their use with patients on sodium restricted diets
SO4 - when sulphate levels exceed 500 mg/L, water may have a laxative effect on some people
MAC – maximum acceptable concentration
+ - Technical Support Document for Ontario Drinking Water Quality Standards, Objectives and Guidelines (MOE 2006)

A review of groundwater quality was conducted as part of the Premier Gateway Phase 1B study located immediately southwest of this current Study Area and included results from Hornby (Hydrology Consultants 1983) and a private well survey (Terraprobe 2006). Bedrock groundwater quality from the 1983 hydrogeological investigation for the rural community of Hornby (Hydrology Consultants 1983) was found to be mineralized as would be expected with elevated hardness (950 mg/l), chloride (260 mg/l) and sulphate (700 mg/l). The overburden water quality was better with values for hardness (300 mg/l), chloride (75 mg/l) and sulphate (90 mg/l). A private

well survey carried out by Terraprobe Ltd. (2006) showed similar results with the exception of elevated sodium and chloride in a number of bored wells which may reflect road salt.

Policies exist within vulnerable areas delineated as part of the Source Water Protection program to protect the long-term quality (and quantity) of groundwater supplies. Wellhead Protection Areas (WHPAs) are one such vulnerable area where it may be necessary to restrict or even prohibit certain land uses in these areas due to the potential to impact groundwater. However, no WHPAs are located within or near the current Study Area. Highly Vulnerable Aquifers (HVAs) are also delineated as part of the Source Water Protection program. These refer to aquifers that are highly susceptible to contamination from both human and natural sources and, similar to WHPAs, certain land uses may be restricted within these areas as presented in Official Plans. The designations are based on factors such as soil types, depth and thickness of aquifer and overlying aquitard, groundwater velocity and potential man-made transport pathways. A localized HVA is present under the eastern extent of the area underlying Mullet Creek as mapped in the Credit Valley Source Protection Area Assessment Report (ref. Figure 4.2 of CTCSPC 2015).

2.1.5 Summary of Findings

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

- The study area is within the Peel Plain physiographic region.
- The surficial overburden consists primarily of the clay silt, silty sand Halton till and glaciolacustrine silt and clay. Within the Halton till discrete sandy layers exist.
- The overburden is underlain by the Queenston shale. The upper portions of the Queenston shale can be extensively fractured.
- A thicker, channelized basal sand / gravel deposit is interpreted along 10th Line. within the Study Area.
- The overburden thickness ranges from 3 m (underlying East Sixteen Mile Creek) to 20 m, with the majority of the Study Area underlain by 15 to 20 m of overburden.
- Groundwater recharge values are reported to be less than 100 mm/year in the area due to the fine-grained surficial sediments; however, greater recharge may occur locally in areas where pockets of sand / gravel are mapped at surface (e.g., area of Steeles Ave. and southern extent of 9th Line). Recharge values on similar surficial geologic units have been noted to range from 49 - 170 mm/year.

- Groundwater supplies are obtained from both the overburden (i.e., sand lenses and basal sands / gravels) and the upper portion of the bedrock where the bedrock is weathered and fractured. Wells generally provide sufficient quantities of quality water.
- Groundwater flow characteristics include the following:
  - lateral flow in the shallow overburden and bedrock, from a relative high in the northwest and declining toward the east (Mullet Creek subwatershed), as well as the southeast and southwest (East Sixteen Mile Creek subwatershed). Shallow overburden groundwater is interpreted to flow towards East Sixteen Mile Creek.
  - lateral flow through the upper 2 to 3 m of till where the till can be significantly fractured.
  - lateral connection within the upper fractured till can be relatively significant, compared to the massive till, but is generally localized (e.g., 10's of metres).
  - horizontal flow patterns in the upper fractured till will be controlled by local depressional topography and restricted by underlying, more massive, and less permeable till where it exists.
  - vertical groundwater flux below the upper fractured till, within the more massive till, is generally low unless more permeable, interconnected lenses exist.
  - largely vertically downward flow through the fine-grained Halton Till, until intercepting a sand lens or basal sand / upper fractured bedrock where it would then migrate laterally. However, some upward gradients between the bedrock and overburden were interpreted based on the WWIS data and is possible in other areas where there is sufficient regional flow supporting thicker and more continuous units of sand / gravels.
- Groundwater discharge is interpreted to occur along various portions of East Sixteen Mile Creek and its tributaries based on:
  - observed baseflow during three monitoring events
  - observed seasonal upward gradients and groundwater discharge during concurrent surface water level and groundwater level monitoring
  - observation of open water during a winter stream survey, and interpreted coolwater thermal regime classification of the creek based on water temperature and present fish communities

2.2 Hydrology

2.2.1 Scope Overview

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

Hydrologic analyses have been completed to establish peak flows for the 2 year through 100 year return period storm events for the existing land use conditions, as well as for the regional storm event. To maintain consistency with the current hydrologic modelling approach within Conservation Halton and CVC jurisdictions, the HSP-F methodology has been applied as the key hydrologic model to establish stormwater management criteria. The Visual OTTHYMO (VO) methodology has been applied as a complement and verification of the HSP-F modelling results.

2.2.2 Background Information Review

Background information have been provided by the Town of Halton Hills, Conservation Halton (CH), Credit Valley Conservation (CVC), and MSH for use in the hydrology and hydraulic analyses and characterization of the surface water hydrology. The following provides an overview of the information received of specific relevance to the surface water component of the Scoped Subwatershed Study:

Mapping:

- 0.5 m topographic contour mapping (Town of Halton Hills)
- 1 m DEM (Town of Halton Hills)
- 1999 Orthophotos (Town of Halton Hills)
- Land use official plan (CVC)
- Zoning (Town of Halton Hills)
- Soil Survey, Physiography (Town of Halton Hills)
- Watershed boundary (Conservation Halton, 2019)

- Rivers and streams mapping (CVC)
- Watercourse mapping (Town of Halton)
- Waterflow mapping (Conservation Halton)
- Lakes and ponds mapping (CVC)
- Waterbody mapping (Town of Halton Hills)
- Wetlands mapping (Town of Halton Hills, Conservation Halton, and CVC)
- Approximate regulation limit (Conservation Halton, 2019)
- Generic regulation limit (CVC, 2012)
- Flood hazard mapping (Conservation Halton, 2019)
- Headwater floodplain hazard mapping (Conservation Halton, 2019)
- HEC-RAS cross-section locations for Sixteen Mile Creek (Conservation Halton)

Background Reports:

- Scoped Subwatershed Study Northeast Corner Steeles Avenue and 8th Line (JLA et. al., September 2020)
- Mullet Creek Rehabilitation Study (City of Mississauga, 2001)
- Premier Gateway Phase 1B Scoped Subwatershed Study (Amec et. al., April 2020)

Models:

- Visual OTTHYMO (VO) hydrologic model for Mullet Creek Subwatershed (CVC, 2020 Draft)
- PCSWMM model for Sixteen Mile Creek Subwatershed 5 (JLA et. al., September 2020)
- HEC2 model for Sixteen Mile Creek (Conservation Halton, 1985)

Time Series Data:

- Hourly rainfall at Burlington RBG Station (1962-2017)
- Daily air temperature at Pearson Airport Weather Station (1962 - 2017)
- Monthly average windspeed at Pearson Airport Weather Station

Wood Legacy Projects:

Background information is available from legacy projects worked on by Wood and predecessor firms. Examples of previous studies include:

- Sixteen Mile Creek Areas 2 & 7 Subwatershed Update Study (Amec, November 2015)
- 401 Corridor Integrated Planning Project (Dillon Consulting, 2001)
- Credit River Flow Management Study (Philips Engineering Ltd., September 2007)
- Ninth Line Lands Scoped Subwatershed Study (Wood, –July 2022)

2.2.3 Field Reconnaissance

A field monitoring program to collect rainfall and stream flow data has been conducted to provide an understanding of the current hydrologic conditions within the study area. The locations of the gauges were reviewed and established in consultation with Conservation Halton, CVC, and the Town. The stream gauge is located on Sixteen Mile Creek East Branch at the crossing of Steeles Avenue. The rainfall gauge is located approximately 1 km west of the study area limit within the Hornby Park on the roof of a storage. Drawing WR1 depicts the location of the rainfall and stream flow gauge installed as part of the study.

The rainfall monitoring commenced on August 12, 2020. Total rainfall was recorded by the tipping bucket and data logger at 15-minute time intervals. The streamflow monitoring commenced on September 15, 2020. A Solinst Levelogger^{TM} sensor has been employed for data logging in the watercourse. Total pressure head and temperature within the watercourse were recorded at 15-minute time intervals. The temporary rain gauge and stream flow gauge were removed from the field on December 3, 2020 prior to freeze-up. Both gauges were installed back at the same locations on March 23, 2021 and data collection continued until November 2021 at which time the gauges were removed from the field.

Velocity metering has been conducted within the channel at the stream flow monitoring location during both dry and wet weather events to establish velocities at various depth. The events and remarks are presented as following:

- October 05, 2020: the flow rate was 0.1 m^3/s at a depth of 0.27 m.
- October 15, 2020: the flow depth was 0.32 m. Water was hardly moving.
- November 23, 2020: the flow rate was 0.19 m^3/s at a depth of 0.31 m. A constant flow did not always present even for a higher water level.

— April 12, 2021: the flow rate was 0.25 m^3/s at a depth of 0.35 m. Water was flowing over the natural weir feature approximately 25 m upstream of the flow gauge.

— May 28, 2021: the flow depth was 0.6 m. Water was not moving during the storm event.

The velocities and the depths have been used to develop the stage-discharge relationship. Corresponding flow areas have been calculated based upon field surveyed cross-sections at the gauge location and recorded flow depths at the time the velocity measurements were obtained. Instantaneous observed flows have been calculated as the product of the measured velocities during the event and the corresponding flow area. Note that the two events with zero velocity (October 15, 2020 and May 28, 2021) have been treated as outliers and excluded from the analysis. A local HEC-RAS hydraulic model has been developed for the monitoring location to establish a stage-discharge relationship at the site, and the roughness coefficients adjusted to best reproduce the observed depth at the corresponding discharge values. The rating curve for the continuous flow monitoring location is presented in **Figure 2.2.1**.

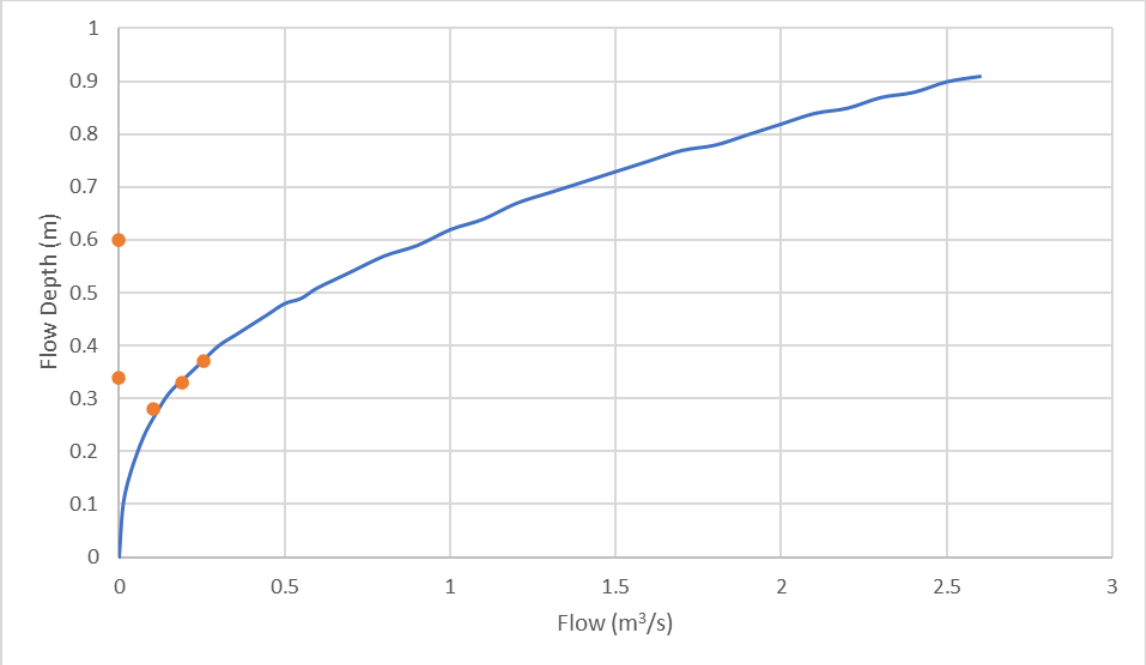

Figure 2.2.1: Rating Curve for the Temporary Steam Guage

The recorded water levels have been compared to the rainfall data in order to identify coincident storm events between the rainfall dataset, the streamflow responses, and the runoff coefficients at the temporary gauge, to thereby screen the rainfall and flow data to determine potential events for use in model validation. The contributing drainage area to

the temporary streamflow monitoring location has been determined based upon the topographic mapping provided for this study. The runoff volumes have been calculated by accumulating the incremental volume of each time step (i.e., average flow rate across the timestep x 15 min timestep) during the event, subtracting the estimated base flow volume. The average depth of runoff has been calculated for each event at each monitoring location based upon the calculated observed runoff volume and the size of the contributing drainage area. Runoff coefficients have been determined for each observed event at the monitoring location, based upon the ratio of the average runoff depth and the total depth of rainfall recorded for that event. The results of this assessment are presented in **Table 2.2.1**.

Table 2.2.1: Screening of Observed Storm Events at Monitoring Gauges for Coinciding Rainfall and Runoff Response

Event No.	Event Date	Duration (Hours)	Total Rainfall Depth (mm)	Peak Rainfall Intensity (mm/hr)	Max. Hourly Depth (mm)	Calculated Runoff Coefficient
1	2020-09-28	7.75	7.60	11.20	2.80	No Flow Response
6	2020-10-13	2.75	7.40	6.40	1.60	No Flow Response
7	2020-10-15	12.25	12.20	4.80	1.20	0.02
10	2020-10-21	8.50	6.60	4.00	1.00	0.02
13	2020-11-15	23.50	14.00	8.00	2.00	0.05
14	2020-11-23	4.25	12.40	8.00	2.00	No Flow Response
15	2020-11-24	37.00	8.60	2.40	0.60	0.22
16	2020-11-30	14.75	11.60	4.00	1.00	0.18
18	2021-03-25	12.00	30.80	20.80	5.20	0.19
20	2021-04-11	30.25	13.60	6.40	1.60	0.10
21	2021-06-29	3.75	19.6	11.2	12.6	0.12
22	2021-07-07	0.75	8.60	8.40	8.40	0.01
23	2021-07-08	7.00	15.0	5.60	6.60	0.01
26	2021-09-14	1.50	22.2	8.00	21.2	0.11
28	2021-10-03	10.5	14.4	3.00	6.00	0.20
29	2021-10-09	8.50	18.4	3.80	7.40	0.22

The information indicates that the calculated runoff coefficients for the observed storm events are generally less than 0.20, with the majority of the runoff coefficients being below 0.10. Three events did not generate runoff responses during the monitoring period. The low runoff coefficients are considered partially attributable to the variation in

rainfall distribution across the total contributing drainage area to the gauge, as well as lower velocity measurements at the gauge due to a backwater condition generated by the online weir structure upstream of the Steeles Avenue culvert. However, the low runoff coefficients are also considered potentially attributable to the higher permeability soils within the headwater features and watercourses of the contributing drainage area to the gauge, which yielded a higher infiltration and lower runoff volume for the storm events monitored. The findings are similar to the Premier Gateway Scoped Subwatershed Study Phase 1B (Amec, 2020) for the Secondary Plan Area proximate to the study area.

2.2.4 Characterization and Analysis

2.2.4.1 Baseline Characterization

The study area is located between Eighth Line and Winston Churchill Boulevard. The study area crosses two jurisdictions – Conservation Halton and CVC (ref. Drawing WR2). The total size of the study area is 253.74 ha of which185.6 ha is within Sixteen Mile Creek Watershed in Conservation Halton jurisdiction, with the remaining 68.14 ha lying within the Mullet Creek Subwatershed in CVC jurisdiction. The following provides an overview of the study area characteristics within the respective watersheds / subwatersheds and corresponding jurisdictions.

Conservation Halton Jurisdiction

Drainage System

Within the Conservation Halton jurisdiction, East Branch of Sixteen Mile Creek enters the study area between Eighth Line and Ninth Line and exits the study area at Steeles Avenue. Several non-regulated drainage features were characterized along the East Branch of Sixteen Mile Creek. The external drainage area to Sixteen Mile Creek East Branch is approximately 1940 ha. The total drainage area to Sixteen Mile Creek East Branch at the downstream boundary of the study area (i.e., Steeles Avenue) is approximately 2068.06 ha. The Sixteen Mile Creek East Branch East Lisgar Branch drains north to south within the study area between Ninth Line and Tenth Line, with a total contributing area of approximately 143 ha at Steeles Avenue.

Soils

Soils within the study area have been characterized based upon a review of the surficial geology mapping information (Ontario Ministry of Energy, Northern Development and Mines, 2020), Soil Survey Complex (Ontario GeoHub, 2019) and the physiography mapping provided the Town for use in this study. The surficial geology soil mapping is presented in **Drawing WR3**. The study area is characterized by bevelled till plains

based on the physiography mapping. The surficial geology for the study area is noted to consist predominately of Halton Till, which is characterized as diamicton with primary material of clayey silt to silt. Modern Alluvium area concentrated along the Sixteen Mile Creek East Branch. Glaciolacustrine deposits with primary material of clay and silt are found in proximity to drainage features contributing to Sixteen Mile Creek. Overall, the soils are with low permeability and low infiltration potential. Although the overall soils within the Sixteen Mile Creek Watershed exhibit low permeability and low infiltration potential, the soil along the Sixteen Mile Creek watercourse is mainly modern alluvium, which can be highly permeable.

Slopes

The surface slopes within the urban expansion area and the existing urban area tend to be moderate between 1.5 and 2.5%. There are slightly steeper areas along watercourses (between 3 and 5% +/-).

Land Use

The existing land use conditions are primarily agricultural lands and open space. Rural development and rural residential areas are noted along the major roads (ref. Drawing WR4).

CVC Jurisdiction

Drainage System

Within the CVC jurisdiction, Mullet Creek enters the study area from the north. A tributary of Mullet Creek within the study area drains from west to east and confluences with the Mullet Creek west of Winston Churchill Boulevard. At the confluence, Mullet Creek continues to flow east between two private properties and exits the study area at Winston Churchill Boulevard. The external drainage area to the study area is approximately 193 ha. The total contributing drainage area at the downstream boundary of the study area (i.e., Winston Churchill Boulevard) is approximately 267.92 ha. The wetland within the study area, between Tenth Line and Winston Churchill Boulevard, is characterized as an internally draining subcatchment during smaller rainfall events.

Soils

The soils within the CVC jurisdiction are largely similar to the soils within the Conservation Halton jurisdiction. The soils have been characterized by bevelled till plains based on the physiography mapping. The surficial geology for the study area is noted to consist predominately of Halton Till, which is characterized as dimincton with primary material of clayey silt to silt. Glaciolacustrine deposits with primary material of

clay and silt are found in proximity to drainage features contributing to Mullet Creek. Overall, the soils are with low permeability and low infiltration potential.

Slopes

The surface slopes within the urban expansion area and the existing urban area tend to be moderate between 1 and 2%.

Land Use

The existing land use conditions are primarily agricultural lands and open space. Rural development areas are noted along the Steeles Avenue and Winston Churchill Boulevard.

2.2.4.2 Hydrologic Model Development

Per the requirements of the Terms of Reference, the hydrologic model is required to be deterministic and capable of completing continuous simulation. In addition, the hydrologic model needs to be capable of representing surface water runoff, base flows, surface and groundwater interactions, and water budget analyses. As indicated in the Terms of Reference, although various hydrologic models have been applied across the study area (i.e., HSP-F, Visual OTTHYMO, GAWSER) to establish peak flows for Flood Hazard Mapping as well as to establish stormwater management criteria, the HSP-F methodology has been applied for this Scoped Subwatershed Study as the core platform for completing the hydrologic analyses and establishing stormwater management criteria. The HSP-F model satisfies the criteria noted above for the hydrologic analyses and has a legacy of application throughout the Sixteen Mile Creek Watershed over the last 20 years, including recent studies such as the South Milton Urban Expansion Area Subwatershed Study and the Premier Gateway Phase 1B Scoped Subwatershed Study, and has been supported by Conservation Halton for use in the Sixteen Mile Creek Watershed before recent Federal Tribunals. In addition, the HSP-F methodology has a legacy of use within CVC jurisdiction as part of the broader Flow Management Study and has been used specifically for Subwatershed Studies in support of secondary plans within the Fletcher's Creek and Huttonville Creek Subwatersheds. The "parent" HSP-F model, as referenced in this study, represents the HSP-F model which was originally developed for the Sixteen Mile Creek Watershed as part of the Sixteen Mile Creek Subwatershed Planning Study: Areas 2 and 7 (Philips Planning and Engineering Limited, January 2000) and subsequently refined, calibrated, and validated as part of various studies (i.e., hydrologic verifications, subwatershed studies, subwatershed update studies, and optimization studies) for the Town of Milton, the Town of Halton Hills, and Conservation Halton over the intervening twenty years.

While the HSP-F methodology has been applied as the core analytical model to establish stormwater management criteria per the requirements outlined above, the results of the hydrologic analyses, specifically the recommended sizing criteria for stormwater management, are to be verified using the current Visual OTTHYMO models for the Mullet Creek Subwatershed Study (draft) and the headwaters of the Lisgar District, to provide consistency with the current hydrologic modelling within the respective study areas and agency jurisdictions. The “parent” VO model for the Lisgar District, as referenced in this study, represents the VO model which was originally developed for the North Sixteen District Scoped Subwatershed Study and Ninth Line District Floodline Mapping Study, and most recently updated for the Ninth Line Lands Scoped Subwatershed Study (Wood, September 2022). The VO hydrologic model which was developed for the September 2022 Scoped Subwatershed Study for the Ninth Line lands built upon the SWMHYMO hydrologic model which was originally developed for the Ninth Line District Scoped Subwatershed Study (Philips Engineering Ltd., 2003). That SWMHYMO hydrologic model incorporated the OTTHYMO ‘89 modelling from the 2001 Dillion Study for the 401 Integrated Planning Project. It is thus noteworthy that although the current VO model has incorporated hydrologic modeling information extending back to 2000, the model has nevertheless undergone several updates and modifications including refinements/ revisions to subcatchment discretization, application of different modelling commands (i.e., COMPUTE STANDHYD vs. CALIB URBHYD) as well as updates to routing elements within the Lisgar district based upon the more current information. Although the flows generated by the updated model differ from those developed from previous studies, the updated models have nevertheless been reviewed by the proponent municipalities for the studies and Conservation Halton and have been accepted. The “parent” VO model for the Mullet Creek Subwatershed, as referenced in this study, represents the VO model which was developed by CVC for the Mullet Creek Study, CVC, 2020.

Conservation Halton Jurisdiction

HSP-F Development

Hydrologic analyses for the Premier Gateway Phase 2B Area have been completed using the HSP-F methodology, which is fully supported and maintained by the USGS. The HSP-F hydrologic model has been applied for the hydrologic analyses within the Sixteen Mile Creek Watershed for over 20 years and has been refined and calibrated over that time for five secondary plans (i.e., Premier Gateway Phase 1B, 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 foregoing Secondary Planning Areas. 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.

The HSP-F hydrologic model has been further refined within the limits of the Premier Gateway Lands, based upon the watercourse information and LiDAR mapping provided for the Subwatershed Study. The refinements have established subcatchments and channel routing elements at tributary confluences within the Premier Gateway Lands, to increase the resolution of the model and more discretely assess local hydrologic conditions. The model refinements have increased the number of subcatchments within the study area from 2 (+/-) subcatchments in the parent model to 20 (+/-) subcatchments within the refined model. Soil parameterization for the model subcatchments has been retained from the parent model and verified against surficial soils and surficial geology mapping. The subcatchment boundary and node location plan for the refined HSP-F model is presented in **Drawing WR6**. The model schematic is presented in **Drawing WR7b**.

The subcatchment parameters for the subcatchments external to the study area have been retained from the parent HSP-F model. The subcatchment parameters within the limits of the study area have been established based upon the parameterization for the parent HSP-F hydrologic model for the Southwest Milton Subwatershed Study Area, due to the common physiographic conditions within each area (i.e., soils, surface cover / land use, overland slopes). The subcatchment parameters for key parameters of interest are summarized in **Table 2.2.2**.

As shown in the table above, there are 24 subcatchments representing the Sixteen Mile Creek East within the Premier Gateway Study Area. Subcatchments 164 and 165 are the external drainage areas and their combined drainage area is 1833 ha out of a total of 2068 ha. Subcatchments 201 to 204 are located along the East Lisgar Branch. The LIDAR data indicates that the floodplains are mostly flat in general as indicated by the slopes. The slopes vary from 0.6% to 2.4% with 1.3% being the average value. Apart from the external drainage areas, the average subcatchment area is around 13 ha which gives a fairly detailed resolution for hydrologic analysis. Based on the information available, all the subcatchments within study area are considered to be “undeveloped” or “rural” and have been modelled accordingly. The external subcatchments show some residential development based in the available aerial imagery and have been accounted for in calculating weighted imperviousness.

The updated and refined HSP-F hydrologic model has been validated using observed precipitation and flow data collected under 2020 - 2021 field monitoring program.

The validation has executed the hydrologic model in continuous mode, using the full suite of rainfall for the 2020 - 2021 monitoring period. The simulated hydrographs and observed hydrographs for the validation events are presented in **Appendix D**.

The hydrographs comparing between simulated flows and observed flows for the validation events indicate that the trendline for the simulated and observed peak flows at the Hornby flow monitoring station yields a slope of 1.09 and a correlation of 0.39, indicating a slight over estimation of flows with a strong correlation between the observed and simulated flow response at the Hornby gauge (i.e., simulated flows generally within 9% of observed values). The Hornby gauge is located at Steeles Ave on Sixteen Mile Creek East. The trendline for the simulated and observed run-off volumes at the Hornby flow monitoring station yields a slope of 0.32 and a correlation of 0.38, indicating a considerable under estimation of run-off volumes with a strong correlation between the observed and simulated flow response at the Hornby gauge. This can be explained due to existence of significant base flow of +/-0.15 m^3/s in the observed data at Hornby gauge. The simulated flows have almost no baseflow as shown in **Appendix D**. The simulated base flow can be improved during subsequent model parameterization updates which would address the weak baseflow correlation. It should be noted that since the base-flow is subtracted to calculate the peak run-off in both the scenarios (observed and simulated), having no base-flow for the simulated model does not undermine a very good correlation for peak flows and model reliability for this study.

As shown in the **Figures Figure 2.2.2** to **2.2.3**, the model shows run-off response as anticipated and is also significantly matching with the overall shape of the observed response. The results indicate that the simulated peak flows are generally similar to the observed hydrographs at the monitoring station. In some instances, the simulated baseflow response (i.e., baseflow recession) is noted to be very little (<0.01 m^3/s) and is under-estimated compared to the observed condition, however the overall shape of the peak flow response is noted to correspond to the observed runoff response from the storm event. As such, the HSP-F hydrologic model is considered to be representative of the hydrologic conditions within the Sixteen Mile Creek Watershed East Branch.

Table 2.2.2: HSP-F Subcatchment Parameters for Existing Land Use Conditions - Sixteen Mile Creek East Branch

Subcatchment ID	Total Area (ha)	Pervious Area (ha)	Pervious								Impervious	
			INFILT (mm/hr)	UZSN (mm)	LZSN (mm)	INTFW (day^{-1})	IRC (day^{-1})	AGWRC (day^{-1})	SLOPE (m/m)	LSUR (m)	SLOPE (m/m)	LSUR (m)
161	41.45	38.96	5.73	12	100	4	0.1	0.97	0.010	120	0.010	120
162	34.14	33.12	6.00	12	100	4	0.1	0.97	0.014	150	0.014	150
163	15.93	14.97	6.02	12	100	4	0.1	0.97	0.011	125	0.011	125
164	1641.31	1542.83	6.07	12	100	4	0.1	0.97	0.006	700	0.006	700
165	192.54	186.76	6.07	12	100	4	0.1	0.97	0.006	700	0.006	700
166	14.33	13.9	6.76	12	100	4	0.1	0.97	0.008	110	0.008	110
167	12.43	12.06	6.74	12	100	4	0.1	0.97	0.018	120	0.018	120
168	4.64	4.51	7.02	12	100	4	0.1	0.97	0.017	85	0.017	85
169	6.89	6.68	6.45	12	100	4	0.1	0.97	0.024	120	0.024	120
170	10.94	10.62	6.87	12	100	4	0.1	0.97	0.002	85	0.002	85
171	3.44	3.33	5.60	12	100	4	0.1	0.97	0.014	85	0.014	85
172	1.99	1.93	7.47	12	100	4	0.1	0.97	0.021	60	0.021	60
173	4.19	3.64	6.63	12	100	4	0.1	0.97	0.016	100	0.016	100
174	7.62	6.94	6.08	12	100	4	0.1	0.97	0.023	90	0.023	90
175	3.28	3.18	7.42	12	100	4	0.1	0.97	0.010	80	0.010	80
176	17.58	17.06	5.85	12	100	4	0.1	0.97	0.013	130	0.013	130
177	12.92	11.11	5.97	12	100	4	0.1	0.97	0.005	200	0.005	200
178	3.96	3.56	6.03	12	100	4	0.1	0.97	0.025	110	0.025	110
179	11.16	8.82	7.07	12	100	4	0.1	0.97	0.008	90	0.008	90
180	27.35	24.89	5.81	12	100	4	0.1	0.97	0.007	140	0.007	140
201	20.68	20.06	6.00	12	100	4	0.1	0.97	0.010	120	0.010	120
202	36.76	35.65	6.03	12	100	4	0.1	0.97	0.014	225	0.014	225
203	52.47	50.9	6.03	12	100	4	0.1	0.97	0.011	125	0.011	125
204	33.09	32.1	6.00	12	100	4	0.1	0.97	0.013	170	0.013	170

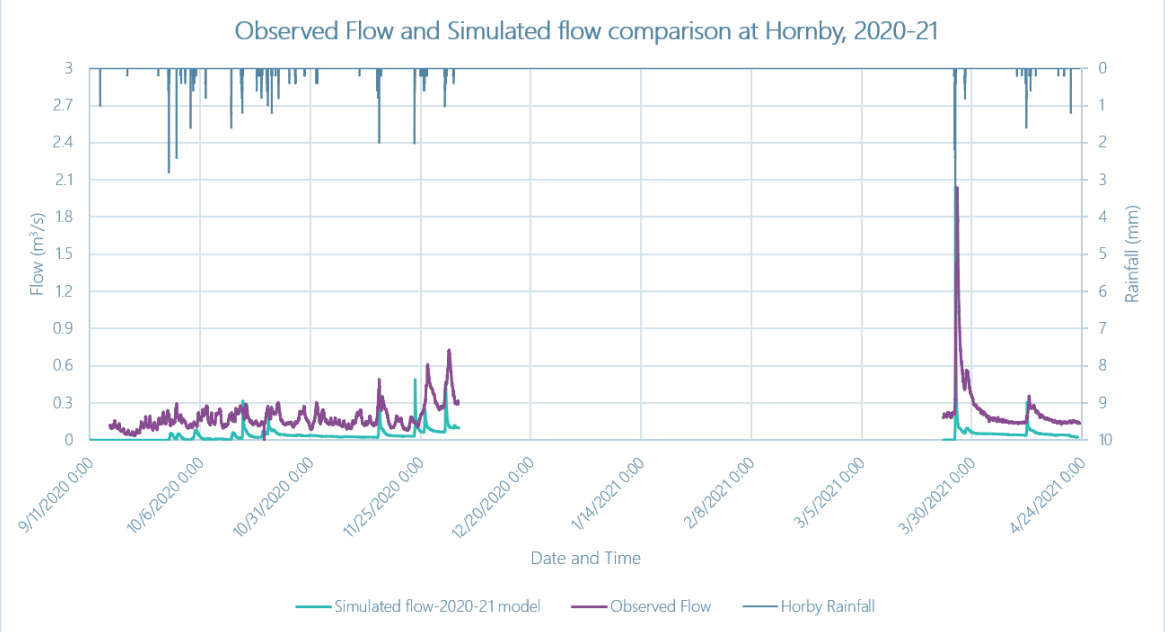

Figure 2.2.2: Simulated Flow vs Observed Flow at the Temporary Flow Gauge

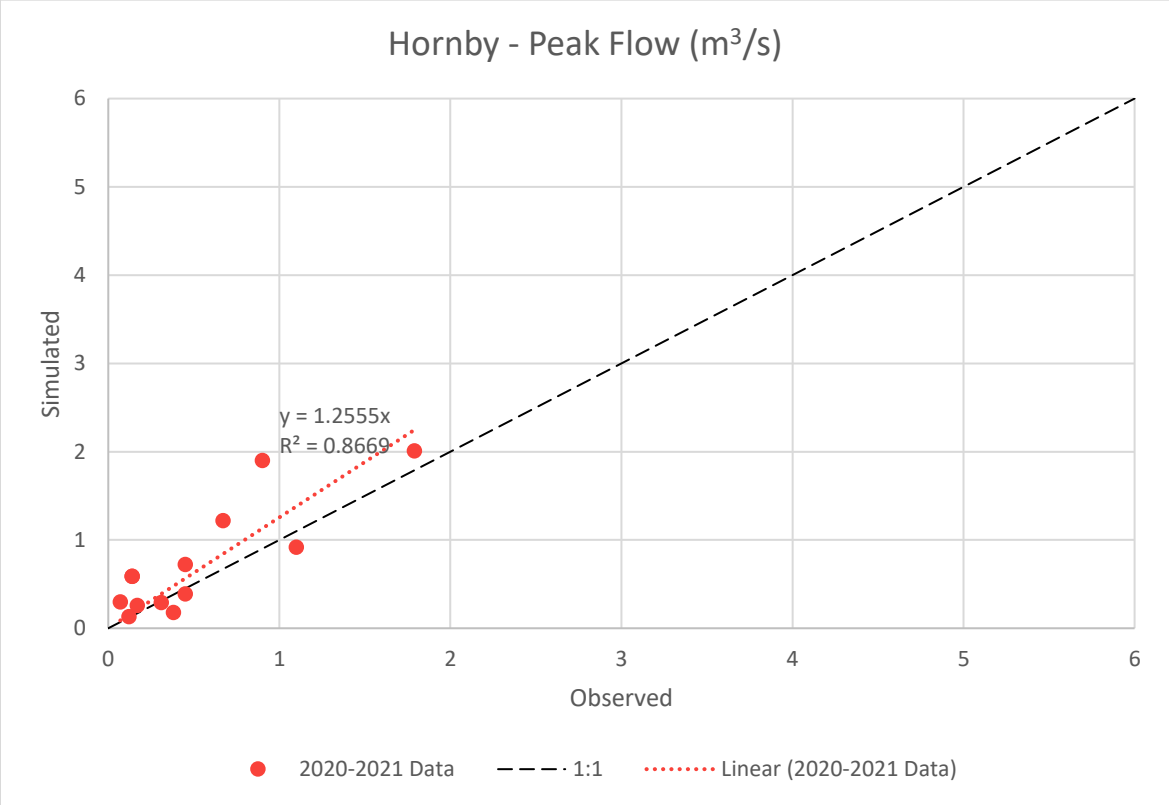

Figure 2.2.3: Scatter Plot of Simulated Flow vs Observed Flow at the Temporary Flow Gauge

The results indicate that, generally speaking, the simulated hydrographs are representative of the hydrologic conditions within the contributing drainage area to the temporary flow gauge, based upon the land use and soils within the contributing drainage areas. Base flow separation has been completed to establish the runoff hydrograph at each gauge for the corresponding event, and the surface runoff peak flow was calculated based upon the resulting hydrographs. As shown in **Figure 2.2.3**, the simulated and observed peak flows has a very good correlation as indicated by the slope value of 1.25. It means that after base flow separation, the simulated peak flows on average are 25% higher than the observed peak flows for the considered storm events for validation. The R2 value of 0.87 is also indicative of an acceptable goodness-of-fit measure for the linear regression of simulated and observed flows. As such, the HSP-F hydrologic model, currently parameterized, is considered to be representative of the hydrologic conditions within the Sixteen Mile Creek Watershed East Branch.

Visual OTTHYMO Model Development

The Visual OTTHYMO (VO) model developed for the 9th Line Lands Scoped Subwatershed Study Phase 1 (Amec Foster Wheeler, 2020) has been refined and updated for the East Lisgar Branch within the limits of the study area. The subcatchment plan overlooking the Sixteen Mile Creek Watershed is presented in **Drawing WR-5**. The subcatchment plan focusing on the study area is presented in **Drawing WR-6**.

The soils within the study area consist of Chinguacousy clay loam and Jeddo clay loam, which are classified as SCS Type ‘C’ soils, exhibiting relatively low rates of infiltration and comparatively high rates of runoff. The existing land use conditions within the study area are generally agricultural and open space, with some low-density residential land use along Tenth Line and Steeles Avenue. Surface slopes are typically flat at approximately 0.5%. It is noteworthy that the VO model for the Lisgar Community has not undergone calibration and/or validation as part of previous studies, hence the model parameterization remains based on literature values only.

The CALIB NASHYD Command has been applied for the rural subcatchments within the study area in accordance with the OTTHYMO methodology. The SCS Curve Numbers values have been determined based on the land use type and soil groups following the Visual OTTHYMO User’s Manual Version 6.0 (CIVICA, 2019). The land use, soil, and CN lookup table is included in **Appendix D**. The CN values have been converted to AMC III soil conditions for the Regional Storm event. Time of concentration (t_c) have been calculated using Airport Method. The cross-section details of the channel routing elements have been determined based on the DEM of the study area with a cell size of one meter. The roughness coefficient (Manning’s n) has been established as

0.035 for the main channel and 0.08 for the overbanks. The parameters for the updated subcatchments within the East Lisgar Branch of East Sixteen Mile Creek is summarized in **Table 2.2.3**. The model schematic is presented in **Drawing WR7a**.

Table 2.2.3: Visual OTTHYNO Subcatchment Parameters – East Lisgar Branch

NHYD	Name	Area (ha)	S (%)	CN	CN III	IA (mm)	Tc (hr)	Tp (hr)
201	S-201	20.68	0.5	83.0	91.7	5	1.58	0.95
202	S-202	36.76	0.3	82.1	91.2	5	2.05	1.23
203	S-203	52.47	0.6	83.1	91.8	5	2.12	1.27
204	S-204	33.09	0.6	85.8	93.3	5	1.65	0.99

The base mapping suggests that a portion of subcatchment in the parent model (Subcatchment 309 in the updated model) would contribute to Mullet Creek through a crossing culvert under Winston Churchill Boulevard. The site visit verified that the drainage from Subcatchment 309 is unlikely to cross Steeles Avenue and contributes to the study area.

CVC Jurisdiction

HSP-F Development

A scoped hydrologic model for the Premier Gateway Study Area within Credit Valley Conservation jurisdiction has been created which covers the headwaters of the Mullet Creek subwatershed. Given the physiographic similarities across the study area in terms of soil types, surface cover / land use, and overland slopes, key modelling parameters related to soil infiltration, upper and lower zones soil storage capacity were retained from the HSP-F model for the Sixteen Mile Creek watershed. The subcatchment parameters for the HSP-F model representing the headwaters of the Mullet Creek Subwatershed are summarized in **Table 2.2.4** for key parameters of interest. The subcatchment boundary and node location plan for the scoped HSP-F model is presented in **Drawing WR6**. The model schematic is presented in **Drawing WR7b**.

As shown in the table above, there are nine subcatchments representing the upper reaches of the Mullet Creek subwatershed within the Premier Gateway Study Area and upstream. All the Subcatchments are in the headwaters for the Mullet creek Main Branch and their combined drainage area is 336 ha. Similar to the Sixteen Mile Creek East Branch, the LiDAR data indicates that the floodplains are mostly flat in general as indicated by the slopes. The slopes vary from 0.1% to 2.4% with 1.2% being the

average value. As mentioned, since it is in the headwaters, the average subcatchment area is around 37 ha.

The base mapping for subcatchment 304, which encompasses the wetland within the Premier Gateway Area, has been reviewed to verify whether the subcatchment is internally draining or whether it contributes to the downstream reaches. Based upon the LiDAR mapping, it has been determined that this subcatchment is internally draining, particularly during smaller storm events, hence does not contribute runoff toward the downstream watercourse. For the current modelling, the drainage connection between this feature and the downstream watercourse has been retained within the hydrologic model.

Table 2.2.4: HSP-F Subcatchment Parameters for Existing Land Use Conditions – Mullet Creek

Subcatch ID	Total Area (ha)	Pervious Area (ha)	Pervious								Impervious	
			INFILT (mm/hr)	UZSN (mm)	LZSN (mm)	INTFW (day-1)	IRC (day-1)	AGWRC (day-1)	SLOPE (m/m)	LSUR (m)	SLOPE (m/m)	LSUR (m)
301	145.32	140.97	5.86	12	100	4	0.1	0.97	0.001	150	0.001	150
302	48.21	46.77	5.83	12	100	4	0.1	0.97	0.007	130	0.007	130
303	12.07	11.59	5.80	12	100	4	0.1	0.97	0.007	85	0.007	85
304	13.71	13.3	6.00	12	100	4	0.1	0.97	0.024	90	0.024	90
305	8.71	8.45	6.00	12	100	4	0.1	0.97	0.023	75	0.023	75
306	30.91	29.12	5.80	12	100	4	0.1	0.97	0.011	180	0.011	180
307	8.99	6.58	5.98	12	100	4	0.1	0.97	0.021	160	0.021	160
308	41.04	34.43	5.56	12	100	4	0.1	0.97	0.016	250	0.016	250
309	27.16	20.67	5.80	12	100	4	0.1	0.97	0.003	140	0.003	140

Visual OTTHYMO Model Development

The draft Visual OTTHYMO model for the Mullet Creek Subwatershed (CVC, 2021) has been refined within the limits of the study area based upon the provided base mapping. The soils within the study area consist of Chinguacousy clay loam and Jeddo clay loam, which are classified as SCS Type 'C' soils, exhibiting relatively low rates of infiltration and comparatively high rates of runoff. The existing land use conditions within the study area are generally agricultural and open space, with some low-density residential land use along Winston Churchill Boulevard and rural development land use along Steeles Avenue. Surface slopes within this area are typically flat at approximately 0.5 to 1.4%. The subcatchment boundary and node location plan is presented in **Drawing WR6**.

The CALIB NASHYD Command has been applied to represent the refined subcatchments given the predominantly rural land use conditions. The SCS Curve Numbers values have been determined based on the land use type and soil groups following the Visual OTTHYMO User's Manual Version 6.0 (CIVICA, 2019). The land use, soil, and CN lookup table is included in **Appendix D**. The CN values have been converted to AMC III soil conditions for the regional storm event. Time of concentration (t_c) have been calculated using Airport Method. The cross-section details of the routing channels are determined based on the DEM of the study area with a cell size of one meter. The roughness coefficient (Manning's n) of 0.035 has been applied for the main channel and 0.08 for the overbanks. The parameters for the refined subcatchments within the Mullet Creek Watershed is summarized in **Table 2.2.5.** The model schematic is presented in Drawing WR7b.

Table 2.2.5: Visual OTTHYMO Subcatchment Parameters – Mullet Creek

NHYD	Name	Area (ha)	S (%)	CN	CN III	IA (mm)	Tc (hr)	Tp (hr)
301	S-301	145.32	1.5	85.8	93.2	5	1.75	1.05
302	S-302	48.21	1.6	83.3	91.9	5	1.07	0.64
303	S-303	12.07	1.8	81.8	91.0	5	1.05	0.63
304	S-304	13.71	0.8	81.3	90.7	5	1.37	0.82
305	S-305	8.71	0.6	79.6	89.8	5	1.42	0.85
306	S-306	30.91	1.4	82.4	91.4	5	1.30	0.78
307	S-307	8.99	0.9	81.4	90.8	5	1.08	0.65
308	S-308	41.04	0.7	86.8	93.8	5	1.53	0.92
309	S-309	27.16	1.0	84.0	92.3	5	1.58	0.95

Consistent with the approach applied for the Mullet Creek Visual OTTHYMO hydrologic model developed by CVC, the 24 hour Chicago distribution has been applied to generate the synthetic design storms for the return period storm events. The Hurricane Hazel Strom has been applied for the Regional Storm event.

2.2.4.3 Hydrologic Analysis

Sixteen Mile Creek Watershed Hydrologic Modelling

Frequency Peak Flows and Regional Peak Flows

The updated and refined HSP-F hydrologic model has been executed for a 56-year continuous simulation (1962 – 2017) using the updated meteorological dataset developed for the Agerton / Trafalgar MESP (Wood et. al.). Simulated instantaneous annual maximum peak flows have been extracted from the continuous simulation dataset, and frequency analyses have been completed using the Log Pearson Type III Distribution, which 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 areal 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 2.2.6**.

Table 2.2.6: Simulated Peak Frequency Flows and Regional Storm Event Flows for Existing Land Use Conditions – Sixteen Mile Creek East (m^3/s)

Node	Location	Contributing Drainage Area (ha)	Frequency (Years)							Regional
			1.25	2	5	10	20[2]	50	100	
3.565	SMCE[1] +/-2250 m U/S of Steeles Ave. (Inlet of Sub166)	1833.85	3.20	5.12	8.54	11.30	14.50	19.20	23.30	68.60
3.566	SMCE +/-1536 m U/S of Steeles Ave. (Outlet of Sub166)	1848.18	3.01	4.93	8.34	11.10	14.20	18.90	23.00	68.30
3.567	SMCE +/-1236 m U/S of Steeles Ave. (Outlet of Sub167)	1860.61	2.99	4.87	8.25	11.00	14.10	18.90	23.00	67.90
3.568	SMCE +/-914 m U/S of Steeles Ave. (Outlet of Sub168)	1865.25	2.97	4.85	8.23	11.00	14.10	18.80	22.90	67.50
3.563	HDF[1] tributary to SMCE +/-914 m U/S of Steeles Ave. (Outlet of Sub163)	15.93	0.04	0.06	0.09	0.11	0.13	0.15	0.17	0.84
3.581	Confluence of HDF and SMCE +/-914 m U/S of Steeles Ave. (Confluence of sub 163 & 168)	1881.18	2.99	4.89	8.29	11.1	14.2	18.9	22.9	68.10
3.569	SMCE +/-761 m U/S of Steeles Ave. (Outlet of Sub169)	1888.07	2.98	4.88	8.28	11.10	14.20	18.90	23.00	67.70
3.570	SMCE +/-265 m U/S of Steeles Ave. (Outlet of Sub170)	1899.01	2.91	4.79	8.16	10.90	14.00	18.70	22.70	65.70
3.561	HDF tributary +/-110m east of 8th Line (Outlet of Sub 161)	41.45	0.12	0.16	0.24	0.30	0.36	0.45	0.52	2.44
3.562	HDF tributary +/-120m east of 8th Line (Inlet of Sub173)	75.59	0.17	0.25	0.39	0.49	0.61	0.77	0.92	4.20
3.573	HDF tributary to SMCE +/-265 m U/S of Steeles Ave. (Outlet of Sub173)	79.78	0.18	0.27	0.41	0.51	0.63	0.79	0.94	3.93
3.582	Confluence of HDF and SMCE +/-265 m U/S of Steeles Ave. (Confluence of sub 173 & 170)	1978.79	3.02	4.97	8.46	11.30	14.50	19.30	23.50	68.50

Node	Location	Contributing Drainage Area (ha)	Frequency (Years)							Regional
			1.25	2	5	10	20[2]	50	100	
3.572	SMCE +/-323 m U/S of Steeles Ave. (Outlet of Sub172)	1980.78	3.01	4.97	8.46	11.30	14.50	19.40	23.60	68.40
3.575	SMCE +/-65 m U/S of Steeles Ave. (Outlet of Sub175)	1987.5	3.02	4.97	8.47	11.40	14.60	19.40	23.60	67.60
3.584	SMCE +/-59 m U/S of Steeles Ave. (Inlet at Sub 178)	1995.11	3.02	4.99	8.50	11.40	14.60	19.40	23.60	67.80
3.578	SMCE U/S of Steeles Ave.	1999.07	2.97	4.96	8.50	11.40	14.60	19.40	23.60	66.10
3.586	SMCE D/S of Steeles Ave.	2029.58	3.02	5.02	8.61	11.60	14.80	19.70	24.00	67.00
3.579	SMCE +/-457 m D/S of Steeles Ave. (Outlet of Sub 179)	2040.73	2.99	4.99	8.58	11.50	14.80	19.70	23.90	67.00
3.580	Tributary to SMCE +/-457 m D/S of Steeles Ave. (Outlet of Sub 180)	27.35	0.10	0.14	0.20	0.24	0.27	0.33	0.36	1.49
3.587	Confluence of tributary and SMCE +/-457 m D/S of Steeles Ave. (Confluence of Sub 179 & 180)	2068.09	3.02	5.07	8.71	11.70	15.00	19.90	24.10	67.70
3.511	Lisgar Branch at Steeles Ave. +/- 130 m east of 9th Line (Outlet of Sub201)	20.68	0.04	0.06	0.09	0.12	0.16	0.21	0.25	1.08
3.512	Lisgar Branch at Steeles Ave. +/- 568 m east of 9th Line (Outlet of Sub202)	36.76	0.06	0.10	0.16	0.21	0.27	0.36	0.44	1.68
3.513	Lisgar Branch at Steeles Ave. +/- 1127 m east of 9th Line (Outlet of Sub203)	52.47	0.13	0.19	0.28	0.35	0.42	0.53	0.62	2.84
3.514	Lisgar Branch at Steeles Ave. +/- 1473 m east of 9th Line (Outlet of Sub204)	33.09	0.12	0.17	0.24	0.28	0.33	0.39	0.43	1.8

[1]SMCE represents Sixteen Mile Creek East Branch. HDF represents headwater feature.

[2]Frequency analysis of long-term data reports 20 year frequency flow, versus the 25 year flow generated by synthetic design storm methodology.

The unitary Regional storm event peak flows for the major nodes have been compared against different nodes from other studies having similar drainage areas. These studies have been withing the Sixteen Mile Creek subwatershed and have used HSP-F hydrologic modelling. The reference Node locations from the other studies have been shown on their respective drainage area plans and have been included in Appendix D. The parent HSP-F model which was revised as part of the current study was prepared during the southwest Milton Subwatershed Study and has been part of the comparison table. The following table shows the comparison of the Regional Storm event unitary peak flows between current study and previous studies.

Table 2.2.7: Simulated Peak Frequency Flows and Regional Storm Event Flows for Existing Land Use Conditions – Sixteen Mile Creek East (m^3/s)

Project Title and Project No.	Reference Node	Location	Drainage Area (ha)	Regional Storm Peak Flow (m^3/s)	Regional Storm Unitary Peak Flow ($m^3/s/ha$)
Southwest Milton Subwatershed Study (TP116007A)	3.160	Sixteen Mile Creek Main Branch at Derry Road	2269.4	58.6	0.026
Agerton Trafalgar MESP (TP116007A)	3.160	Sixteen Mile Creek Main Branch at Derry Road	2269.4	60.3	0.027
Premier Gateway Scoped Subwatershed Study Phase 1 (TP115042)	2.030	Sixteen Mile Creek Subwatershed 4 at Sixth Line North of Highway 401	2150.04	82.1	0.038
Premier Gateway Scoped Subwatershed Study (WW20101004)*	3.578	East Sixteen Mile Creek at Steeles Ave.	1999.07	66.10	0.033

**: Current Study*

The results in the above table indicate that, in general, the refined model generates peak Regional Storm event flows within the Study Area which are comparable to those generated by other HSP-F models. At Node 3.587, the increase in Regional Storm event peak flow is considered primarily attributable to refinements to the contributing drainage area, as well as the increased number of subcatchments within the model at this location.

The results in **Table 2.2.7** indicate that downstream of the Premier Gateway Area (Node 3.587), the refined HSP-F hydrologic model generated Regional Storm event peak flows are generally comparable to those generated for the Southwest Milton Subwatershed Study, hence validating model performance for the Sixteen Mile Creek East Branch.

For some nodes, the Regional Storm event peak flows are slightly lower than their immediate upstream node. This considered primarily attributable to the effect of channel routing. To further validate the Regional Storm Event peak flows generated as part of the current study, unitary Regional Strom event peak flows generated through various studies have been plotted on a graph. The graph plots the drainage area in sq. km on X-axis on a logarithmic scale and unitary Regional Storm Event peak flow on Y-axis on a linear scale.

Design Storm and Regional Peak Flows for Sixteen Mile Creek East Lisgar Branch (VO)

Consistent with the approach applied for the 9th Line Lands Scoped Subwatershed Study, the 12 hour SCS distribution has been applied to generate the synthetic design storms for the return period storm events. The Hurricane Hazel Strom has been applied for the regional storm event. The updated Visual OTTHYMO hydrologic model has been executed for the 2 to 100 year return periods using the 12 hour SCS storm distribution as well as the Regional Storm event. Peak flows have been extracted at the outlets of the study area and are presented in **Table 2.2.8.**

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Table 2.2.8: Simulated Peak Flow Rates for Return Period and Regional Storm Event Under Existing Land Use Conditions for the Study Area – East Lisgar Branch (m^3/s)

NHYD	Location	Contributing Drainage Area (ha)	Return Period (Years)						Regional
			2	5	10	25	50	100	
201	Lisgar Branch at Steeles Ave. +/- 568 m east of 9th Line (Outlet of Sub202)	20.68	0.33	0.55	0.77	0.96	1.13	1.33	2.23
202	Lisgar Branch at Steeles Ave. +/- 1127 m east of 9th Line (Outlet of Sub203)	36.76	0.45	0.77	1.09	1.35	1.61	1.89	3.63
203	Lisgar Branch at Steeles Ave. +/- 1473 m east of 9th Line (Outlet of Sub204)	52.47	0.66	1.11	1.57	1.94	2.30	2.70	5.14
204	Lisgar Branch at Steeles Ave. +/- 568 m east of 9th Line (Outlet of Sub202)	33.09	0.57	0.95	1.32	1.62	1.91	2.22	3.55

The updated Visual OTTHYMO hydrologic model has been executed for the Regional Storm event and the peak flows have been compared against the results generated by the parent Visual OTTHYMO hydrologic model (i.e., 9th Line Lands Scoped Subwatershed Study Phase 1), in order to validate the performance of the Visual OTTHYMO model. The results of this assessment are presented in **Table 2.2.9.** Information regarding flow values and flow change locations used for hydraulic modeling is provided in Appendix D.

Table 2.2.9: Comparison of Simulated Regional Storm Peak Flows – East Lisgar Branch (Updated VO Mode vs Parent VO Model)

NHYD	Location	Updated Contributing Drainage Area (ha)	9th Line VO (m^3/s)	Premier Gateway 2B VO (m^3/s)	Difference (m^3/s)	Difference (%)
75 (201)	Lisgar Branch at Steeles Ave. +/- 568 m east of 9th Line (Outlet of Sub202)	20.68	2.63	2.23	-0.4	-15.21
21 (202)	Lisgar Branch at Steeles Ave. +/- 1127 m east of 9th Line (Outlet of Sub203)	36.76	2.42	3.63	1.21	50.00
29 (203)	Lisgar Branch at Steeles Ave. +/- 1473 m east of 9th Line (Outlet of Sub204)	52.47	3.11	5.14	2.03	65.27
10 (204)	Lisgar Branch at Steeles Ave. +/- 568 m east of 9th Line (Outlet of Sub202)	33.09	2.14	3.55	1.41	65.89
236	Lisgar Branch at Highway 401	210.02	16.99	21.67	4.68	27.55
260	Lisgar Branch at CNR Rail	449.41	41.31	42.23	0.92	2.23
45	Lisgar Branch at Derry Road	643.14	59.63	60.60	0.97	1.63
104	Lisgar Branch at Britannia Road	1511.27	146.33	148.31	1.98	1.35

Note: NHYD in brackets represents the NHYD in the updated model

The results indicates that the simulated peak flow rates generated from the updated Visual OTTHYMO model for the Regional Storm event are generally higher than peak flow rates generated from the parent Visual OTTHYMO mode, particularly at the boundary of the study area. Although the percentage differences range from -15.21 to 65.89%, the absolute differences are less significant, ranging from -0.4 to 4.68 m^3/s. The differences in the regional peak flows are considered attributable to the refined drainage area boundaries, updated parameters, and the use of AMC III CN values for

the regional storm event. In general, the updated VO model is considered comparable to the parent model.

Mullet Creek Subwatershed Hydrologic Modelling

Frequency Peak Flows and Regional Peak Flows (HSP-F)

Similar to the Sixteen Mile Creek East Branch, the scoped HSP-F model for the Mullet Creek has been updated and refined. The scoped HSP-F hydrologic model has been executed for a 56-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 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 simulated peak frequency flows and Regional Storm peak flows for the existing land use conditions are summarized in **Table 2.2.10**.

Since the HSP-F model developed for the Mullet Creek is a scoped model and there is no existing parent model unlike Sixteen Mile Creek subwatershed, it is difficult to validate the simulation results by directly comparing the results from previous studies. With that said, based on the similarities of physiological conditions (i.e., soil type, land use, vegetation and routing) with the Sixteen Mile Creek subwatershed, the simulated unitary frequency peak flows at nodes with similar drainage areas are relatively close as anticipated (i.e. Node 3.506, 3.513 and 3.561). The unitary peak flows for the Regional Storm event also match well with the unitary flows from the HSP-F model for Sixteen Mile Creek East Branch.

Design Storm and Regional Peak Flows for Mullet Creek (VO)

The Visual OTTHYMO hydrologic model has been executed for the 2-to-100-year return periods using the 24 hour Chicago storm distribution as well as the Regional Storm event. Peak flows have been extracted at key locations within the study area and are presented in **Table 2.2.11**.

Table 2.2.10: Simulated Peak Frequency Flows and Regional Storm Event Flows for Existing Land Use Conditions – Mullet Creek (m^3/s)

Node	Location	Contributing Drainage Area (ha)	Frequency (Years)							Regional
			1.25	2	5	10	20	50	100	
3.502	Mullet Creek +/-509 m U/S of Winston Churchill Blvd. (Outlet of Sub302)	193.53	0.24	0.42	0.73	1.00	1.29	1.74	2.13	6.25
3.503	Mullet Creek +/-316 m U/S of Winston Churchill Blvd. (Outlet of Sub303)	205.61	0.25	0.44	0.78	1.06	1.37	1.85	2.25	6.50
3.504	Headwater tributary to Mullet Creek +/-946 m U/S of Winston Churchill Blvd. (Outlet of Sub304)	13.71	0.02	0.04	0.06	0.09	0.11	0.15	0.18	0.85
3.505	Confluence of headwater features tributary to Mullet +/-946 m U/S of Winston Churchill Blvd. (Confluence of Sub 304 & 305)	22.42	0.04	0.06	0.10	0.14	0.18	0.24	0.30	1.39
3.506	Headwater tributary to Mullet Creek +/-316 m U/S of Winston Churchill Blvd. (Outlet of Sub306)	53.33	0.11	0.16	0.24	0.31	0.39	0.50	0.60	2.40
3.519	Confluence of headwater and Mullet Creek +/-316 m U/S of Winston Churchill Blvd. (Confluence of Sub 303 & 306)	258.93	0.34	0.57	0.99	1.33	1.72	2.30	2.81	8.73
3.507	Mullet Creek at Winston Churchill Blvd.	267.92	0.37	0.61	1.02	1.37	1.75	2.34	2.86	8.90
3.508	Mullet Creek at Steeles Ave.	308.96	0.52	0.79	1.25	1.61	2.00	2.58	3.07	10.60
3.509	Mullet Creek at Winston Churchill Blvd. South of Steeles Ave.	26.86	0.21	0.29	0.41	0.47	0.54	0.61	0.67	1.85

Table 2.2.11: Simulated Peak Flow Rates for Return Period and Regional Storm Event Under Existing Land Use Condition for the Study Areas – Mullet Creek (m^3/s)

NHYD	Location	Contributing Drainage Area (ha)	Return Period (Years)						Regional
			2	5	10	25	50	100	
2008	Headwater tributary to Mullet Creek +/-316 m U/S of Winston Churchill Blvd. (Outlet of Sub306)	53.33	0.86	1.47	2.10	2.63	3.13	3.68	5.95
2001	Mullet Creek +/-509 m U/S of Winston Churchill Blvd. (Outlet of Sub302)	193.53	2.64	4.41	6.12	7.68	9.07	10.61	19.66
2002	Mullet Creek +/-316 m U/S of Winston Churchill Blvd. (Outlet of Sub303)	205.6	2.76	4.63	6.44	8.09	9.56	11.18	20.80
2004	Mullet Creek at Winston Churchill Blvd.	267.92	3.67	6.19	8.63	10.82	12.79	15.02	27.40
2006	Mullet Creek at Steeles Ave.	308.96	4.26	7.18	10.03	12.49	14.75	17.29	31.49

The refined Visual OTTHYMO hydrologic model has been executed for the Regional Storm event, and the peak flows have been compared against the results generated by the parent Visual OTTHYMO hydrologic model (i.e., CVC Mullet Creek Model) to verify the performance of the updated Visual OTTHYMO model. The results of this assessment are presented in **Table 2.2.12**.

Table 2.2.12: Comparison of Simulated Regional Storm Peak Flows – Mullet Creek (Updated VO Mode vs. Parent VO Model)

NHYD	Location	Updated Contributing Drainage Area (ha)	VO (CVC Mullet Creek)	VO (Premier Gateway 2B)	Difference (m^3/s)	Difference (%)
3401 (2004)	Mullet Creek at Winston Churchill Blvd.	267.92	33.71	27.40	-6.31	-18.72
3403 (2006)	Mullet Creek at Steeles Ave.	308.96	41.24	31.49	-9.75	-23.64
3408	Mullet Creek at Highway 407 (Ref. CVC Node 1)	509.1	53.87	43.31	-10.56	-19.60
3418	Mullet Creek Highway 401 (Ref. CVC Node 2)	911.44	91.20	81.36	-9.84	-10.79
3449	Mullet Creek at Britannia Road (Ref. CVC Node 11)	687.36	47.77	47.51	-0.26	-0.54
3486	Mullet Creek Outlet (Ref. CVC Node 21)	1808.25	178.93	178.80	-0.13	-0.07

Note: NHYD in brackets represent the NHYD in the updated model

The comparison indicates that the simulated peak flow rates generated from the updated Visual OTTHYMO model for the Regional Storm event are generally lower than peak flow rates generated from the parent Visual OTTHYMO model. The percentage differences range from -0.54 to -23.64%. The differences in the Regional Storm peak flows are considered attributable to the refined drainage area boundaries, updated parameters, and change of drainage direction for Subcatchment 309. In general, the updated VO model is considered comparable to the parent model.

2.2.4.4 Erosion Analysis

The results of the continuous simulation completed using the HSP-F model have also been used to assess the erosion potential of the existing watercourse systems under existing land use conditions. Duration analyses have been conducted at the stations used for fluvial geomorphologic monitoring, to determine the duration (in hours) of flows above the critical erosion flow rate at each monitoring location. In addition, analyses have been completed to determine the total volume of water which would be above the critical erosive flow at each location, based upon the results of the continuous simulation. The fluvial geomorphologic monitoring location for Sixteen Mile creek east branch was ~200 m downstream of Steeles Ave. (Node 3.586). The fluvial geomorphologic monitoring location for Mullet creek east branch was ~100 m

downstream of Winston Churchill Boulevard (Node 3.507). The critical flow values for the significant nodes within Lisgar District have been determined by area weighing the critical flow value for Mullet Creek (0.79 m^3/s for total drainage area of 264.26 ha). The results of these analyses are presented in **Table 2.2.13** and **Table 2.2.14.**

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Table 2.2.13: Duration Analysis for Erosion Assessment of Existing Land Use Conditions

Erosion Site	Location	Contributing Drainage Area (ha)	$Q_{critical}$ (m^3/s)	Total Hours Exceeded	Percent of Total Time Exceeded (%)
ESMC(2)	East Sixteen Mile Creek +/-200 m D/S of Steeles Ave.	2029.58	0.70	11165	2.27
MC(4)	Mullet Creek +/-100 m D/S of Winston Churchill Blvd.	267.92	0.79	290	0.06
Node 3.511	Outlet of Subcatchment 201 at Steeles Ave.	20.68	0.062	267	0.05
Node 3.512	Outlet of Subcatchment 202 at Steeles Ave.	36.76	0.110	267	0.05
Node 3.513	Outlet of Subcatchment 203 at Steeles Ave.	52.47	0.157	269	0.05
Node 3.514	Outlet of Subcatchment 204 at Steeles Ave.	33.09	0.099	268	0.05

Table 2.2.14: Volume of Erosive Flow for Erosion Assessment of Existing Land Use Conditions

Erosion Site	Location	Contributing Drainage Area (ha)	$Q_{critical}$ (m^3/s)	Total Runoff Volume Exceeded (Mm^3)
ESMC(2)	East Sixteen Mile Creek +/- 200 m D/S of Steeles Ave.	2029.58	0.70	40.14
MC(4)	Mullet Creek +/-100 m D/S of Winston Churchill Blvd.	267.92	0.79	0.50
Node 3.511	Outlet of Subcatchment 201 at Steeles Ave.	20.68	0.062	0.037
Node 3.512	Outlet of Subcatchment 202 at Steeles Ave.	36.76	0.110	0.067
Node 3.513	Outlet of Subcatchment 203 at Steeles Ave.	52.47	0.157	0.096
Node 3.514	Outlet of Subcatchment 204 at Steeles Ave.	33.09	0.099	0.061

The results of the duration analyses indicate that the receiving watercourses would be susceptible to erosion flows for 2.27% and 0.06% of the time under existing land use conditions for Sixteen Mile Creek East branch and Mullet Creek respectively. This suggests that Mullet Creek is relatively insensitive to the erosion due to high critical flow value for a significantly smaller drainage area. In comparison, the Sixteen Mile Creek East Branch is relatively erosion sensitive, which is consistent with findings and observations elsewhere within the Sixteen Mile Creek Watershed (ref. Sixteen Mile Creek Subwatershed Update Study, Amec et. al., November 2017).

2.2.4.5 Water Balance

The water balance analysis has been conducted as part of the Phase 2 study. Based on the Premier Gateway Scoped Subwatershed Study Phase 1 report (Amec, April 2020) for the Secondary Plan Area proximate to the study area, the average annual groundwater recharge was estimated at 99 mm/annum within the Secondary Plan Area due to low permeable soils.

2.2.5 Summary of Findings

An HSP-F hydrologic model and a Visual OTTHYMO hydrologic model have been developed based on the current available models provided for this study. The purpose of developing the hydrologic model in different platforms is to maintain consistency with the current hydrologic modelling approach within Conservation Halton and CVC jurisdictions. The HSP-F methodology has been applied as the key hydrologic model to establish stormwater management criteria. The Visual OTTHYMO methodology has been applied for comparison with the HSP-F modelling results.

The HSP-F hydrologic model has been executed for a 56-year continuous simulation. The peak frequency flows as well as Regional Storm event have been determined for the existing land use conditions. In addition, erosion analyses have been completed for the existing land use conditions. The Visual OTTHYMO hydrologic model has been executed to determine the design storm 2-to-100-year return period peak flows as well as Regional Storm peak flows for the existing land use conditions.

Differences in simulated flows were noted between the two modelling platforms and when comparing to the parent models, the observed differences are potentially due to refined parameters as well as different algorithms and methodologies applied within the two platforms. However, in general, both the HSP-F hydrologic model and a Visual OTTHYMO hydrologic model are comparable to the parent hydrologic models and are considered representative of the existing land use condition.

2.3 Hydraulics

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

2.3.1 Scope Overview

The existing HEC-2 hydraulic models for the Sixteen Mile Creek East Branch has been used as the base model to establish the existing floodplain through the study area. The hydraulic model has been truncated and refined within the limits of the study area based upon the provided base mapping, georeferenced cross-sections, as well as field survey for the hydraulic structures.

Currently, no floodline mapping has been established for the streams within the portion of the study area which lies within Mullet Creek Subwatershed. In consultation with CVC, it has been confirmed that the watercourse enters from the north boundary of study area and exists at Winston Churchill Boulevard has been included in the hydraulic model using available information provided for this study.

The HEC-RAS hydraulic model for the Sixteen Mile Creek East Branch has been updated to include the peak flows for the 2-year through 100-year and Regional Storm events, as determined by the hydrologic analyses of the HSP-F model. Floodline mapping has been prepared to depict the Regional Storm Floodplain through the limits of the study area. In response to comments provided by CVC, the HEC-RAS hydraulic model for Mullet Creek has been updated to incorporate the simulated peak flows from the Visual OTTHYMO modelling, and to generate the floodplain through the study area under existing land use conditions.

2.3.2 Background Information Review

The background information listed in **Section 2.2.2** has been applied and referenced as appropriate for the hydraulic chromatinization and analysis.

2.3.3 Field Reconnaissance

A geodetic topographic survey has been conducted to develop an inventory of hydraulic structures within the Premier Gateway Lands. A summary of the hydraulic structures surveyed is provided in **Table 2.3.1**. The locations of the hydraulic structures are presented in **Drawing WR8**.

Table 2.3.1: Hydraulic Structure Inventory

ID	Location	Type	Size of Opening (span x rise) (m)	Upstream Invert (m)	Downstream Invert (m)	Length (m)	Road Deck Elevation (m)
Sixteen Mile Creek Watershed							
1	Sixteen Mile Creek at Steeles Ave.	bridge	12.5 x 4.7	200.26	200.25	26.3	205.75
4	8th Line	CSP pipe	0.9	209.19	209.00	16.06	209.47
5	+/-154 m east of 9th Line at Steeles Ave.	twin concrete box	3.0 x 0.92 3.0 x 0.88	213.33 213.38	213.08 213.16	37.4	215.20
6	+/-821 m west of 10th Line at Steeles Ave.	concrete box	3.0 x 0.82	214.78	214.55	32.46	217.14
7	+/-63 m west of 10th Line at Steeles Ave.	twin concrete box	3 x 0.68 3 x 0.89	213.53 213.35	213.34 213.26	33.39	215.04
8	10th Line	CSP pipe	0.6	215.63	215.47	10.37	
9	+/-77 m east of 10th Line at Steeles Ave.	twin concrete box	3 x 1.34 3 x 1.51	214.24 214.07	214.15 214.17	38.17	216.36
16	9th Line	concrete box	1.8 x 0.52	213.74	213.44	26.53	215.21
17	+/-430 m west of 9th Line; parallel to Steeles Ave.	CSP pipe	1.2	209.85	209.62	17.85	210.12
18	+/-624 m west of 9th Line; parallel to Steeles Ave.	CSPA pipe	1.4	207.95	207.69	15.25	208.11
19	+/- 681 m west of 9th Line; parallel to Steeles Ave.	CSP pipe	1.2	206.87	206.87	4.13	208.13
20	+/- 292 m East of 8th Line; parallel to Steeles Ave.	concrete pipe	1.05	205.54	205.39	15	206.78

ID	Location	Type	Size of Opening (span x rise) (m)	Upstream Invert (m)	Downstream Invert (m)	Length (m)	Road Deck Elevation (m)
Mullet Creek Subwatershed							
12	on private land	CPP culvert	not surveyed (inaccessible)				
13	on private land	CPP culvert	not surveyed (inaccessible)				
10	Winston Churchill Blvd.	open bottom concrete box	10.4 x 2.2	203.67	203.32	25.3	206.35

A comparison of the surveyed top of road with the elevations provided in the Town's DEM has been undertaken to confirm that the datasets are comparable and the elevations consistent. The results of this comparison have indicated that, in general, the differences between the elevations are less than 0.1 m, hence the information between the datasets is considered comparable.

2.3.4 Characterization and Analysis

A HEC-GeoRAS hydraulic model has been developed to conduct hydraulic analysis along the regulated watercourses within the study 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 model for the Sixteen Mile Creek East Branch. The alignments and locations have been reviewed and revised as appropriate in order to correspond to the contours within the DEM mapping provided for use in this study, as well as the US Army Corp HEC methodology. The limits of the model have been extended to encompass the regulated watercourse within the Mullet Creek Subwatershed which is currently not included in a hydraulic model. The extent of the hydraulic model for the Mullet Creek Subwatershed is from +/- 30 m upstream of the upper study area boundary to +/- 75 m downstream of Winston Churchill Boulevard. The hydraulic structures have been incorporated into the model as per the hydraulic structure inventory.

Reach Length

The reach lengths downstream of each cross-section have been measured based on the standard practice of calculating the length of the anticipated path of the center of mass for the overbank flow. Since HEC-GeoRAS was used to develop the HEC-RAS

model, the reach flow length for each cross-section has been calculated based on the designated bank stations and the distance to its immediate downstream cross section.

Roughness Coefficients

Standard values of Manning's 'n' have been applied for the new cross-sections. Manning's 'n' values for the existing cross-sections along Sixteen Mile Creek have been adjusted based on observations of the land cover. Overall, channel roughness values have been set to 0.035 for all channel reaches. Overbank values have range from 0.025 (where the overbank is predominately hard surfaces), to 0.08 (where the overbank is dominated by woods / forest cover).

Hydraulic Structures

Hydraulic structures 1 and 10 shown in **Table 2.3.1** have been incorporated into the model. Hydraulic Structure 1 is located at Steeles Avenue on Sixteen Mile Creek East Branch. Hydraulic Structure 10 is located at Winston Churchill Boulevard on Mullet Creek. At the structures, cross-sections have been added such that each structure would have four bounding cross-sections (two upstream and two downstream) as per standard practice and the recommendations of the HEC-RAS software documentation.

Ineffective Flow areas

Ineffective flow areas have been included for the upstream and downstream bounding cross-sections around hydraulic structures, 0.5 m away from the structure openings on each side. For the upstream bounding cross-section, the ineffective flow elevations have been set to the low point of the road deck. For the downstream bounding cross-section, the ineffective flow elevations have been set to the middle point between the road deck and the structure obvert, as is standard practice.

Expansion / Contraction Coefficients

Expansion and contraction coefficients are required to account for energy losses associated with potential changes between cross-sections. The Default value of 0.1 and 0.3 have been applied for regular cross-sections. Higher values of 0.3 and 0.5 have been applied at the immediately upstream and downstream of the cross-sections around hydraulic structures to represent the more abrupt contractions and expansions.

Obstructions and Levees

Buildings have been modelled as obstructions with an assumed 4 m height. Levees have been applied at high ground points separating low-lying areas and potential split flow areas.

Inline Structures

An inline structure has been added at the location approximately 25 m upstream of the hydraulic structure at Steeles Ave., to represent the weir feature identified during the monitoring program. The weir elevations are based on the geodetic topographic survey.

Boundary Condition

Normal depth has been applied as the boundary condition at both the Sixteen Mile Creek East Branch and Mullet Creek. The downstream slope for normal depth computation has been estimated at 0.0034 m/m for the Sixteen Mile Creek Reach and 0.0037 m/m for the Mullet Creek Reach.

The Regional Storm event peak flow rates, as determined from the hydrologic modelling, have been incorporated into the model to represent the Regulatory condition for the area watercourses. The Regulatory floodplain are provided in **Drawing WR9**, along with the current Regulatory Limit from Conservation Halton and CVC. The updated Regulatory floodlines are noted to be generally consistent with the current floodline mapping and wider through the study area. The differences are considered attributable to the differences in base mapping, refined parameters, as well as the differences in peak flowrates. Nevertheless, recognizing that the purpose of the hydraulic analyses for the current study is to inform the impact assessment rather than to delineate Regulatory Floodlines for the study area, the hydraulic model is considered appropriate for completing the impact assessment for this study.

To provide insights to potential influences on floodlines as a result from Regional Storm peak flow rates generated from different hydrologic platforms, a sensitivity analysis based on differences in peak flows for similar size drainage areas has been conducted as part of the Phase 2 study. Based on various previous studies it is estimated that approximately 5% changes in the floodline would be seen from the sensitivity analysis.

2.3.5 Summary of Findings

The Regulatory floodline mapping for the Premier Gateway Phase 2B study area has been updated, based upon the best available mapping and hydraulic stormwater data, as well as the updated hydrologic analyses. The floodlines are noted to be comparable to the current floodline mapping developed as part of the 1986 Flood Damage Reduction Program (FDRP) for the Sixteen Mile Creek Watershed. The floodplain within the reach of Mullet Creek through the study area is noted to extend beyond the current Regulatory Limit applied by CVC for the subject watercourse. The floodlines presented herein have been developed using updated hydrologic modelling and, in the case of the Sixteen Mile Creek East Branch, validated hydrologic modelling, and have been

parameterized in accordance with Conservation Halton and CVC practices. Sensitivity analyses for the hydraulic model are provided in Appendix E. While the floodlines are considered to be sufficient for comparison against current flood hazard limits and for informing natural flood hazard extents for land use planning purposes, the floodlines presented herein are not intended to represent Engineered Flood Hazard Mapping for Regulatory Flood Hazard Mapping purposes. The floodlines as presented herein are subject to further revision and refinement as part of future studies.

2.4 Stream Morphology

2.4.1 Scope Overview

The primary purpose of the fluvial geomorphology assessment and characterization component of the Scoped Subwatershed Study (SWS) (Phase 1 Characterization) is to identify and characterize surface water features within the study area, and collecting supplemental, available information to evaluate downstream sites (e.g., downstream erosion indices). This has been completed to determine the sensitivity of the form and contributions of each feature to development, while also limiting risk to settlement areas from fluvial erosion hazards. Each feature has been identified as either a watercourse or headwater drainage feature, with each having different requirements for characterization and analysis. They are evaluated in terms of form, composition, erosion hazards (watercourses), downstream contributions, and sensitivity to development (e.g., erosion sensitivity).

In order to identify and characterize watercourses and headwater drainage features (HDFs), a clear understanding on their definitions is required. The following definitions have been adapted from the guidance document *Evaluation, Classification and Management of Headwater Drainage Features Guidelines* (TRCA / CVC, 2014), and based on the existing understanding of drainage features within the FSA from the background review, and professional experience in other jurisdictions.

Watercourses

Watercourses are defined as permanently to intermittent flowing drainage features with defined bed and banks. They exhibit clear evidence of active channel processes including planform, profile, and material sorting, with evidence of a balance between erosion and deposition throughout the reach. They are often second-order or greater but may be first order when verified by the practitioner(s). Watercourses are currently identified as regulated features by the Conservation Authority, and fish are typically found within these features. The contributing drainage area is, in general, greater than

or equal to 50 ha, however, there may be instances where watercourses have smaller contributing areas.

Headwater Drainage Features (HDFs)

Non-permanently flowing drainage features that may not have defined bed or banks have been designated as HDFs. The presence of bed and bank definition within these features may be attributed to anthropogenic intervention (e.g., cutting a drainage feature into the surface), or seasonally as spring freshet concentrates flows in depressions, causing channel development into surfaces lacking vegetated cover. HDFs are first order and zero order intermittent and ephemeral channels, swales and connected headwater wetland, but do not include rills or furrows. They are not identified as a regulated feature, and fish may or may not be found within the feature. The contributing drainage area is generally less than 50 ha, however there may be instances where an HDF has a drainage area greater than 50 ha.

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 local and downstream channels and habitats is mitigated. This information will provide guidance to channel management and enhancements within the Study Area in relation to future development and infrastructure through Phases 2 and 3 of the Scoped SWS.

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 hydrologically informed watercourse mapping (shapefiles).
- Use available mapping to delineate channel reach boundaries for watercourses and HDFs, based on the definitions described above.
- Characterize valley setting (confined or unconfined) on a reach basis based on available topographical data (e.g., DEM derived contours).
- Delineate the meander belt and long term stable top of slope as appropriate on a reach basis for watercourses within the study area.
- Complete field reconnaissance to confirm existing geomorphic conditions, document evidence of active erosion and confirm desktop results for watercourses, and to execute seasonally based HDF Assessments by applying TRCA / CVC (2014) protocols.

— Determine erosion threshold values for receiving watercourses to inform preliminary SWM opportunities and quantity targets.

The Premier Gateway Phase 2B study area includes watercourse reaches and headwaters of Sixteen Mile Creek and Mullet Creek, which fall under the regulatory jurisdiction of Conservation Halton (CH) and Credit Valley Conservation (CVC), respectively. Reaches associated with Sixteen Mile Creek fall along the East Branch, with a permanently flowing, well-defined, meandering watercourse through a floodplain set within a confined valley system. Mullet Creek study reaches contrast those of Sixteen Mile with highly impacted (agriculture and lawn), channelized features that are intermittent in nature, with poor definition in the majority of the study area, with some definition upon approach to Winston Churchill Boulevard. Impacts continue downstream of the study area, and only the immediate ~500 m of channel within a narrow, forested riparian area while further downstream agricultural impacts persist. **Figure 2.4.1** presents the overall layout of the study area in the context of area drainage mapping.

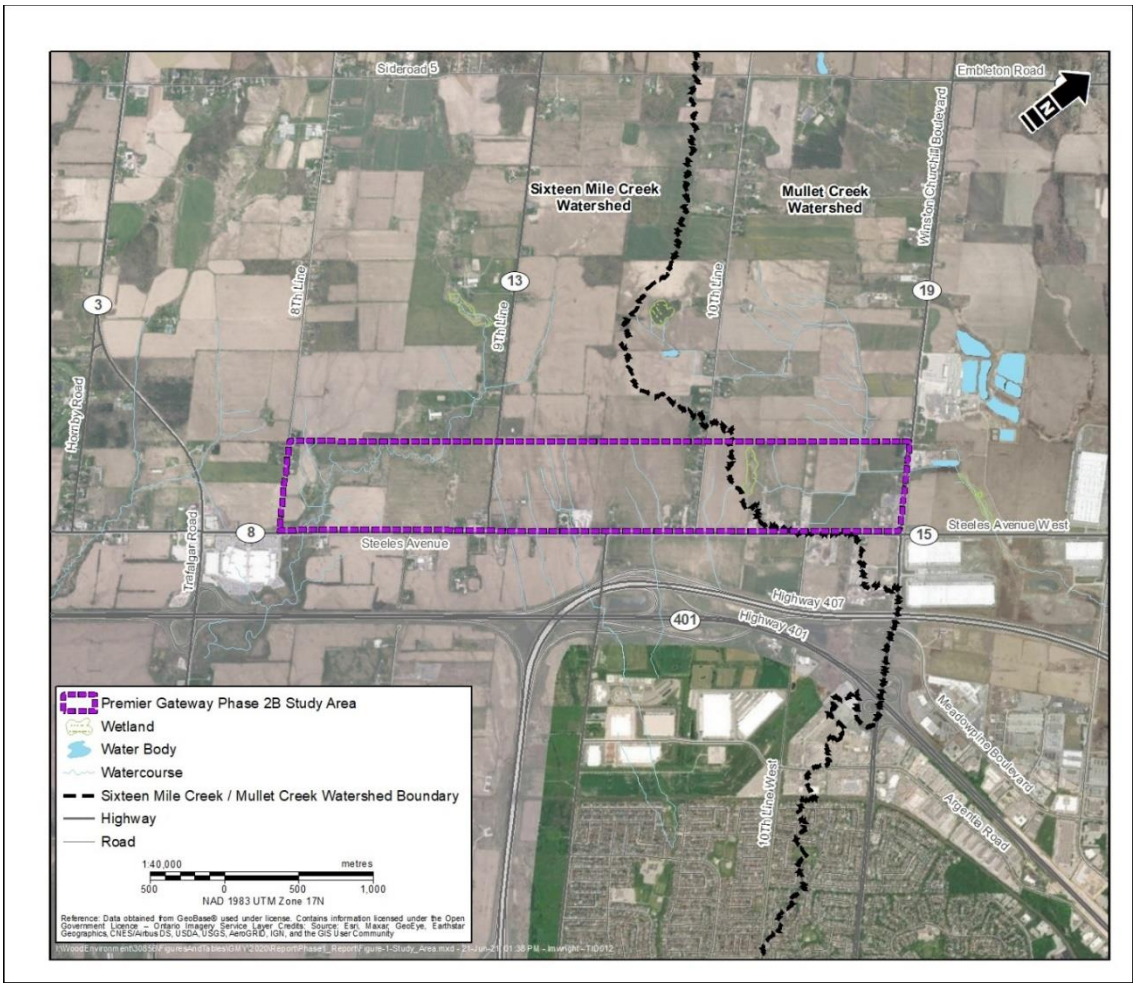

Figure 2.4.1: Study Area in the Context of Area Drainage Mapping

2.4.2 Background Information Review & Preliminary Desktop Characterization

A background review has been undertaken to gather information on the drainage features contained within the study area. Reviewed data included previous studies, policy documents, and mapping information. This information forms the foundation of the initial characterization work, as well as the field program, ensuring proper focus on pertinent characteristics. Key documents and mapping are summarized below.

Reports:

- Scope Subwatershed Study Northeast Corner Steeles Avenue and 8th Line. Prepared for Hodero Holdings Ltd. September 2020
    - The subject property is located within the study area of the current Premier Gateway Phase 2 area, and primarily occupies lands between 8th Line and East Sixteen Mile Creek. This study was undertaken with limited detail necessary for the purpose of supporting the completion of the Official Plan and Zoning By-Law Amendments and associated servicing studies related to a development proposal for the subject property.
    - Headwater Drainage Feature assessments were completed by Savanta Inc. as a part of the ecological investigations. All HDFs evaluated are relevant to the current study, with classifications ranging from 'No Management Required' to 'Conservation', with several features being unassessed as they fall under protection within the East Sixteen Mile Creek valley corridor.
    - Fluvial Geomorphology Assessment was prepared by GEO Morphix Ltd. and included: reach delineation, historical assessment, erosion hazard delineation, rapid field assessment, detailed field survey and erosion threshold and exceedance analyses. Reach ESMC0, ESMC1, the Hodero study are relevant to the current Scoped SWS for main branches of East Sixteen Mile Creek. Both were described as meandering within a floodplain with primary observations of widening and planform adjustment. A detailed geomorphic survey was completed on reach ESMC0 (located downstream of Steeles Ave.), and bankfull channel widths averaged 5.63 m with depths of 0.89 m at a slope of 0.3%. The median particle size observed was 11.1 mm (pebble) and applied in the erosion threshold analysis. A critical shear stress of 8 N/m^2 was determined using the Chow (1959) relationship, corresponding to a critical discharge of 0.47 m^3/s.
    - An erosion hazard assessment determined meander belt widths using a selection of empirical relationships based on observations of the bankfull

channel in ESMC1. Reach ESMC1 was evaluated as partially confined whereby meander migration was only partially limited by the valley on one side of the channel. The largest meander amplitude was also measured from historical and current air photos for ESMC1 and proposed as the meander belt. A 20% factor of safety was applied, and a toe-erosion allowance was estimated based on bank composition (sand,silt) and evidence of channel erosion and slope stability (MNR guidelines, 2002). An 8 m toe erosion allowance was recommended. It was noted that these erosion hazard limits should be subject to refinement with more detailed studies.

- Fluvial Geomorphic Assessment of Stream Road Crossings Along Steeles Avenue (Trafalgar Road to Winston Churchill Boulevard, Parish Geomorphic (Submitted to AECOM), August 2010).
  - A watercourse crossing inventory and channel evaluation was completed with respect to fluvial geomorphic hazards and processes for six proposed crossing upgrades (five within the current study area). With the exception of East Sixteen Mile Creek, geomorphic evaluations were limited within the road right of way along Steeles Avenue. For smaller crossings and less-defined channels, estimates of bankfull width and depth from and within the ROW are likely unrepresentative at the reach scale, and possibly over-estimated based on a review of site photography.
- South Milton Urban Expansion Area Subwatershed Study – Final Report (WOOD, 2021)
  - Matrix Solutions completed the fluvial geomorphology component for the Subwatershed Study which is focused on East, Middle, and Main Sixteen Mile Creek within the Town of Milton, South of Highway 401, downstream of the current study area. Relevant to this study is the erosion threshold analysis, which was completed at several locations, including two on receiving features from the Premier Gateway Phase 2 lands. including detailed channel surveys to determine erosion threshold targets.
- Ninth Line Lands Scoped Subwatershed Study, City of Mississauga (Wood, 2020)
  - Matrix Solutions completed the fluvial geomorphology component for this Scoped SWS to determine environmental limitations and requirements for development within a corridor bound by Highway 407 (eastern limit), Highway 401 (northern limit), Ninth Line (western limit), and Lower Base Line (southern limit). Geomorphic characterization was completed along watercourse reaches, including detailed surveys at select locations to determine erosion threshold values for SWM evaluations. These erosion thresholds are relevant to the current

Scoped SWS for receiving watercourses on the south side of Steeles, west of Ninth Line. Reach NL-10 is located upstream of the Lisgar Pond (a large online SWM facility), and the threshold for loose sandy material of 1.09 m^3/s has been applied in the current study.

- Calloway REIT Halton Hills Subwatershed Impact Study 401 Corridor. 13722 Steeles Avenue, Town of Halton Hills. Prepared for Calloway REIT (Halton) Inc. Geomorphic Solutions, 2012.
  - Geomorphic Solutions (2012) undertook an erosion sensitivity analysis and applied of a series of sediment entrainment models. The analysis resulted in a critical discharge 0.18 m^3/s. This threshold was still considered conservative as it correlated to a critical depth of 0.20 m and a critical velocity of 0.45 m/s.
- 401 Corridor Integrated Planning Project, Town of Halton Hills. Scoped Subwatershed Plan Final Report. Dillon Consulting, March 2000
  - The study area extended from James Snow Parkway to Winston Churchill Boulevard, between Steeles Avenue and Highway 401.
  - This Planning Project reviewed erosion potential for downstream sites based on thresholds as determined in the Sixteen Mile Creek Watershed Plan (1996). Only one threshold site from that study is downstream the current study area. It is located on East Sixteen Mile Creek, in the vicinity of Lower Base Line. It is not considered relevant to the current study for which more recent data in closer proximity along sensitive reaches is available.
  - Erosion sites were noted along East Sixteen Mile Creek, downstream of Steeles Avenue.
  - Reach D corresponds to the current study reach downstream of Steeles Avenue along East Sixteen Mile Creek.
  - Mullet Creek was not evaluated in any detail.

The following **policy documents and guidelines** were reviewed to support the geomorphic characterization and analyses:

- OMNR Technical Guide. River and Stream Systems: Erosion Hazard Limit (2002)
- Conservation Halton. Policies and Guidelines for the Administration of Ontario Regulation 162/06 and Land Use Planning Document (2006). Amended 2016.
- CVC Fluvial Geomorphic Guidelines (2015)
- TRCA Belt Width Delineation Procedures (2005)

The following mapping was reviewed:

- Town of Halton Hills Orthophotography (1999)
- Town of Halton Hills topographic contours (0.5 m)
- Credit Valley Conservation (CVC) and Conservation Halton (CH) watercourse mapping shapefile
- CVC and CH regulatory mapping
- CH stable top of slope and meander belt mapping
- Esri basemap 2019 aerial imagery
- Historical aerial imagery (1954)

Physiography and Surficial Geology

The geology of any area influences the characteristics of watercourses and their interactions with their floodplains. Geology influences channel geometry, rates of channel migration, and defines the quantity and type of channel sediments. The Premier Gateway Phase 2B study area falls within the Peel Plain physiographic region. The Peel Plain is a level to gently undulating till plain with consistent grade sloping towards Lake Ontario (Chapman and Putnam, 1984; OGS, 2003). It consists of shale and limestone bedrock covered by predominantly fine-grained overburden sediment. The surficial geology of the study area is heterogeneous with three different deposits: glaciolacustrine, till, and stratified ice-contact (ref. Figure GW-4). The primary surficial material in the area consists of the sandy-silt to clayey-silt Halton Till, with smaller areas of silt / clay glaciolacustrine deposits and a localized coarser sand and gravel deposit. Modern alluvial deposits of gravels, sand, silt, clay, and muck are located within the floodplain of East Sixteen Mile Creek.

Agency Site Walk – October 23, 2020

In addition to the review of site mapping, a coordinated site walk was undertaken on October 23, 2020, shortly after project initiation to identify area drainage features and guide the assessment and review. Representatives from Conservation Halton (CH), Credit Valley Conservation (CVC), and the Town of Halton Hills (the Town) were joined by Scoped SWS staff from Natural Resource Solutions Inc. (NRSI) and Matrix Solutions Inc. (Matrix), to identify and evaluate natural heritage and drainage features within the study area. This included a cursory review of the reach delineation and preliminary identification of watercourse and HDF reaches for Sixteen Mile Creek and Mullet Creek. Members who attended the site walk included:

— Emma DeFields (CH)

— Yves Scholten (CH)

— Rizwan Haq (CVC)

— Christine Wilson (CVC)

— Dorothy DiBierto (CVC)

— Kate Sapozhnikova (Town)

— John McDonald (Matrix)

— Natasha Cyples (Matrix)

— Katharina Richter (NRSI)

2.4.2.1 Reach Delineations and Feature Types

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. In some cases, reaches were defined based on changes in channel alteration or management and are best described as “management reaches” rather than geomorphic reaches. Such management reaches which account for historical land use variations are typically contained within larger geomorphic reaches that reflect the longer-term physical processes in the drainage network. Reach delineation is completed as part of the desktop assessment and used to guide the subsequent field program.

All reaches delineated within the Study Area were given a preliminary categorization during the desktop review as either watercourse or HDF reaches. The reach delineation and initial categorization into “watercourse” and “HDF” reaches was then verified first during the Agency Site Walk (October 23, 2020) and then refined based on observations made during multiple, seasonal field assessments through Summer / Fall of 2020, and Spring of 2021. **Drawing FG-1** presents recommended feature

identification and reach limits for watercourses and headwater drainage features within the Study Area.

Watercourse reaches have been further identified as being located within ‘unconfined’ or ‘confined’ valley systems based on the presence of a defined valley. This type of classification will further assist during the delineation of meander belt widths and erosion hazard limits. Unconfined 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 flat or gently rolling landscapes. Confined watercourses are ones in which the physical presence of a valley walls, with an elevation greater than or equal to 2 m above the floodplain (CH, 2016). 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).

Note: Watercourses and HDFs associated with the Gilbach SWS along the western limit of the Study Area have been evaluated and management recommendations established as a part of that study, submitted under a separate cover. This includes feature mapping, constraints / classifications, hazards and buffers. Discussions, tables, and mapping presented herein within the Watercourse Management sections are exclusive of the findings for the Gilbach Property.

2.4.2.2 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. Historic photos of the Study Area from 1954 were reviewed along with Google imagery and orthophotography from 2019.

2.4.2.3 Erosion Hazard Delineation – Meander Belt and Stable Top of Slope

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 allow natural fluvial and slope processes to occur while minimizing risk to property, human settlement, and infrastructure. Within a Scoped Subwatershed Study context, studies require the general identification of meander belt widths to facilitate the planning process. 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 have been defined by parallel lines drawn tangential to the outside bends of the laterally extreme meanders of the planform for each reach. Due to limitations with the available historic photos (1954 only), 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). Reaches associated with Mullet Creek were found to be unconfined within the study area.

In addition to meander belt delineations for unconfined watercourse reaches, an erosion hazard limit has been determined for confined channel systems by way of the stable top of slope. For the confined systems within the Study Area, a stable top of slope limit has been delineated following Provincial Policy Statement (PPS) technical guidelines. Within the confined reaches of the Study Area, the watercourses typically meander back and forth between valley wall contacts, but some are more confined than others, and several are semi-confined on the reach scale with portions of the reach exhibiting confinement. The PPS requires that a toe erosion setback be applied where a watercourse is within 15 m of the valley toe (MNR, 2002), plus a stable slope allowance (3:1, H:V), and erosion access allowance of 6 m. East Sixteen Mile Creek is considered a major watercourse system within Conservation Halton's jurisdiction, and as per their policy, a regulatory setback of 15 m is required from the greatest of all hazards. Therefore, 15 m was applied as a setback to the long-term stable top of slope along East Sixteen Mile Creek.

It is understood that as a part of the Scoped Subwatershed Study Northeast Corner Steeles Avenue and 8th Line (JLA et. al., 2020), top of bank staking has occurred in consultation with Conservation Halton along the western slope of East Sixteen Mile Creek. A staking exercise has yet to be completed on the opposite valley slope. In the absence of field staking, long term stable top of slop analyses as per the PPS have been undertaken as part of this Scoped Subwatershed Study to provide a conservative setback for development and is subject to further refinement as part of future staking exercise as supervised by Conservation Halton and subsequent planning studies. This approach has been accepted by Conservation Halton (ref. email correspondence April and May 2021 (various dates) in Appendix F.4), and details regarding the methodology are provided further in this report.

2.4.3 Field Survey Methods – Watercourses and HDFs

2.4.3.1 Watercourses

Rapid Assessments

In order to provide insight into existing geomorphic conditions on a reach basis, field reconnaissance was completed in September of 2020. 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 2.4.1**).

Table 2.4.1: RGA Classification

Score	Classification	Observations
≤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 widespread

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

To gain further insight into geomorphic processes, detailed field sites have been established based on the results of the rapid assessments. The sites selected are generally those that are representative of the overall study area in terms of spatial and morphologic perspective. Sites also have been selected based on stability; areas that are most vulnerable to change need to be characterized in order to inform development planning.

The detailed field assessment uses standard protocols and known field indicators to quantify the bankfull geometry of the reach (i.e., bankfull depth, width, and gradient). The “bankfull” channel area generally represents the maximum capacity of the channel before flow spills onto the floodplain, and it is usually identified by obvious breaks, or inflections, in the cross-section profile and changes in vegetation along the channel margin. Generally, 5 - 10 cross-sections are measured to determine the bankfull channel geometry. At each cross-section, a modified Wolman (1954) pebble count is completed to characterize the channel bed materials. Banks are also characterized at

the cross-sections (height, angle, composition, degree of vegetative cover). A longitudinal profile is surveyed to define the local channel gradient through the site and also included key features along the channel bed (top and bottom of riffles, max pool depths, flow obstructions). These detailed channel measurements may then be used to estimate the hydraulic parameters at bankfull stage (i.e., discharge, velocity, shear stress) and identify the respective critical values needed to entrain sediment from the channel bed. Two detailed surveys were completed downstream of the study area limits: one on East Sixteen Mile Creek downstream of Steeles Avenue and one on Mullet Creek downstream of Winston Churchill Boulevard within sensitive downstream reaches.

The data from the detailed field assessment has been used to complete the erosion threshold analysis. This analysis determines the hydraulics, such as discharge, channel depth, or average channel velocity, at which the channel produces sufficient shear stress to initiate the mobilization of sediment of a give size (Dcrit). The analysis also helps to evaluate a reach's erosion sensitivity by comparing the boundary shear stress associated with modeled flows to the critical shear stress required to entrain sediment. **Section 2.4.4.4** includes further detail and discussion.

Geomorphic Monitoring

To establish a baseline from which to measure channel changes subsequent to the Scoped SWS, a geomorphic monitoring program has been established within each detailed survey reach: ESMC(2) and MC(4). It was initiated late in 2020 with a subsequent visit following the Spring freshet (**Table 2.4.2**). Within each, a monumented cross-section was established with control-points installed beyond the bankfull channel, within the floodplain or at the top-of-bank depending on valley geometry. The control cross-section typically represents a 'riffle' location within the reach when riffle-pool morphology is observed, and on a 'run' location in reaches without riffle-pool morphology. Although not required within the TOR, erosion pins were installed horizontally into eroding banks to provide a means of comparison between channel cross-section trends and estimates of bank erosion.

Table 2.4.2: Survey Date of Geomorphic Monitoring Sites

Site ID	Date Surveyed – Fall 2020	Date Surveyed – Spring 2021
ESMC(2)	December 14, 2020	May 11, 2021
MC(4)	December 14, 2020	May 11, 2021

Field Data Collection

Monitoring of channel form and function within the study area is repeated twice a year (fall and spring) at each of the established geomorphic monitoring sites. Each monitoring site was established following standard protocols. This included installing permanent monument pins which can be revisited and re-measured for historical changes in the cross-sectional area of the channel. Two erosion pins were also installed at each site to provide a secondary source of information regarding bank recession. The geomorphic monitoring measurements include:

- Detailed cross sectional profile at benchmarked cross-sections
- Bed substrate characterization (min. 50 pebbles using the modified Wolman pebble count method) at each cross-section
- Erosion pin measurement
- Photographs from fixed vantages to document change in the reach over time

2.4.3.2 Headwater Drainage Features

HDFs are, in general, poorly defined in nature. Within settled regions, many 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 sediment, water, nutrients, and organic matter for downstream reaches. The 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 Study Area were first identified through a review of available watercourse mapping, drainage areas, and current aerial imagery. An agency site walk (October 23, 2020) further informed the identification and delineation of HDFs and watercourses within the Study Area.

Following HDF assessment protocol (TRCA / CVC, 2014) a detailed field study was undertaken to field verify potential features where access was available or from acceptable vantage points. 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 Study Area where property access was granted. The site assessments fell within the recommended timing windows, however, due to the timing of the initiation of the Scoped SWS and the anticipated project schedule, it was proposed to complete the third visit in Summer of 2020, while returning to complete first and second visits the following Spring. Round 3 assessments were completed on September 4, 2020 (summer) by evaluating all features as mapped and any as identified in the field, and the entire study area was walked (within the limits of permission to enter agreements). Round 1 site visits occurred on March 17, 2020. Round 2 visits occurred on June 2 and 9, 2020. **Drawing FG-4** presents the location of HDF and watercourse reaches within the Study Area.

A monitoring program was initiated a part of this study within the detailed survey reaches: ESMC(2) and MC(4). Within each, a monumented cross-section was established with control-points installed beyond the bankfull channel, within the floodplain or at the top-of-bank depending on valley geometry. The control cross-section typically represents a ‘riffle’ location within the reach when riffle-pool morphology is observed, and on a ‘run’ location in reaches without riffle-pool morphology. Although not required within the TOR, erosion pins were installed horizontally into eroding banks to provide a means of comparison between channel cross-section trends and estimates of bank erosion.

2.4.4 Characterization and Analysis

Drainage features within the study area are associated with two systems: East Sixteen Mile Creek and Mullet Creek. Watercourse reaches of East Sixteen Mile Creek are concentrated in the western portion of the study area within a confined valley (Reach ESMC(3)). These are situated within a well-defined valley and may be considered

confined based on CH regulatory framework which describes valley features with an elevation differential between floodplain and tablelands of 2 m or greater as confined (CH, 2016). With that said, there is a relatively expansive floodplain set within the confined valley through which the meandering channel is free to migrate. Therefore, from a geomorphic perspective, it may be considered semi-confined where valley wall contacts with the main channel form a constraint to migration. Since the channel is located within a well-defined valley it has been less impacted by land use and direct modification than those of Mullet Creek, but it appears to be less forested through the study area than downstream reaches (floodplain meadow) suggesting some land cover modification due to historical settlement. Headwater drainage features are located throughout agricultural lands on the table lands elsewhere in the Study Area within the Sixteen Mile Creek catchment (Drawing FG-4).

Mullet Creek is a tributary of the Credit River. Reaches within the study area are primarily intermittent headwaters (watercourses) within an unconfined setting. Watercourse reaches are straight and bound by agricultural fields, with the exception of manicured lawn towards the downstream extent of reach MC(4)1 approaching Winston Churchill Boulevard.

2.4.4.1 Historical Assessment

Available online sources of historical aerial photos have been used to complete a historical assessment of the area drainage features and modifications in land use and landcover that may have had direct or indirect implications on channel form and process.

In 1954, the Study Area was dominated by agricultural land use with associated rural residential dwellings. Occasional woodlots and sparsely treed hedgerows are observed and are connected to the main watercourse through HDFs. The land use type has remained, in general, consistent through to the present. The riparian zone and floodplain along Reach ESMC(3) in 1954 resembles that of the present day, with limited forest cover, however, the channel has become more sinuous by 2019, likely due to historical straightening prior to 1954 and natural recovery of channel length. Watercourse reaches of Mullet Creek appear to have already been straightened by 1954 and have remained in the same location since, without any obvious meandering. Overall, many of the larger, more defined HDFs are still present today that were observed in 1954.

Changes within the Study Area have occurred more recently, associated with road widening along Winston Churchill Boulevard and Steeles Avenue. Based on a review of available aerial imagery, it is understood that Winston Churchill Boulevard was widened between 2009 and 2013, with full replacement of the crossing structure over Mullet

Creek, which is now an open bottom culvert with a low flow channel and floodplain benches within. Steeles Avenue was widened over a period from 2012 to 2015. Some pipe culverts along Steeles Avenue associated with HDFs and low-order watercourses (south of the study area) were replaced by box culverts, and the bridge at East Sixteen Mile Creek was lengthened to the south by approximately 15 m in 2015.

2.4.4.2 Erosion Hazard Delineation

Table 2.4.3 and **Table 2.4.4** detail the results of the erosion hazard assessment for confined (long term stable top of slope) and unconfined (meander belt) systems, respectively, and **Drawings FG-2** (East Sixteen Mile Creek) and **FG-3** (Mullet Creek) present erosion hazard limits and the accompanying regulatory setbacks that are applicable to the Study Area. Due to the limitations with the photo record and the observed direct modification from the historical assessment, a 20% factor of safety was calculated and applied to the meander belt for unconfined reaches of Mullet Creek (10% to either side) in lieu of calculating the 100-year migration rate. For confined reaches of East Sixteen Mile Creek, the long-term stable top of slope has been delineated by first tracing the toe of slope and extending a stable 3:1 (H:V) line outwards on either side. Where the channel is within 15 m of the toe of slope, a toe erosion allowance of either 2 m or 8 m (**Drawing FG-**2) has been added based on the slope material composition of stiff cohesive soil (clays, clay-silt) (OMNR 2002) and is dependent on whether active erosion was observed as per the Provincial Policy Statement 3.1.1. A 6 m erosion access allowance has been added along Mullet Creek meander belts, in accordance with the OMNR Technical Guide (2002). For East Sixteen Mile Creek, a 15 m setback has been added in accordance with CH Policy (CH 2016), which supersedes the 6 m erosion access allowance.

Mullet Creek reaches are located near the headwaters of the subwatershed and the site visit confirmed that the channel is highly impacted by historical and ongoing agricultural practice as well as localized lawn landscaping, and overall, is poorly defined (refer to **Rapid Assessments** in **Section 2.4.4.3**,). Meander development is lacking, as is planform adjustment in general. Nevertheless, the delineated meander belt width provides space for lateral expression (such as split flow, relocation of the low flow channel around organic debris, etc.) as well as providing room for modified reaches to adjust back to a more natural condition. Additionally, the meander belt helps to preserve floodplain and riparian function. The meander belt has been delineated by offsetting the channel centreline using an average of empirical equations (Annable 1996 and Dunne 1978) based on field measurements including drainage area and bankfull discharge.

Table 2.4.3: Meander Belt Widths for Unconfined Reaches

Reach	Meander Belt Width (m)	20% Factor of Safety (10% Either Side of Channel)	Meander Belt Width + FOS (m)	Preliminary Meander Belt Width (m) (including 6 m erosion access allowance)*
Mullet Creek				
MC(4)1	38	7.6	45.6	58
MC(4)2	33	6.6	39.6	52

*rounded up to nearest whole number

Table 2.4.4: Hazard Corridor Delineations for Confined Reaches

Reach	Valley Floor Width (m)	Average Slope Height (m)	3:1 Stable Top of Slope Setback (m)	Conservation Halton 15m regulatory setback for major systems (m)*	Toe Erosion Allowance (m)	Total Hazard Corridor, (m)
East Sixteen Mile Creek						
ESMC1	50 – 175	3 – 5	9 - 15	15	2 - 8	79 – 227

*15 m regulatory setback was applied on either side of erosion hazard

2.4.4.3 Field Investigations

The reach delineation and initial categorization into “watercourse” and “HDF” reaches that was completed during the desktop assessment and was verified during the Agency Site Walk on October 23, 2020 with representatives from CH and CVC, and during rapid assessments and seasonally based HDF field work. Reaches that may be subject to further consideration are noted in following section.

Rapid Assessments

The study area encompasses portions of the East Sixteen Mile Creek and Mullet Creek Subwatersheds. **Appendix F-2** presents site photographs of each watercourse reach that was evaluated as part of the rapid reach assessment as well as reaches within the road right-of way immediately downstream of the Study Area. **Table 2.4.5** provides a summary of the rapid assessment scoring results and a brief description of each reach. A summary overview of each creek system is provided below.

Assessed Watercourses of East Sixteen Mile Creek

The main branch of East Sixteen Mile Creek (ESMC1) contains a very sinuous planform and meanders through a predominantly meadow setting within the Study Area with localized, small pockets of trees along the channel banks. The main branch contains an

expansive floodplain set within the confined, well-defined valley through which the channel is free to migrate. There are approximately six valley wall contacts throughout the assessed reach and where there are valley wall contacts, channel banks are often vertical with exposed parent material. The main channel gradually becomes wider as it approaches Steeles Avenue where a large beaver dam has resulted in significant backwatering in the floodplain up to the valley walls. The creek corridor is relatively unaltered as it is within a large valley. The riparian zone and channel banks are very well vegetated and stabilized by tall grasses and shrubs. Where the channel planform is actively meandering, channel undercutting occurs, providing shade and covers for aquatic species. The channel lacks a defined pool-riffle sequence, and instead, contains transitional zones or “runs” with a mix of substrate ranging from small boulders and cobbles to sand and clay / silt. Bankfull dimensions of the main branch remain relatively consistent, except for the area proximal to the beaver dam. Organic debris is frequently present in the channel due to beaver activity, and vegetation can encroach into the channel. There was evidence of higher flows in early spring (evidenced by debris in branches), and lower flow conditions in late summer, where minimal flow was observed. The dominant geomorphic processes affecting the stability of the channel is widening.

The tributary to East Sixteen Mile Creek within the Gilbach study area, is contained within a partially confined valley (east side) with minimal geomorphic processes observed. The tributary is poorly defined for most of the reach but becomes more defined closer to the confluence with the main branch. Overall, the East Sixteen Mile Creek valley corridor and its tributaries are relatively stable with minimal evidence of active erosion occurring.

Downstream of Steeles Avenue, East Sixteen Mile Creek (Reach ESMC(2)) widens substantially and flows through a dense woodlot. The channel planform is very active and meandering with extensive erosion occurring throughout most of the reach. Bank slumping and exposed tree roots, as well as fallen / leaning trees were prevalent. Pools and riffles were better defined within this reach with an increase in coarse substrate noted. Similar to upstream, the creek corridor appears relatively unaltered and undergoes periods of flashy flows evidenced by debris hanging in trees.

Reaches TESMC(1) and TESMC(2) are watercourse reaches on the south side of Steeles Avenue, beyond the Phase 2B lands, and receive flows from upstream HDFs and Steeles Avenue outfalls and ditches. Permission to Enter agreements were not reached for these properties, and observations were limited to the road right-of-way (ROW). Additionally, observations can be compared to those made by Parish Geomorphic in 2007. Observations made in 2007 noted that the channel in the vicinity of each culvert (within the ROW) was wider than the existing pipe culverts. Downstream

observations made on each reach noted a lack of channel definition and erosion farther downstream. Recommendations were made to replace the existing pipe culverts with larger concrete box culverts. During the 2020 site walks it was noted that these culverts had been replaced accordingly. Ponding was noted downstream of TESMC(1) with a wide, wet area and then wetland vegetation downstream with no channel definition observed. Google imagery reveals that the channel is densely vegetated for the entire length, with the occasional short length of defined channel (possibly furrowed). Slight channel definition was noted to extend from the outlet at TESMC(2) extending downstream for ~10 m before vegetation encroached and obscured observations. Farther downstream it was apparent that agricultural equipment crosses this feature. Google imagery suggests that channel definition continues toward Highway 407. Rapid assessments were not performed on these features due to limitations in the field.

Assessed Watercourses of Mullet Creek

The assessed reaches of Mullet Creek include modified reaches with limited riparian cover and contain wetland-type vegetation within the channel or along channel margins. Both watercourse reaches MC(4)1 and MC(4)2 were historically straightened as a result of agricultural practices and display limited evidence of geomorphic activity. They contain abundant instream vegetation consisting of tall grass and cattails and were not observed to be flowing during any of the seasonal field assessments. Where the RGA was applicable, processes affecting the stability of the channel included aggradation. Reach MC(5) feeds into the watercourse MC(4)1 and has been classified as an HDF based on its small drainage area (~50 ha) and lack of geomorphic processes / elements.

Downstream of Winston Churchill Boulevard, Mullet Creek (Reach MC(4)) is also straightened along the edge of the Maple Leaf industrial property. The channel contains more characteristic geomorphic elements (i.e., pool-riffles, sediment sorting) as well as geomorphic process (i.e., widening and aggradation). Periods of flashy flows appear prevalent as evidenced by recent debris hanging in trees. On the right side, the channel contains a small woodlot and agricultural vegetation.

Table 2.4.5: Rapid Assessment Results for the Study Area

Reach	RSAT Score	RSAT Condition	RGA Score	RGA Condition	
East Sixteen Mile Creek					
ESMC1	30	Moderate	0.13	In Regime	Dominant process: Widening. Estimated bankfull width: 7 m, although larger width towards Steeles Ave. crossing. A beaver dam (~ 15 m wide) was observed immediately upstream of Steeles Ave. and is backwatering a large area of the floodplain. Channel planform is very sinuous, and banks are well vegetated with tall grasses and minor shrubs. The channel is stabilized with riprap at the road crossing on the banks and under the bridge. Small fish were observed.
ESMC(2)*	32	Moderate	0.33	Transitional	Dominant process: Widening. Estimated bankfull width: 8 m, although width varies throughout. Channel planform is very sinuous with evidence of active erosion throughout entire reach. Banks are vertical in most places and overhanging or undercut. The channel is actively widening as seen by fallen / leaning trees and exposed tree roots. Several debris jams in the channel were noted along the reach walk.
TESMC(1)*	14	Low	0	In Regime	Minimal geomorphic processes observed from the road ROW. Several of the RGA criteria do not apply as the channel is entirely vegetated (both on the bed and banks) and was dry during all field assessments.
TESMC(2)*	14	Low	0	In Regime	Minimal geomorphic processes observed from the road ROW. Several of the RGA criteria do not apply as the channel is entirely vegetated (both on the bed and banks) and was dry during all field assessments.
Mullet Creek					
MC(4)1	22	Moderate	0.03	In Regime	Minimal geomorphic processes observed. Estimated bankfull width: 2.5 m. Channel was historically straightened between farm fields. Closer to Winston Churchill Boulevard crossing, lawn has been mowed up to the edge of channel banks causing slight bank instability and slumping. Riprap has been placed around and under relatively new culvert crossing.

Reach	RSAT Score	RSAT Condition	RGA Score	RGA Condition	
MC(4)2	22	Moderate	0.03	In Regime	Minimal geomorphic processes observed. Estimated bankfull width: 1.8 m. Channel was historically straightened between farm fields and is heavily vegetated with tall grass and cattails. Minimal evidence of instream or bank erosion observed.
MC(4)*	22	Moderate	0.29	Transitional	Dominant processes: Widening and aggradation. Estimated bankfull width: 4.5 m. Channel was historically straightened due to industrial and agricultural practices. Banks are near-vertical through most of the reach with extensive basal scour and channel undercutting. Banks are not well vegetated and thus lack stability. No channel hardening has been put in place with the exception of near the downstream end of the culvert crossing where riprap has been places along the channel banks and storm outfall.

*downstream of Study Area

Detailed Assessments

Based on the results of the rapid geomorphic assessments, two detailed geomorphic field sites were established downstream of the Study Area. Results of the detailed field investigation can not only be used to characterize pre-development channel geometry and estimates of bankfull hydraulics, but also to establish targets for stormwater management to be evaluated under future development scenarios.

Selection of the detailed sites is completed by reviewing reach characteristics of existing instability (sensitivity to land use change), representative spatial distribution, and extent of channel alteration. Reaches that are located downstream of the Study Area, or reaches having a greater drainage area, are more frequently selected at the subwatershed study scale as they are more likely to be impacted by broad scale land use changes. Unaltered reaches are preferred as they offer a more accurate depiction of channel processes under existing conditions. However, Mullet Creek has been historically straightened both within the Study Area and downstream of it, making it difficult to select a natural reach. MC(4) immediately downstream of Winston Churchill Boulevard was selected as a result of having a defined channel with observations of geomorphic processes including erosion, deposition, and substrate sorting. Additionally, riparian cover includes tree cover, though relatively narrow compared to reached downstream of Highway 407. In total, two detailed sites were surveyed downstream of the Study Area, with one each on East Sixteen Mile Creek and Mullet Creek.

The detailed field assessments were completed on November 10, 2020 for Mullet Creek (Reach MC(4)) and December 14, 2020 for East Sixteen Mile Creek (ESMC(2)), both along main branches of their respective subwatershed. Five to eight channel cross-sections were surveyed at each study reach along with a total station survey of the channel profile, which provides a measure of the local energy gradient and bed morphology. East Sixteen Mile Creek contained well defined pool-riffle morphology with larger variation in bankfull cross-sectional dimensions, while Mullet Creek contained riffles with shallow pools and bankfull cross-sectional dimensions were fairly uniform as a result of the channel being historically straightened. Where possible, bankfull dimensions were identified using known field indicators, such as changes in vegetation and inflection points in the bank profiles. The ‘bankfull’ channel area generally represents the maximum capacity of the channel before it spills onto the floodplain. At both sites, ‘bankfull’ indicators were present and captured in each survey. ESMC(2) is a permanent watercourse, while MC(4) is an intermittent watercourse.

A modified Wolman (1954) pebble count was completed at each riffle or run cross-section to characterize bed substrates, with a total of 50 particles sampled at each cross-section. Observations of particle shape and composition (e.g., shale, road fill, rip

rap, carbonates) were also noted. Bank substrates, vegetation, and rooting depth were characterized in-general and summarized on our field forms (ref. **Appendix F-1**).

Channel geometry and composition for the detailed sites are presented in **Table 2.4.6**. Bankfull hydraulics estimates based on the most representative measured cross-sections are provided in **Table 2.4.7.** At least three riffle or run / transition cross-sections were surveyed per reach.

Reach ESMC(2)

East Sixteen Mile Creek through the study reach is a permanent watercourse that is, at present, appears to lack direct modification except in the vicinity of Steeles Avenue and toward Highway 401. Elsewhere the channel shows evidence of natural processes in plan, profile, and cross-section. The watercourse contains a very sinuous planform and is contained within a confined valley with an expansive unconfined floodplain within the forested valley. Banks are vertical throughout the majority of the reach and are often overhanging, undercut, and/or slumping into the channel forming small islands. The channel is actively widening and eroding as evidenced by fallen / leaning trees and exposed tree roots. Several debris jams in the channel were noted along the reach walk. The channel contains a pool-riffle sequence, with pools largely around meander bends and riffles in straighter sections of the channel. The flow regime is dynamic in nature with frequent intervals of high flow periods evidenced by debris hanging in trees. In several places the channel bifurcates causing split flow creating large islands.

The channel has mixed substrate with a larger portion consisting of coarser substrate. Substrate includes predominantly clay / silt (13%), gravel (46%), cobbles (31%), and small boulders (10%). The erodibility of this channel is likely a result of non-cohesive banks (sand and minor clay) in conjunction with limited well-rooted vegetation that would aid in bank stabilization.

On average, bankfull dimensions are approximately 6.8 m in width and 0.66 m in depth at riffles and a maximum depth of 1.05 m recorded at pools. Bankfull discharge within the representative riffle-type cross-section is 4.3 m^3/s (at 0.054% slope and n = 0.035). At the bankfull flow, the channel produces a velocity of 1.22 m/s and shear stress of 23.4 N/m^2.

Reach MC(4)

Mullet Creek is an intermittent watercourse with a straight planform as a result of historical agricultural practice, and continues to be maintained in its narrow, straight corridor. Land use is primarily agricultural, though an industrial site (Maple Lodge Farms) sits beyond the riparian zone on the north side of the reach. At the upstream

end of the reach in the vicinity of Winston Churchill Boulevard, the banks near the culvert and the channel under the culvert have been recently armoured with rounded cobbles presumably to maintain the channel position laterally and vertically. There is a small storm outfall on the right bank immediately downstream of the crossing, which was dry during all field visits. The channel banks are near-vertical throughout the reach and are often undercut or overhanging, suggesting active erosion is ongoing. In several locations, channel and bank undercutting was measured as high as 40 cm. Vegetation on the banks consists of sparse trees and shrubs; however, vegetation is minimal, and the banks are generally unstable as they lack well-rooted vegetation. The channel bed through riffles was generally composed of coarser substrate including gravels (59%), cobbles (31%), sand / clay (10%). The creek is widening primarily along the right bank, resulting in several fallen and leaning trees as well as exposed tree roots. Woody debris along the channel banks and in the channel is prevalent. The channel contained riffle and pool morphology, although not well developed as pools were shallow.

On average, bankfull dimensions are approximately 4.2 m in width and 0.52 m in depth, with similar cross-section dimensions measured at both pools and riffle-runs. Bankfull discharge within the representative riffle-type cross-section is 2.25 m^3/s (at 0.039% slope and n = 0.035). At the bankfull flow, the channel produces a velocity of 1.04 m/s and shear stress of 16.9 N/m^2.

Table 2.4.6: Channel Characteristics for the Detailed Geomorphic Field Sites

	ESMC(2)	MC(4)
Average Bankfull Width (m)	6.8	4.2
Average Bankfull Depth (m)	0.66	0.52
Maximum Channel Depth (m)	1.05	0.85
Channel Width: Depth	8.00	4.9
Cross-sectional Area (m^2)	5.14	2.17
Wetted Perimeter (m)	9.94	4.90
Hydraulic Radius (m)	0.52	0.44
D_{50} (mm)	17	19
Bed material	Medium gravel	Medium gravel
Bank material	Medium sand, some clay	Fine sand

Table 2.4.7: Bankfull Hydraulics for the Detailed Geomorphic Field Sites

Parameter	ESMC(2)	MC(4)
Bankfull Discharge (m^3/s)	4.3	2.25
Surveyed Channel Gradient (m/m)	0.0054	0.0039
Bankfull Velocity (m/s)	1.22	1.04
Stream Power (W/m)	229	86.1
Stream Power per unit Width (W/m^2)	31.2	19.3
Shear Stress (N/m^2)	23.4	16.9

2.4.4.4 Erosion Threshold Analysis

Data from the detailed field assessment was 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 representative particle size (Dcrit), i.e., the 'threshold' condition at which sediment will start to mobilize typically the median grain size, or an equivalent force to erode cohesive or vegetation bound materials. 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'. Erosion threshold analysis was completed in two reaches downstream of the Study Area, one each in East Sixteen Mile Creek and Mullet Creek as these reaches are considered sensitive to downstream impacts as a result of development. These two sites are identified on **Drawing FG-1**.

Several different established entrainment relationships are used 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 is 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. Cross-sections that were considered the most representative of the reach were selected for use in the analysis.

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 functions are applicable (e.g., appropriate grain sizes). The goal of the erosion threshold analysis is to determine a threshold discharge for selected reaches above which a critical fraction of the boundary materials is 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 impacts such as channel erosion and habitat degradation.

An appropriate erosion threshold method is selected based on the characteristics of the bed and bank materials, as determined from the detailed geomorphic assessment. For both reaches ESMC(2) and MC(4), the median grain size is in the medium gravel range, therefore the method outlined by Komar (1987) was selected. For each study reach, a critical discharge, velocity, and shear stress was determined using the median sediment size (D_{50}) at one representative cross-section. Based on a D_{50} of 17 mm at ESMC(2) and 19 mm at MC(4), the critical discharge values were 0.70 m/s^3 and 0.79 m/s^3, respectively. The recommended critical discharge values represent approximately 16% and 35% of the bankfull flow at both sites, which is not considered unreasonable based on our field observations. During the geomorphic field assessments, the creeks were flowing minimally, below the calculated thresholds and sediment transport was not occurring.

It is possible that stormwater may be discharged into the smaller, non-permanently flowing reaches of East Sixteen Mile Creek tributaries TESMC(1) and TESMC(2) south of Steeles Avenue, therefore erosion threshold targets were identified for these reaches, but based on unitary rates from the Ninth Line Scope Subwatershed Study (Wood, 2020), these tributaries are within the headwaters of the creek system and are often dry throughout the year, resulting in the establishment of dense instream vegetation. Site access agreements were not attempted for these reaches as they appeared to be poorly defined and unsuitable for this type of analysis, therefore geomorphic surveys were not completed as a part of the current Scoped SWS. The utilization of downstream thresholds on a unitary basis from previous work is a suitable approach at the Scoped SWS stage. From that study, a single threshold value from Reach NL-10 in the vicinity of Britannia Road and Ninth Line was calculated at **1.09 m^3/s**. A drainage area of 1488 ha has been estimated using the Ontario Flow Assessment Tool (LIO, 2020) for reach NL-10, which results in a unitary erosion threshold of **0.7 l/s/ha**.

Results of the erosion threshold analysis based on current field surveys are provided in **Table 2.4.8.**

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Table 2.4.8: Threshold Characteristics Estimated for the Detailed Geomorphic Field Sites

Parameter	ESMC(2)	MC(4)
Bankfull Channel Geometry		
Channel Width (m)*	9.1	4.4
Channel Depth (m)*	1.0	0.7
Gradient (m/m)	0.0054	0.0039
Bed Material		
D_{50} (mm)	17	19
D_{84} (mm)	39	65
Manning's 'n'	0.035	0.035
Bankfull Channel Hydraulics		
Channel Discharge (m^3/s)	4.33	2.25
Channel Velocity (m/s)	1.22	1.04
Average Shear Stress (N/m^2)	23.4	16.9
Thresholds		
Recommended Critical Discharge (m^3/s)	0.70	0.79
Percent of Bankfull Discharge (%)	16	35
Percent of Bankfull Depth (%)	49	59
Critical Velocity (m/s)	0.73	0.76
Critical Shear Stress (N/m^2)	10.9	10.6
Critical Flow Depth (m)	0.39	0.43
Sources	Komar (1987): Gravels and larger	Komar (1987): Gravels and larger

*Channel dimensions of selected representative cross-section

2.4.4.5 Headwater Drainage Feature Assessments

Headwater Drainage Features have been assessed with management classifications determined in accordance with TRCA / CVC (2014) guidelines and a recently developed classification and evaluation methodology for subwatershed studies in Milton, Ontario (Wood, 2020). This approach combines watercourse constraints and HDF classifications and management recommendations into one streamlined process, with a central document for definitions, recommendations, and opportunities (ref. Table 3.2.1). This methodology was proposed and reviewed collaboratively with Conservation Halton, Halton Region, Town of Milton, MNRF, and other environmental practitioners (consultants) working in the Milton area. A drainage feature focused TAC meeting for Premier Gateway Phase 2 was held on September 25, 2020, to present and review the proposed HDF / Watercourse methodology. Meeting notes from the September 25, 2020, meeting as well as the November 2021 TAC meeting were circulated for review by all attendees (ref. **Appendix F-5** for meeting notes and email distribution). These

notes document that the proposed methodology is supported by CH and CVC, and also provide points for revision and clarification which have since been completed as presented in **Table 3.2.1**. For HDFs, the modified evaluation approach for the subwatershed study first applies the guidelines set by TRCA / CVC (2014) to determine a feature classification ("**HDFA Management**"). The following describes general functions and management recommendations for HDF classifications:

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. Under the recommended 'protection' management practices, these reaches must be protected in-situ. Localized channel adjustments may be permitted at select locations given sufficient rationale, and as approved by Regulatory Agencies. For protection HDFs, 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 no reach scale realignments can be performed. Future SWM systems are to be designed and located to avoid impacts to both sediment and temperatures to protection features. Regulatory setbacks do not include erosion hazards, and any regulatory setbacks or buffers (if required) are to be determined through agency consultation.

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. For these reaches, the feature must be maintained as open features with a riparian zone corridor, and relocations are permitted through the use of natural channel / corridor design principles and techniques based on the physical requirements of the system, or an appropriate reference, such that the overall productivity of the reach is maintained or enhanced. Additionally, if a terrestrial linkage is present, this linkage must be maintained as a part of the realignment unless alternate linkages exist and have been assessed. 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. Conservation Features do not have attributes that attract conservation

authority regulation. Buffers (if required) are to be determined through agency consultation.

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. For these reaches functions have to be replicated or enhanced 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 Study Area, these reaches are designated as a result of a 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.

HDF Classification – Preliminary and Final Management Column

The above describes, in general, the field component of the HDF assessment. The collected HDF site assessment data was used to determine a management classification for every reach as per the TRCA / CVC 2014 protocols. **Table 2.4.9** details the evaluation and classification of HDFs within the study area, with two columns for classification / management. One column to display the results of the TRCA / CVC HDFA protocols “**HDFA management**” which may then be carried forward to “**Final Management**” or altered based on site opportunities, or other constraints that the protocol may not capture (e.g., feature protection based on location within a significant valley or terrestrial feature). Final Management recommendations are subject to review and agreement from the TAC. Overall, the final characterization for each feature is intended to be a collaborative and integrated effort between members of the study team and the TAC. At present, this is only proposed for HDF MC(6) to increase the constraint

from ‘mitigation’ to ‘conservation’ to maintain an open connection to an upstream wetland within the Mullet Creek subwatershed. **Drawing FG-4** illustrates reach specific (preliminary) **Final Management** recommendations for headwater features within the Study Area. More detail on the integrated approach to determine watercourse and HDF constraints and recommendations is located in **Section 3.2.2.1**. Site photos are available in **Appendix F-2**.

Table 2.4.9: Headwater Drainage Feature Evaluation and Recommendations

HDF ID	Hydrology	Riparian	Fish Habitat	Terrestrial	HDF Type	HDFA Management (TRCA / CVC 2014)	Final Recommendation*	Rationale / Comments
ESMC(3)1-1	Limited	Limited	Contributing	Limited	Swale	No Management Required	TBD	swale with some definition, however standing water on first visit and dry by second Findings consistent with Hodero Scoped SWS results.
ESMC(3)1-1a	Limited	Limited	Contributing	Limited	Swale	No Management Required	TBD	poorly defined swale, no water observed. Findings consistent with Hodero Scoped SWS results.
H4S1	-	-	-	-	-	-	TBD	Not observed during Matrix HDF assessment but mapped in Savanta Hodero SWS study. Lack of observation at this location supports the previous findings of “no management required”
TESMC(4)	Limited	Limited	Contributing	Limited	Swale	No Management Required	TBD	swale with some definition, however standing water on 1st visit and dry by 2nd visit.
TESMC1b	Limited	Limited	Contributing	Limited	No Defined Feature	No Management Required	TBD	poorly defined feature, no water observed.
TESMC1a	Contributing	Important	Contributing	Valued	Wetland	Conservation	TBD	"conservation" based on important riparian vegetation and contributing hydrology. Important riparian due to feature type and vegetation being wetland. Final Management TBD pending further wetland studies at subsequent planning stages.
TESMC(1)1-1	Limited	Limited	Contributing	Limited	No Defined Feature	No Management Required	TBD	poorly defined feature, no water observed.
TESMC(1)5-1	Contributing	Contributing	Contributing	Limited	Channelized	Conservation	TBD	Feature would be "mitigation" based on contributing hydrology score, however connection to wetland upstream results in "conservation" to maintain linkage. Final Management TBD pending further wetland studies at subsequent planning stages.
TESMC(1)3-1a	Contributing	Important	Contributing	Valued	Wetland	Conservation	TBD	"conservation" based on important riparian vegetation and contributing hydrology. Important riparian due to feature type and vegetation being wetland
TESMC(1)2-1a	Contributing	Important	Contributing	Valued	Wetland	Conservation	TBD	"conservation" based on important riparian vegetation and contributing hydrology. Important riparian due to feature type and vegetation being wetland. Final Management TBD pending further wetland studies at subsequent planning stages.
TESMC(1)3-1	Limited	Limited	Contributing	Limited	Swale	No Management Required	TBD	poorly defined feature, no water observed.
TESMC(1)2-1	Limited	Limited	Contributing	Limited	No Defined Feature	No Management Required	TBD	poorly defined feature, no water observed.
TESMC(1)4-1	Limited	Limited	Contributing	Limited	Swale	No Management Required	TBD	"no management required" as it is a swale with standing water 1st visit and dry by 2nd visit.

HDF ID	Hydrology	Riparian	Fish Habitat	Terrestrial	HDF Type	HDFA Management (TRCA / CVC 2014)	Final Recommendation*	Rationale / Comments
TESMC(2)1-1	Contributing	Limited	Contributing	Limited	Channelized	Mitigation	TBD	"mitigation" based on contributing hydrology score and valued riparian score. Maintain contribution downstream. Contributing hydrology score due to feature type being channelized and contained standing water 1st and 2nd visit. Valued riparian score due to cultural meadow vegetation.
TESMC(2)2-1	Limited	Limited	Contributing	Limited	Swale	No Management Required	TBD	"no management required" as it is a swale with standing water 1st visit and dry by second visit
TESMC(2)2-1a	Contributing	Valued	Contributing	Limited	Channelized	Mitigation	TBD	"mitigation" based on contributing hydrology score. Maintain contribution downstream. Contributing hydrology score due to feature type being channelized and contained flowing water first visit, standing water second visit.
TESMC(3)1	Limited	Limited	Contributing	Limited	Swale	No Management Required	TBD	poorly defined swale, no water observed.
TESMC(3)2	Limited	Limited	Contributing	Limited	Swale	No Management Required	TBD	poorly defined swale, no water observed.
MC(6)	Contributing	Limited	Contributing	Limited	Swale	Mitigation	TBD	."mitigation" based on contributing hydrology score
MC(6)1-1	Limited	Limited	Contributing	Limited	Swale	No Management Required	TBD	defined swale; standing water first visit and dry by second visit
MC(5)3-2	Limited	Limited	Contributing	Limited	Swale	No Management Required	TBD	defined swale; standing water first visit and dry by second visit
MC(5)	Contributing	Important	Contributing	Contributing	Channelized	Conservation	TBD	"conservation" due to wetland riparian vegetation.

*Final management recommendations have been determined through Phase 2 and 3 of the SWS

2.4.4.6 Geomorphic Monitoring

Data from both monitoring sites – ESMC(2) and MC(4) – has been summarized and compared between the first and second visits to characterize any geomorphological changes in support of establishing baseline conditions. Any emerging trends identified will assist in the evaluation of short and long term channel adjustment and the response to changes in hydrology and sediment supply. The analyses undertaken are described in the following sections.

Cross sectional Analyses

Cross sectional data collected at each monitoring station has been plotted for the Spring 2021 monitoring event was overlain on the Fall 2020 data (Refer to **Appendix F-3**). After plotting the cross-section data, cross sectional area was calculated through the panel area method. The overlay of cross-sectional monitoring data is used for comparison to evaluate change in area which indicates the increase or decrease of cross-sectional capacity. A summary of the cross-sectional area values for each cross-section is provided in **Table 2.4.10** and a summary of observations at each cross-section is provided.

Characterization of Channel Substrate

Substrate characterization (using a modified Wolman pebble count method) was completed to determine the particle size distribution at each monitoring cross-section. This particle size data has been used to determine the D_{10}, D_{50}, and D_{90} percentiles. Year over year comparisons of these values will allow for the evaluation of adjustment in substrate size characteristics over time. Refer to **Table 2.4.11** for a summary of the Fall 2020 and Spring 2021 results.

Erosion Pins

Erosion pins were installed in 2020 at both monitoring sites. Two erosion pins were installed at each site. The pins were installed with care to avoid disturbing the creek banks. Refer to **Table 2.4.12** for a summary of changes in erosion pin exposure from the Fall of 2020 to the Spring of 2021.

Visual Change

Field observations and photographs have been collected from each monitoring site to document existing conditions. These photographs provide record of qualitative information to support the interpretation of quantitative adjustments, such as: change related to bar feature development, the presence / absence of woody debris, vegetative

cover / control, and other factors that may influence channel morphology and general stability. Photos taken at the monitoring cross sections are provided in **Appendix F-3**.

Geomorphic Monitoring Results

Cross Sectional Profile

Cross sectional profiles for each of the monitoring sites are presented within the Geomorphological Data Sheets included within **Appendix F-3**. These plots are based on the measured cross-sections at each site using the installed pins as benchmarks. A summary of calculated cross sectional area for Fall 2020 and Spring 2021 is provided as **Table 2.4.10**.

Table 2.4.10: Cross-sectional Area Calculated for Geomorphological Monitoring Sites

Site	Parameter	Fall 2020 Results	Spring 2021 Results	Total Change 2020 to 2021
ESMC(2)	Cross-sectional area (m^2)	5.14	5.24	0.1 (2%)
MC(4)	Cross-sectional area (m^2)	2.94	2.99	< 0.1 (1%)

The area of the monitoring cross-sections underwent negligible change during the monitoring period. Examination of the cross-sectional profile of MC(4) indicates that slight widening occurred between the monitoring events, which was offset by deposition on the right side of the creek bed. Field observations noted that the deposition along the right bank was composed of soft sand. At ESMC(2) the bank profiles did not change, but the thalweg deepened slightly between monitoring events.

Characterization of Bed Substrate

The results of the pebble counts are provided in **Table 2.4.11**. No notable changes were observed in bed substrate composition during the monitoring period. The Spring 2021 data indicate that the monitoring section at East Sixteen Mile Creek remains composed primarily of gravel with some pebbles, and at the Mullet Creek monitoring section the substrate remains composed primarily of gravel with some coarse sand. However, at both sites there has been a slight decrease in the D_{10}, D_{50} and D_{90} between monitoring events. This decrease is considered within the range of natural variability of both sites.

Table 2.4.11: Bed Substrate Characteristics for Geomorphological Monitoring Sites

Site	Percentile	Dec 2020 (mm)	May 2021 (mm)	Change Since 2020	Comments
East Sixteen Mile Creek XS1	D_{10}	0.56	0.52	**Decrease**	Continues to consist predominantly of gravel with some pebbles.
	D_{50}	1.59	0.99	**Decrease**	
	D_{90}	6.12	5.59	**Decrease**	
Mullet Creek XS1	D_{10}	0.13	0.03	**Decrease**	Continues to consist predominantly of gravel with some coarse sand.
	D_{50}	1.15	1.14	**Decrease (negligible)**	
	D_{90}	5.99	4.79	**Decrease**	

Erosion Pin Measurements

The erosion pin located on the right bank of East Sixteen Mile Creek underwent the most change (40 cm) of the four pins installed. This is consistent with its location on the outer bank of a meander. Both pins at the Mullet Creek monitoring cross section became more exposed by several centimetres during the monitoring period, which is consistent with the slight bank recession shown in the overlay of cross-sectional profiles.

Table 2.4.12: Erosion Pin Exposure

Site	Pin Location	Dec 2020 (cm)	May 2021 (cm)	Change Since 2020 (cm)	Comments
East Sixteen Mile Creek	~10 m DS of XS1, Left Bank	25	65	40	Outer bend
	~5 m US of XS1, Right Bank	25	27	2	Bank is slumping
Mullet Creek	XS1 Left Bank	25	21	4	
	XS1 Right Bank	20	25	5	

2.4.5 Summary of Findings

Historical Assessment

The historical assessment indicated that natural lateral channel adjustment or migration has been fairly limited since 1954 along Mullet Creek, but there has been lengthening and meander development along East Sixteen Mile Creek – Reach ESMC1 – as it continues to regain sinuosity. Prior to 1954 it is assumed that some direct modification occurred within ESMC1 based on the straighter channel planform and assumed clearing of trees relative to the forested corridor downstream of the Study Area. Land use has remained fairly consistent and between 1954 and 2019 photography, agricultural impacts to watercourse and HDFs persist. This is most notable along impacted reaches of Mullet Creek which appear to have remained in the same position within cropped lands, and a narrow riparian zone. East Sixteen Mile Creek meanders within a well-developed floodplain situated within a defined valley, and agricultural practice seems to be limited to tablelands in recent years. Local alterations to watercourses occurred within the last 5 - 10 years where crossings were upgraded (replaced), or lengthened.

Erosion Hazard Assessment

The study area contains unconfined (meander migration is not restricted by valley slopes), and partially confined (valley slopes restrict migration in some parts of the reach) to confined reaches (valley slope restricts migration throughout the reach). Unconfined reaches are limited to Mullet Creek, while East Sixteen Mile Creek is characterized by a meandering channel in a well-developed floodplain, set within a defined valley with some valley wall contacts (partially confined to confined). Meander belts were delineated for Mullet Creek reaches – MC(4)1 and MC(4)2. East Sixteen Mile Creek may exhibit some partial confinement; however, it has a floodplain to tableland differential along the well-defined slopes that exceeds 2 m and must be treated as a confined system (CH, 2016). Therefore, a long-term stable top of slope was delineated for ESMC1 following guidelines from Provincial Policy (OMNR, 2002). Due to limitations with the available photo record, 20% of the bankfull width was added as a factor of safety in lieu of a projected 100-year migration limit based off photo measurements. A 6 m erosion access allowance was added to the meander belt widths of Mullet Creek in accordance with Provincial Policy (OMNR, 2002), while a 15 m regulatory setback was applied to East Sixteen Mile Creek (CH, 2016). A toe-erosion allowance was also included in the long-term stable top of slope delineation, and a value of either 2 m or 8 m was applied based on stiff cohesive soil (clays, clay-silt) slope materials and the presence / absence of active erosion.

Rapid Assessments

The Rapid Assessment of watercourses within the Study Area characterized dominant geomorphic processes and evidence of instability. East Sixteen Mile Creek reaches were mostly well defined and migrating. Reaches ESMC1 and ESMC(2) are permanently flowing, with active geomorphic processes occurring. Each reach contained widening as the dominant geomorphic process. The occurrence of vertical banks, slumping, and undercutting, with occasional debris jams in ESMC(2) has resulted in the creek system being more unstable or 'transitional' in the RGA scoring when compared to ESMC1 upstream of Steeles Ave., which is considered more stable and was scored as 'in regime' in the RGA. Reaches TESMC(1) and TESMC(2) downstream of Steeles Ave. were inaccessible, but noted to be poorly defined and not suitable for the completion of Rapid Assessments made from the road ROW.

Mullet Creek reaches were noted to be highly impacted by current and historical land-use (agricultural), with a narrow riparian zone and poor channel definition upstream of Winston Churchill Boulevard. Manicured lawns were present up to the poorly defined channel banks on either side upon approach to Winston Churchill Boulevard. All watercourse reaches upstream of Winston Churchill Boulevard. were found to be in-regime and vegetatively controlled. Downstream of Winston Churchill Boulevard within Reach MC(4), a well-defined, intermittent channel extended for approximately 500 m, within a narrow riparian corridor with deciduous trees along either side. Aggradation and widening towards the right bank were noted to be the dominant geomorphic processes for this relatively unstable reach ('transitional'). Vertical and undercut banks were noted throughout as bank vegetation was minimal.

Erosion Thresholds

Detailed geomorphic surveys were completed on more sensitive, downstream reaches of ESMC(2) and MC(4) within each subwatershed. Critical discharge, velocity, and shear stress values were determined for each site using the Komar (1987) equation for gravel substrates. Median particle sizes of 17 mm and 19 mm were evaluated for ESMC(2) and MC(4), respectively. The recommended critical threshold values were provided to inform the exceedance analysis for the purposes of developing a stormwater management plan that does not exacerbate erosion in receiving watercourses. For potential receivers along Steeles Avenue – TESMC(1) and TESMC(2) – a unitary rate was of 0.7 l/s/ha was derived from erosion threshold analyses completed in the Ninth Line Scoped Subwatershed Study (Wood, 2020) and is considered appropriate at the Scoped SWS level of study.

Headwater Drainage Feature (HDF) Assessment

HDFs were found predominantly in agricultural settings within the Study Area. Previously unmapped HDFs were identified on most properties that were visited. An agency site walk occurred on October 23, 2020, to confirm the feature type, and location of HDFs and watercourses. Due to project scheduling, a modification to the HDFA protocols (TRCA / CVC, 2014) was proposed and accepted whereby the third visit was completed in September of 2020, then followed by first and second visits in March and June of 2021. Updates, where necessary, were made to the feature type and extent following the agency site walk.

HDF assessments were completed following the protocols outlined in the TRCA / CVC (2014) guidelines, to develop an “HDFA Management” classification. Due to limited or contributing hydrology scores, HDFs were given ‘no-management required’, or ‘mitigation’ HDFA Management classifications based on the guidelines. As site-specific nuances may require a modification to the management classification from the protocol, a “Final Management” recommendation have been provided through Phase 2 and 3 of the Scoped SWS with supporting rationale. HDF management recommendations are subject to approval by the TAC and is anticipated to be a collaborative effort to finalize management recommendations and opportunities. Some HDF management classifications may be deferred to subsequent study (e.g., SIS) where further data collection is required.

Geomorphic Monitoring

Baseline geomorphic monitoring stations have been established in downstream reaches along Mullet Creek and East Sixteen Mile Creek, where detailed surveys had been completed. One monumented cross-section has been installed within each reach, and two seasonal surveys have occurred: Fall / Winter 2020 and Spring 2021. Cross-sections remained essentially the same with nominal adjustment, and channel substrates were consistent between samples. An erosion pin measurement at a zone of anticipated erosion (cutbank), measured 40 cm of bank migration between surveys on East Sixteen Mile Creek, and this may give some sense of the anticipated rates of erosion downstream of the Study Area. Note that the other erosion pin at a more stable location only noted 2 cm in difference of rebar exposure.

2.5 Water Quality

The surface water quality assessment provides an indication of the aquatic health of the watercourses and tributaries with respect to contaminant loadings under existing land use conditions, and thereby provides a baseline condition which can be used to verify

the performance of the recommended stormwater quality management plan, as part of subsequent phases of study and monitoring.

2.5.1 Scope Overview

The surface water quality characterization has been completed based upon a review and analysis of background information provided for use and reference in this study. In addition, a scoped water quality monitoring program has been developed and implemented in order to characterize the surface water chemistry within the study area. The surface water quality monitoring program has been completed in accordance with the Approved Work Plan.

2.5.2 Background Information Review

Water quality monitoring has been completed by Conservation Halton as part of the Authority's Watershed Monitoring Program. Water quality samples from site SXM-205 (ref. CH station 06006301102) has been received from Conservation Halton as part of the Scoped Subwatershed Study. The station is located on East Oakville Creek at Lower Base Line, approximately 10 km downstream of the study area.

2.5.3 Field Reconnaissance

Water quality monitoring has been conducted at the temporary flow gauge location to characterize the surface water quality. Samples have been collected on October 15, 2020, to represent a wet weather condition event and on May 28, 2021, to represent a wet weather condition event.

2.5.4 Characterization and Analysis

Long-Term Sampling

The water quality monitoring at Station SXM-205 has been conducted between 1975 and 2019 by Conservation Halton. The Station is located at East Oakville Creek at Lower Base Line approximately 10 km downstream of the study area (Ref. Drawing WR10). Majority of the Sixteen Mile Creek Watershed contributes to the drainage area to this Station including urban Milton, Ninth Line Area, and North Sixteen District. The monitoring has been completed by obtaining grab samples on a monthly basis between spring and fall, however the collected data have not distinguished between wet weather and dry weather conditions. The water quality parameters reported are listed below.

Statistical analyses have been completed for key contaminants based upon the monitoring data to determine the range, mean, and median concentrations. The results of the assessment are presented in **Table 2.5.1**.

Table 2.5.1: 1975 – 2019 Statistical Results of Water Quality Samples for Station SXM-205 (ug/L unless otherwise noted)

Contaminant	Range	Mean	Median
Arsenic	1 - 2	1.02	1
Beryllium	0 - 0.5	<0.07	<0.04
Cadmium	0 - 2.35	<0.70	<0.61
Cobalt	0 - 2.8	<0.76	<0.55
Copper	0.5 - 56	3.25	2.17
Iron	20 - 24500	513.36	182
Lead	0 - 30	<5.11	<4.7
Nickel	0 - 22	<2.14	<2
Selenium	1 - 1	1	1
Silver	<0.058 - 12	<4.20	<6
Zinc	<0.052 - 75	<5.17	<3
Chloride (mg/L)	17 - 284	67.36	55.32
Nitrite	1 - 66	12.06	9
Nitrate	2 - 2605	557.33	343
Nitrate + Nitrite	5 - 3060	621.34	371
BOD5	110 - 8100	1269.32	1000
Total Phosphorus	7 - 1200	57.4	29
TSS(1)	0.5 - 292	16	6.3
Total Kjeldahl Nitrogen (TKN)	13 - 3300	618.63	530

(1) Particulate Residue samples from the water quality data has been considered as TSS

The median concentration statistical results determined from the statistical analyses 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 Station SXM-205 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 comparisons are presented in **Table 2.5.2** and **Table 2.5.3.**

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Table 2.5.2: Comparison of Median Concentrations with Findings from other Studies for Wet Weather Flow Conditions

Contaminant	Sixteen Mile Creek Subwatershed updated Study				Ninth Line Scoped Subwatershed Study		Premier Gateway Scoped Subwatershed Study	Premier Gateway 2B (SXM-205)
	Q1	Q2	Q3	Q4	Railway	Britannia		
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**
Total P (mg/L)	0.076	0.2	0.078	0.24	0.154	0.150	0.205	**0.029**
TSS (mg/L)	17	51	92	49	17.7	45.4	10	**6.3**
Copper (mg/L)	0.0035	0.012	0.002	0.007	0.0040	0.0050	0.003	**0.0022**
Zinc (mg/L)	0.014	0.015	0.014	0.020	0.0117	0.0251	0.008	**0.0030**
Lead (mg/L)	0.001	0.0031	0.00205	0.0046	<0.0007	0.00157	0.0006	**0.0047**
Nitrate+Nitrite (mg/L)	0.6	1.7	0.65	0.9	<0.175	<0.163	0.25	**0.37**

Table 2.5.3: Comparison of Median Concentrations with Findings from other Studies for Dry Weather Flow Conditions

Contaminant	Sixteen Mile Creek Subwatershed updated Study				Ninth Line Scoped Subwatershed Study		Premier Gateway Scoped Subwatershed Study	Premier Gateway 2B (SXM-205)
	Q1	Q2	Q3	Q4	Railway	Britannia		
BOD / CBOD (mg/L)	4	3	3	1	<2	2.5	3	**1**
E.coli (#/100mL)	86	8600	126		250	230	126	**-**
TKN (mg/L)	1.35	3.4	1.2		0.73	0.72	1.2	**0.53**
Total P (mg/L)	0.123	0.54	0.205	0.029	0.073	0.082	0.205	**0.029**
TSS (mg/L)	24	22	10		14	41.6	10	**6.3**
Copper (mg/L)	0.0035	0.010	0.003	0.0022	<0.0062	<0.00705	0.003	**0.0022**
Zinc (mg/L)	0.0105	0.027	0.008	0.0030	<0.01845	<0.02185	0.008	**0.0030**
Lead (mg/L)	0.0014	0.0046	0.0006	0.0047	<0.002815	<0.003235	0.0006	**0.0047**
Nitrate+Nitrite (mg/L)	4	ND	0.25	0.37	<0.6	<0.625	0.25	**0.37**

The results indicate the following:

- Median concentrations of nutrients (i.e., BOD5, TKN, and Total P) at Station SXM-205 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 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 TSS at Station SXM-205 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 Station SXM-205 tend to be below median concentrations reported elsewhere in the Sixteen Mile Creek Watershed for wet weather conditions; median concentrations of copper at Station SXM-205 are comparable to results reported elsewhere in the Sixteen Mile Creek Watershed for dry weather conditions.
- Median concentrations of certain metals (i.e., lead) at Station SXM-205 tend to be at or above median concentrations reported elsewhere in the Sixteen Mile Creek Watershed.

The sampling data have been compared with current Provincial Water Quality Objectives (PWQO's) for various contaminants, 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. The results have been summarized in **Table 2.5.4.**

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Table 2.5.4: 1975 – 2019 PWQO Exceedance of 1975 – 2019 Water Quality Samples (Station SXM-205)

Contaminant	PWQO Limit	Number of Samples	Number of Exceedance
Arsenic	100 ug/L	170	0
Beryllium	1100 ug/L	140	0
Cadmium	0.2 ug/L	140	116
Cobalt	0.9 ug/L	140	45
Copper	5 ug/L	290	31
Iron	300 ug/L	291	87
Lead	25 ug/L	289	4
Nickel	25 ug/L	289	0
Selenium	100 ug/L	19	0
Silver	0.1 ug/L	57	56
Zinc	30 ug/L	290	3
Chloride (mg/L)	NA	NA	NA
Nitrite	60 ug/L	144	2
Nitrate	2900 ug/L	138	0
Nitrate + Nitrite	NA	NA	NA
BOD5	NA	NA	NA
Total Phosphorus	NA	NA	NA
TSS	NA	NA	NA
Total Kjeldahl Nitrogen (TKN)	NA	NA	NA

The results indicate that concentrations of chloride, nitrate, nitrite and certain metals at Site SXM-205 are relatively low compared to the PWQO's. PWQO exceedances are frequently noted for other metals (i.e. silver, cadmium cobalt, and iron).

Grab Sampling

In addition to the analysis of the water quality sampling data provided for Site SXM-205, water quality sampling has been completed on October 15, 2020, at the flow gauge location (ref. Drawing WR10) to represent a wet condition. The sample was analyzed by BV Labs for key contaminants as well as other elements. The detailed lab report and analysis for PWQO exceedances are included in **Appendix D**. **Table 2.5.5** presents the concentration and PWQO exceedance for key contaminants.

Table 2.5.5: Wet Weather Flow Condition Water Quality Sampling Results at Temporary Flow Gauge (ug/L unless otherwise noted)

Contaminant	Lab Results	PWQO Limit	PWQO Exceedance
Arsenic	1.4	100 ug/L	OK
Beryllium	<0.4	1100 ug/L	OK
Cadmium	<0.09	0.2 ug/L	OK
Cobalt	1.1	0.9 ug/L	FAIL
Copper	15	5 ug/L	FAIL
Iron	2700	300 ug/L	FAIL
Lead	3.7	1 ug/L	FAIL
Nickel	3.1	25 ug/L	OK
Selenium	<2	100 ug/L	OK
Silver	<0.09	0.1 ug/L	OK
Zinc	69	30 ug/L	FAIL
Chloride (mg/L)	58	NA	-
Nitrite	16	60 ug/L	OK
Nitrate	130	2900 ug/L	OK
Nitrate + Nitrite	140	NA	-
BOD5	4000	NA	-
Total Phosphorus	150	NA	-
TSS	59000	NA	-
Total Kjeldahl Nitrogen (TKN)	490	NA	-

The results in **Table 2.5.5** indicate that concentrations from the grab sampling lab analysis are generally below the PWQO limit. Some metals (i.e., copper, cobalt, iron, and zinc) exhibit high levels of PWQO exceedance. The high concentrations and PWQO exceedances are considered possibly due to the agricultural land use and farming activates from upstream contributing drainage areas.

Table 2.5.6 compares the grab sampling mean concentrations with the long-term statistical results for Station SXM-205.

Table 2.5.6: Comparison of Grab Sampling Results and Long Term Sampling Results (ug/L unless otherwise noted)

Contaminant	Lab Results	Mean (Station SXM-205)	Range (Station SXM-205)
Arsenic	1.4	1.02	1 - 2
Beryllium	<0.4	<0.07	0 - 0.5
Cadmium	<0.09	<0.70	0 - 2.35
Cobalt	1.1	<0.76	0 - 2.8
Copper	15	3.25	0.5 - 56
Iron	2700	513.36	20 - 24500
Lead	3.7	<5.11	0 - 30
Nickel	3.1	<2.14	0 - 22
Selenium	<2	1	1 - 1
Silver	<0.09	<4.20	<0.058 - 12
Zinc	69	<5.17	<0.052 - 75
Chloride (mg/L)	58	67.36	17 - 284
Nitrite	16	12.06	1 - 66
Nitrate	130	557.33	2 - 2605
Nitrate + Nitrite	140	621.34	5 - 3060
BOD5	4000	1269.32	110 - 8100
Total Phosphorus	150	57.4	7 - 1200
TSS	59000	16	0.5 - 292
Total Kjeldahl Nitrogen (TKN)	490	618.63	13 - 3300

Comparisons presented in **Table 2.5.6** indicate that the concentration of the key contaminates under the wet weather condition are generally near the mean values of long term monitoring data with the exception of copper, cobalt, iron, zinc, BOD5, total phosphorus, and TSS. All the analyzed contaminates are within the range of the long term statistical range except for TSS. High level of TSS is noted in the gram sampling results potentially due to the sediment contributions along the watercourse during the wet weather condition, which may be a result of natural channel forming processes.

The results of the grab sampling have been compared with previous studies within the Sixteen Mile Creek Watershed under the wet weather flow condition in **Table 2.5.7.**

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Table 2.5.7: Comparison of Lab Results with Findings from Other Studies for Wet Weather Flow Conditions

Contaminant	Sixteen Mile Creek Subwatershed updated Study				Ninth Line Scoped Subwatershed Study		Premier Gateway Scoped Subwatershed Study	Premier Gateway 2B (Wood)
	Q1	Q2	Q3	Q4	Railway	Britannia		
BOD / CBOD (mg/L)	2	4	2	3	2.6	<0.163	3	**4**
E.coli (#/100mL)	363	3200	242	10	2850	1600	126	**240**
TKN (mg/L)	1.15	2	1.4	4	1.50	1.135	1.2	**0.49**
Total P (mg/L)	0.076	0.2	0.078	0.24	0.154	0.150	0.205	**0.15**
TSS (mg/L)	17	51	92	49	17.7	45.4	10	**59**
Copper (mg/L)	0.0035	0.012	0.002	0.007	0.0040	0.0050	0.003	**0.015**
Zinc (mg/L)	0.014	0.015	0.014	0.020	0.0117	0.0251	0.008	**0.069**
Lead (mg/L)	0.001	0.0031	0.00205	0.0046	<0.0007	0.00157	0.0006	**0.0037**
Nitrate+Nitrite (mg/L)	0.6	1.7	0.65	0.9	<0.175	<0.163	0.25	**0.1**

The comparison shows that the concentrations are comparable to results reported elsewhere in the Watershed. Higher concentration and PWQO exceedances are noted for certain metals (i.e., Copper, Lead, and Zinc). It is recognized that one event sampling is insufficient to represent the water quality condition for the study area and further sampling would be suggested to support the characterization of the surface water quality. However, for the purpose of establishing future management strategies, the long term monitoring program along with the grab sampling would provide understanding of the surface water quality within the study area.

2.5.5 Summary of Findings

The water quality monitoring samples indicate that the existing surface water quality 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 compared to other locations in the watershed, PWQO exceedances were noted to be highly infrequent.

Grab Sampling indicates higher concentration for s copper, cobalt, iron, zinc, BOD5, total phosphorus, and TSS. Compared with the long-term statistical results and previous studies, the findings from the grab sampling are considered consistent with the surface water quality within the Sixteen Mile Creek Watershed.

2.6 Natural Environment Existing Conditions

2.6.1 Scope Overview

The Subwatershed Study Team has conducted the biological surveys and characterization of the natural heritage features within the Secondary Plan Area (SPA) ('study area') in addition to an area of approximately 120 m on adjacent lands. The study area and adjacent lands consists of rural residential areas along the major roads, industrial and commercial lands, agricultural fields, and natural heritage features. The study area includes the East Sixteen Mile Creek corridor and associated wetlands, woodlands, and other natural features. In addition, lands to the east within the study area include other small woodlands, an un-evaluated wetland, watercourses, HDFs, and meadow communities. Natural features within the study area are designated as part of the natural heritage system for the Town of Halton Hills (2019) and Regional Official Plan (Halton Region 2018). Although the natural features have not been identified as being included within the Greater Golden Horseshoe Growth Plan area natural heritage system (2020), the policies of the Growth Plan apply to Key Natural Heritage Features / Key Hydrologic Features identified within the study area. The Greenbelt Plan area is located to the southwest of the study area, and does not apply to this project.

This section of the report documents the characterization of the existing natural heritage features within the study area and adjacent lands, as well as its environs based on the results of the background review and original field surveys including breeding and migratory birds; mammals; herpetofauna; insects; vascular flora; aquatic habitat; fish community; and benthic macroinvertebrates. Whereas the Draft Phase 1 report provided information on the results from field surveys conducted in the fall of 2020 and spring of 2021 (up to including June 2, 2021), this Final Draft report combines all results from the field surveys completed for the SWS, for a fulsome characterization of the study area. This section also identifies natural feature constraints in association with land use policy designations in order to inform the Secondary Plan and land use planning strategy. The subject area is located within Ecoregion 7E.

For the purposes of this report, the term "study area" refers to the lands identified within the SPA. The term "adjacent lands" refers to 120 m surrounding the study area for which additional information was collected and reviewed (as could be gathered without

direct access to these areas). Legacy data collected from agencies and wildlife atlases encompassed an area of approximately 1 - 10 km (depending on the scope of background atlases) around the study area to ensure that all surrounding natural features were considered.

The scope of the materials included within this report reflect preliminary comments from Conservation Halton (May 14, 2021) on the previously submitted *Data Gap Analysis and Preliminary Constraint Assessment*.

2.6.2 Background Information Review

Background information was collected for both terrestrial and aquatic resources throughout the study area and adjacent lands. In addition, data was also provided by Conservation Halton (CH), Credit Valley Conservation Authority (CVC), Ministry of Natural Resources and Forestry (MNRF), and the Ministry of the Environment, Conservation, and Parks (MECP), and has been incorporated into the appropriate sections below.

2.6.2.1 Terrestrial Resources

A variety of background sources has been reviewed in order to inform terrestrial habitats and features that may be present. This has included the following wildlife atlases and databases:

- Natural Heritage Information Centre (NHIC) (MNRF 2020)
- Ontario Breeding Bird Atlas (BSC et al. 2006)
- eBird Database (2020)
- iNaturalist (2020)
- Ontario Reptile and Amphibian Atlas data (Ontario Nature 2019)
- Ontario Butterfly Atlas (Macnaughton et al. 2020)
- Atlas of the Mammals of Ontario (Dobbyn 1994)
- Ontario Odonate Atlas (OOAD 2020)

In addition, data from CH, CVC, MNRF, and MECP has been received and reviewed which has included:

- Mapping of Ecological Land Classification (ELC) and Regional Official Plan layers (Greenlands; Significant Woodland; Enhancement Areas, Linkages and Buffers)
- Technical reports

— Species lists

— Wetland evaluation for Levi's Creek Provincially Significant Wetland Complex and preliminary catchment boundary for the proposed East Sixteen Mile Creek Headwater Wetland Complex.

Mapping of natural heritage features within the study area and adjacent lands is provided on Map 1.

2.6.2.2 Aquatic Resources

A variety of aquatic background sources has been reviewed in order to inform aquatic habitats and species that have the potential to occur within the study area. This has included the following information:

— Natural Heritage Information Centre (NHIC) (MNRF 2020)

— Department of Fisheries and Oceans (DFO) Aquatics Species at Risk Mapping (DFO 2019)

— Ministry of Agriculture, Food and Rural Affairs (MAFRA) AgMaps (Ontario 2021)

In addition, data from CH, CVC, MNRF, and MECP has been received and reviewed which has included:

— Mapping layers of watercourses, waterbodies, and subwatershed boundaries

— Technical reports

— Fish and benthic sampling data for East Sixteen Mile Creek

Project Scoping

Following completion of the background review for terrestrial and aquatic resources, a complete list of Species at Risk (SAR) and Species of Conservation Concern (SCC) that have the potential to occur within the study area and adjacent lands was compiled. For the purposes of this report, SAR are defined as species listed as Threatened or Endangered provincially which are afforded protection under the Endangered Species Act. SCC refer to:

— species designated provincially or nationally as Special Concern

— species that have been assigned a conservation status (S-Rank) of S1 to S3 or SH by the NHIC

— species that are designated federally as Threatened or Endangered by the Committee for the Status of Endangered Wildlife in Canada (COSEWIC) but not

provincially by the Committee on the Status of Species at Risk in Ontario (COSSARO). These species are protected by the federal Species at Risk Act but not by the provincial Endangered Species Act.

A screening exercise has been conducted to determine whether there are suitable habitats within the study area for these species, as well as to ensure that the potential presence of all SAR and SCC within the study area was adequately considered and identified. This involved cross-referencing the preferred habitat for reported SAR and SCC (OMNR 2000) against habitats known to occur in the study area and adjacent lands. Full results of the SAR and SCC screening are provided in **Appendix H.1**. SCC are discussed within the context of Significant Wildlife Habitat (SWH).

A screening for the presence of Significant Wildlife Habitat (SWH) has also been completed for the study area and adjacent lands. The Significant Wildlife Habitat Technical Guide (SWHTG) is a guidance document that outlines the types of habitats that the MNRF considers significant in Ontario as well as criteria to identify these habitats (OMNR 2000, MNRF 2015). The SWHTG groups SWH into four broad categories: seasonal concentration areas, rare vegetation communities and specialized wildlife habitat, habitats of SCC, and animal movement corridors. Full results of the SWH screening are provided in **Appendix H.2**.

2.6.3 Field Survey Methods

The field program was informed by the *Premier Gateway Phase 2B Secondary Plan, Appendix B: Terms of Reference for Scoped Subwatershed Study* prepared by Halton Hills, in addition to ongoing correspondence with agency staff. Preliminary comments from Conservation Halton (CH) (May 14, 2021) on the previously submitted *Data Gap Analysis and Preliminary Constraint Assessment* have also been incorporated into the field methods. **Table 2.6.1** lists the field surveys that have been completed to date, in chronological order.

Table 2.6.1: Field Survey

Field Survey	Survey Date	Weather Conditions
Fall vegetation / ELC, raptor migration	September 14, 2020	Air Temp (°C): 18 Cloud Cover (%): 0 (sunny) Wind Speed (Beaufort): 0 - 2 Precipitation: None
Agency site walk to review natural features	October 23, 2020	Air Temp (°C): 24 Cloud Cover (%): 30 Wind Speed (Beaufort): 2 Wind Direction: S

Field Survey	Survey Date	Weather Conditions
		Precipitation: None
Fall spawning survey	October 30, 2020	Air Temp (°C): 2 Cloud Cover (%): 80 Wind Speed (Beaufort): 3 Wind Direction: NW Precipitation: None
Winter wildlife survey # 1	February 8, 2021	Air Temp (°C): -14 Cloud Cover (%): 15 Wind Speed (Beaufort): 2 - 3 Precipitation: None
Winter wildlife survey # 2	February 26, 2021	Air Temp (°C): -3 Cloud Cover (%): 5% Wind Speed (Beaufort): 2 - 3 Precipitation: None
Bat habitat assessment (leaf off), raptor migration, waterfowl stopover habitat assessment	March 17, 2021	Air Temp (°C) Start: 4 Air Temp (°C) Finish: N/A Cloud Cover (%): 90 Wind Speed (Beaufort): 1 Wind Direction: W Precipitation: None
Headwater Drainage Feature survey # 1 (with Matrix)	March 24, 2021	Air Temp (°C) Start: 8 Air Temp (°C) Finish: 11 Cloud Cover (%): 90 Wind Speed (Beaufort): 3 - 4 Wind Direction: S Precipitation: None
Salamander habitat / egg mass survey, herpetofauna area search	April 14, 2021	Air Temp (°C) Start: 7 Air Temp (°C) Finish: 14 Cloud Cover (%): 0 Wind Speed (Beaufort): 2 Wind Direction: NW Precipitation: None
Anuran call survey # 1, nocturnal owl survey	April 26, 2021	Air Temp (°C) Start: 5 Air Temp (°C) Finish: 6 Cloud Cover (%): 80 Wind Speed (Beaufort): 1 Wind Direction: N/A Precipitation: None
Spring vegetation and ELC refinement, herpetofauna area search, raptor migration	May 3, 2021	Air Temp (°C) Start: 9 Air Temp (°C) Finish: 11 Cloud Cover (%): 100 Wind Speed (Beaufort): 2 - 5 Wind Direction: N/A Precipitation: None to Light

Field Survey	Survey Date	Weather Conditions
HDF electro-fishing, OSAP site selection, spring spawning survey, stream morphology / barrier assessment, riparian characteristics	May 7, 2021	Air Temp (°C) Start: 11 Air Temp (°C) Finish: N/A Cloud Cover (%): 100 Wind Speed (Beaufort): 1 Wind Direction: N/A Precipitation: limited
Benthic invertebrate sampling	May 10, 2021	Air Temp (°C) Start: 12 Air Temp (°C) Finish: 13 Cloud Cover (%): 25 Wind Speed (Beaufort): 3 - 4 Wind Direction: WNW Precipitation: None
Anurans # 2, marsh bird survey # 1	May 26, 2021	Air Temp (°C) Start: 19 Air Temp (°C) Finish: 13 Cloud Cover (%): 20 - 80 Wind Speed (Beaufort): 3 - 6 Wind Direction: N/A Precipitation: None
Insects # 1, herpetofauna area search, raptor migration	May 27, 2021	Air Temp (°C) Start: 15 Air Temp (°C) Finish: 20 Cloud Cover (%): 5 Wind Speed (Beaufort): 3 Wind Direction: E Precipitation: None
Breeding birds # 1	June 1, 2021	Air Temp (°C) Start: 11 Air Temp (°C) Finish: 23 Cloud Cover (%): 10 Wind Speed (Beaufort): 2 Wind Direction: SW Precipitation: None
OSAP Fish Community Assessment	June 1, 2021	Air Temp (°C) Start: 23 Air Temp (°C) Finish: 25 Cloud Cover (%): 30 Wind Speed (Beaufort): 2 - 4 Wind Direction: N/A Precipitation: None
OSAP Habitat Assessment	June 2, 2021	Air Temp (°C) Start: 18 Air Temp (°C) Finish: 25 Cloud Cover (%): 30 - 40 Wind Speed (Beaufort): 2 Wind Direction: SE Precipitation: None
Breeding birds # 2, insect survey # 2, herpetofauna area search	June 15, 2021 / 06:07-10:00 hrs	Air Temp (°C): 14-20 Cloud Cover (%): 10 - 60 Wind Speed (Beaufort): 1 - 2

Field Survey	Survey Date	Weather Conditions
		Wind Direction: W, NW Precipitation: None
Bat acoustic monitoring, marsh birds # 2	June 16, 2021 / 20:15-22:37 hrs	Air Temp (°C): 18-19 Cloud Cover (%): 0 - 20 Wind Speed (Beaufort): 1 Wind Direction: N Precipitation: None
Anurans # 3	June 24, 2021 / 21:35-22:28 hrs	Air Temp (°C): 19-25 Water Temp (°C): 19 - 23 Cloud Cover (%): 80 - 90 Wind Speed (Beaufort): 0 - 3 Wind Direction: -- Precipitation: None
Leaf-on bat survey	June 30, 2021 / 10:00-14:20 hrs	Air Temp (°C): 25 Cloud Cover (%): 90 Wind Speed (Beaufort): 3 Wind Direction: NW Precipitation: None
Breeding birds # 3, insect survey # 3, herpetofauna area search	July 6, 2021 / 06:00-11:21 hrs	Air Temp (°C): 22 - 27 Cloud Cover (%): 40 - 70 Wind Speed (Beaufort): 2 - 3 Wind Direction: SW Precipitation: None
Summer vegetation inventory, herpetofauna area search	July 20, 2021 / 08:11-17:21 hrs	Air Temp (°C): 23.5 Cloud Cover (%): 20 Wind Speed (Beaufort): 2 Wind Direction: -- Precipitation: None
Wetland boundary review with CH and CVC staff	July 28, 2021 / 08:00-16:15 hrs	Air Temp (°C): 27 Cloud Cover (%): 0 Wind Speed (Beaufort): 0 - 1 Wind Direction: -- Precipitation: None
Wetland survey	July 30, 2021 / 08:00-16:15 hrs	Air Temp (°C): 18-22 Cloud Cover (%): 30 Wind Speed (Beaufort): 1 - 4 Wind Direction: -- Precipitation: None
Wetland boundary review with CH staff	September 8, 2021 – 08:50-14:30 hrs	Air Temp (°C): 18-23 Cloud Cover (%): mostly sunny Wind Speed (Beaufort): 1 Wind Direction: -- Precipitation: None

Field Survey	Survey Date	Weather Conditions
Anuran Survey (Stations 7, 8, 9, 10)	June 28, 2022 – 21:36-22:28 hrs	Air Temp (°C): 18.5-18 Cloud Cover (%): 40 Wind Speed (Beaufort): 3 Wind Direction: SW Precipitation: None

Survey methodologies for each of these field assessments are described in detail below.

2.6.3.1 Terrestrial Field Survey Methods

Comprehensive, four-season field investigations were undertaken within the study area and allowed for the refinement of natural heritage feature and area boundaries as well as the identification of significant species and habitats. Terrestrial field methodologies are described in detail below and locations of survey stations are shown on Map 2. Field surveys were undertaken in 2020 and throughout 2021.

Vegetation and ELC Surveys

Vegetation communities found within the study area have been mapped and described using the ELC system (Lee et al. 1998). This includes wetlands (as noted above), as well as riparian areas as discussed under the aquatic work program discussion. Cavity trees were identified for potential bat habitat. All natural features and functions were identified based on their representativeness and rarity, using the ELC vegetation type within the context of the study area, Town of Halton Hills, and the Province of Ontario. Where vegetation communities extend beyond the study area, the entire community was assessed, including portions outside of the study area boundary.

Three season floral inventories were completed. The surveys have been carried out in all ELC polygons.

Wetlands

Wetlands within the study area have been identified through Ecological Land Classification (ELC, Lee et al. 1998) and reviewed in the field with staff from Conservation Halton and the CVC. Comments from Conservation Halton (ref: DeFields-Ricci, May 14, 2021; Appendix H.6) identified the need to stake and survey the wetland boundaries. Through additional correspondence it was agreed that the wetland boundaries would be flagged by the SWS Team and reviewed in the field with staff from Conservation Halton and the CVC, and then surveyed by the SWS Team using a Trimble R10 GNSS receiver and antenna to achieve centimeter-level accuracy. The Conservation Authorities' regulatory limits will be confirmed through Subwatershed

Impact Studies (SIS) when the wetland boundaries will be staked and surveyed with an Ontario Land Surveyor (OLS) in the presence of Conservation Authority staff.

Bird Surveys

Surveys of breeding birds have been conducted within the study area. Locations for targeted surveys have been chosen that represent the full diversity of habitat found within the study area. Breeding bird surveys were carried out at selected point count locations on three occasions, spaced at least one week apart, throughout the breeding bird period (May 24 - July 10). Surveys occurred during mornings from dawn to 4 hrs after sunrise and have been completed during fair weather conditions (low wind, no precipitation, good visibility). Breeding evidence was recorded as per the Ontario Breeding Bird Atlas protocol (OBBA 2001).

Raptor surveys were carried out during the migration and breeding period, with notes on movement patterns and locations recorded. In addition, raptor surveys for SWH were completed (e.g., Woodland Raptor Nesting Areas). Owl surveys were completed during the first anuran call survey (April) during the nesting period for Eastern Screech Owl (*Megascops asio*) and Great Horned Owl (*Bubo virginianus*). Surveys involved the use of playback recordings of common owl species as per the *Eastern Screech Owl Survey Protocol for the Ontario Breeding Bird Atlas* (Cadman 2021).

Marsh bird surveys were carried out on two evenings in May / June according to the Marsh Monitoring Protocol (BSC 2009). As part of these surveys, the Scoped SWS Team carried out broadcast calls of targeted marsh species over a 15-minute period at each suitable location. Based on the Team's review of the site from field reconnaissance, marsh bird habitat was not found to be present within the study area (wetland communities were noted to have unsuitable characteristics related to water depth and vegetation structure). However, as per correspondence with CH staff, it was recommended that marsh bird surveys proceed in order to be conservative (E. DeFields pers. comm. 2021).

Amphibian Surveys

Targeted surveys for anurans (frogs and toads) have been completed in April, May and June as per the Marsh Monitoring Protocol (BSC 2009).

In addition, a targeted survey was completed in early April for any potentially suitable amphibian breeding habitat, such as ephemeral pools, ponds, or wetlands. This survey involved examining ponds for egg masses for salamanders and anurans as well as evaluating these features for breeding habitat (e.g., egg attachment sites, standing water throughout breeding periods, presence of fish, etc.).

Reptile Surveys

Targeted surveys for snakes and turtles have been conducted in conjunction with other scheduled field surveys. Field surveys consisted of systematic area searches of potential habitats. Suitable habitat areas were scanned during appropriate weather conditions using binoculars.

Mammal Surveys

All mammal observations (e.g., individual sightings or signs such as tracks, scat, dens sites) during field surveys were documented. Habitat for SAR bats was assessed according to the most recent guidelines at the time (MNRF 2017). This involved the completion of a leaf-off survey during March to identify suitable bat SAR habitat as well as a plot analysis of snag densities that could be considered SWH for candidate bat maternity roosts. A leaf-on survey was undertaken in June to assess habitat associated with leaf clusters for SAR bats. During evening amphibian surveys in June, bat activity was recorded with the use of an acoustic monitoring device that enabled Team staff to identify bat species that are utilizing habitats within the study area.

In order to assess movement corridors and linkages within the study area and adjacent lands, winter wildlife surveys were undertaken on two occasions in February 2021. Surveys were carried within 24 - 48 hours of a snowfall of at least 2 cm. These surveys included area searches through suitable wildlife habitat / potential movement corridors and identifying species based on direct observations, tracks, and other signs. Specific notes were made relating to vegetation patches that facilitate wildlife movement and connectivity between important habitats. Winter wildlife habitats specified within the Ecoregion 7E Criterion Schedule (MNRF 2015) were reviewed / evaluated during field surveys (e.g., Deer Winter Congregation Areas, Raptor Wintering Areas).

Insect Surveys

Targeted surveys for butterflies and odonates (dragonflies and damselflies) have been completed in May, June and July. All butterflies and odonates were identified to species and locations of any significant species / habitats was recorded. Incidental observations of bumble bees were to be recorded but none were observed.

Incidental Observations

Observations of all species of plants and wildlife observed throughout the study have been recorded. Location by ELC polygon, or finer as warranted, was used. These observations have been integrated with results of the targeted wildlife surveys described above.

2.6.3.2 Aquatic Field Survey Methods

Study Team aquatic biologists conducted five visits to the study area between October 30, 2020 and June 2, 2021. During these site visits a detailed characterization of aquatic habitats has been completed, as well as a fish community assessment, spawning surveys, and benthic invertebrate community assessment within East Sixteen Mile Creek. The additional watercourses or HDF within the study area were also assessed from an aquatic habitat perspective, including completing fish community surveys if water was present and where property access was granted. These surveys are described in further detail in the following sections. Monitoring locations are shown on Map 2. The HDF survey details are described by Matrix in **Section 2.4**.

Aquatic Habitat Assessment

To characterize the aquatic habitats within the study area, NRSI biologists assessed the different types of watercourses (i.e., ephemeral, intermittent, etc.). East Sixteen Mile Creek was divided into three sampling reaches and each of these reaches was then characterized following the Ontario Stream Assessment Protocol (OSAP) point transect methodology using Section 4, Module 2 (Stanfield 2017). The reaches were defined following the methods outlined in Section 1, Module 1 of OSAP as follows: the boundaries were established at thalweg crossovers that were at least 40 m apart. The number of transects, longitudinal spacing and points per transect were determined based on minimum wetted width and length of the sampling site. In-stream habitat and adjacent lands were assessed using both qualitative and quantitative parameters including wetted width, depth, hydraulic head, substrate size, available cover, bank angle, bank composition, and riparian and aquatic vegetation communities present. This protocol was identified within the work plan as it provides repeatable quantitative measurements that facilitate accurate habitat comparisons for each sampling site from year to year.

The habitat assessment was also conducted to identify key habitat areas within the study area and included an inventory of barriers to fish migration (using Stanfield et al. 2013) and sources of stream baseflow and groundwater discharge (e.g., seeps and springs).

The additional watercourses / aquatic features within the study area were assessed through the HDF surveys, including Mullet Creek, with additional information being collected by Study Team biologists following a modified OSAP. This included recording (where possible) substrate type, channel depth, width and bankfull width, general bank stability, riparian and aquatic vegetation, and flow conditions.

In addition, watercourses (permanent, intermittent, and ephemeral features) were assessed and classified based on the priority of habitat type and were assigned a cold, cold-cool, cool, cool-warm, or warmwater designation, based on background information, fish species present, and habitat features.

Fish Community Sampling

Fish communities within East Sixteen Mile Creek, within the study area have been characterized following the screening level assessment protocol as described in OSAP, Section 3, Module 1 (Stanfield 2017) on June 1, 2021. Fish sampling timing was selected as per the TOR that specified sampling was to occur during May / June. The screening level assessment uses a comparatively low level of sampling intensity, assessing all habitat types within the sampling reach through a single pass of electrofishing. This protocol is designed to provide a qualitative assessment of species abundance and characterize the fish communities throughout each sampling reach. The fish sampling was conducted within the three previously identified OSAP reaches.

A License to Collect Fish (LCF) for Scientific Purposes was issued to the Study Team biologists to allow for electrofishing to be completed starting June 1, 2021 by the MNRF Aurora District (No. 1097479). This LCF was then amended by the MNRF to allow electrofishing to occur within the headwater drainage features starting after May 1, 2021.

Fish sampling was conducted using a Smith-Root backpack electrofisher (LR-20B), set to a pulsating frequency of 60 – 80 Hz, and an electric potential of 200 – 250 V. Sampling involved one biologist with the backpack electrofisher and one alongside with a dip net walking in transects from the downstream end of the OSAP reach to the upstream end, for the three reaches.

Backpack electrofishing also occurred on the HDF features that were conveying flow. This included Mullet Creek at the eastern edge of the study area (under Winston Churchill Boulevard) and the tributary that conveys flow to East Sixteen Mile Creek (where water was present). The other HDF features were either dry or had too little water to electrofish. All culvert crossing locations were assessed to see if water was present on May 7, 2021, and dip-netting for fish did occur at one location where the pond feature outlets to an ephemeral channel (the ‘OA’ feature located east of 9th Line, HDF TESMC(1)5-1).

The observed electrofishing conditions, settings and total sampling time are summarized in **Table 2.6.2** for each sampling site. All captured fish were identified, enumerated and released.

Table 2.6.2: Electrofishing Conditions, Settings and Shocking Time

	Mullet Creek	Tributary to East Sixteen Mile	East Sixteen Mile Creek Reach 1	East Sixteen Mile Creek Reach 2	East Sixteen Mile Creek Reach 3
Date	May 7, 2021	May 7, 2021	June 1, 2021		
Sampling start time	0830 hrs	1315 hrs	0845 hrs	1200 hrs	1400 hrs
Sampling end time	0900 hrs	1325 hrs	0920 hrs	1220 hrs	1430 hrs
Air temperature (°C)	11	15	23	23	24
Water temperature (°C)	8	10	18	21	22
Time water temp. taken	915 hrs	1325 hrs	1100 hrs	1300 hrs	1505 hrs
Number of Netters	1	1	2		
Voltage (V)	200	200	200 - 250		
Pulsating Frequency (Hz)	60	60	60 - 80		
Ampere (Amps)	2.5 - 4	4.5	4 - 4.5		
Shocking time (sec.)	541	75	231	311	374

Spawning Surveys

A fall and spring spawning survey has been completed on East Sixteen Mile Creek to assess the likelihood of sensitive species (e.g., Trout) utilizing the creek (Imhof 2010). Spawning surveys consisted of visual observations throughout East Sixteen Mile Creek to identify the presence of actively spawning Trout or redds (i.e., fish ‘nests’) that may have been used during the fall of 2020 and spring of 2021. Visual surveys were conducted by NRSI aquatic biologists wearing polarized sunglasses and walking the banks of the creek. If evidence of spawning was observed, the location, number of spawning fish, and habitat features would be recorded.

Benthic Invertebrates

As part of this study, surveys of benthic macroinvertebrates have been undertaken at three stations within East Sixteen Mile Creek. These stations utilized the same reaches as the OSAP habitat and fish community sampling. The sampling methodology followed the Before / After / Control / Impact (BACI) experimental design and the Ontario Benthos Biomonitoring Network Protocol Manual (OBBNPM) (Jones et al. 2007). The

OBBN data form was used to record habitat information at the benthic invertebrate sample stations.

According to the OBBN methods for streams, a total of three sub-stations are to be collected at each station in stream habitat: two from riffle habitat and one from pool habitat. For wadeable streams, such as East Sixteen Mile Creek within the study area, the OBBN protocol employs a “Travelling Transect Kick and Sweep” method, where each sub-sample is made up by sampling 10 linear meters of stream transect over a 3-minute period (Jones et al. 2007; EC 2011). Beginning at one bank and moving across each transect, the substrate was disturbed to a depth of approximately 5 cm by vigorously kicking the substrate. A 500 µm mesh D-net was held downstream of and close to the disturbed area by the person sampling. The net was held on or close to the bottom of the channel and was swept back and forth so that dislodged invertebrates would be carried into the net. In areas of slow current, the sweeping motion is important for collecting the invertebrates into the net. A timer was used to time the sampling.

When sampling was complete, the net was rinsed and the sample was placed in a plastic jar. The sample was then preserved with a buffered 70% ethanol solution and stored for later identification.

Benthic samples have been processed and identified in the NRSI laboratory. Samples have been subsampled using the weight-based subsampling procedure as described by Sebastien et al. (1988) to accurately represent the makeup of the benthic community. Sub-samples were sorted using a dissection microscope to collect all invertebrate individuals within the sub-sample.

Successive sub-samples were sorted to achieve a minimum of 100 organisms, as indicted by the OBBN protocol (Jones et al. 2007). Upon collection of the 100th organism, the remaining sub-sample was assessed until all remaining organisms in that sub-sample were identified. The level of sub-sampling and sorting was 100 organisms plus the remaining organisms in the last sub-sample. The samples were then identified to the lowest practical taxonomic level. The difference between the two measurements represents the portion sampled, which is recorded as a percentage of the total sample (Environment Canada 2011).

Benthic Invertebrate Analysis

Benthic organisms that do not fall within the 27 groups of benthic invertebrates outlined in the OBBN protocol were not included in the tally (Jones et al. 2007). The benthic invertebrate data was analyzed using a number of metrics in order to characterize the general condition of the watercourse. A total of 12 metrics and indices were calculated

in order to assess the water quality within each monitoring station. These metrics include:

- Taxa Richness – the number of taxa generally increases with habitat diversity and water quality (Jones et al. 2007)
- EPT Taxa Richness – the number of taxa from orders sensitive to pollution, specifically the orders *Ephemeroptera, Plecoptera*, and *Tricoptera* (Barbour et al. 1999; Weber 1973)
- Percent EPT – percent composition of a community by taxa from orders sensitive to pollution, specifically the orders *Ephemeroptera, Plecoptera,* and *Tricoptera* (Barbour et al. 1999; Weber 1973)
- Percent *Oligochaetes* – percent composition of a community by aquatic worms, a group tolerant to pollutants (Jones et al. 2007)
- Percent *Diptera* – percent composition of a community by fly larvae which provides a context for other analysis (Jones et al. 2007)
- Percent *Chironomidae* – percent composition of a community by larval midges, a highly tolerant family (Bouchard 2004; Jones et al. 2007)
- Dominant / Subdominant Taxa – highest and second highest number of taxa sampled
- Percent Functional Feeding Groups – the percent composition of a community by Collector-filterers, Collector-gatherers, Predators, Scrapers, and Shredders. Feeding groups can provide an indication of habitat conditions (Merritt et al. 2008)
- Shannon Wiener Index (H') – an index used to measure the diversity in categorical data, taking into account the number of species and evenness of the species. Calculated as:

$$H' = -\sum (p_i)\,(lnp_i)$$

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

- BI – a measure of water quality based on the species-level "tolerance values" and the number of individuals of each species, as well as the total number of individuals within the sample. Calculated as:

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

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

— FBI – a measure of water quality based on the family-level "tolerance values" and the number of individuals within each family and the total number of individuals within the sample. Calculated as:

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

Where "x_i" is the number of individuals within the ith family, "t_i" is the tolerance value of the "ith" family, and n is the total number of individuals within the sample (Hilsenhoff 1988).

— Simpson's Diversity Index – Diversity of a benthic invertebrate community where values of 1 indicate high diversity and 0 indicate low diversity. Calculated as:

$$DI = 1 - \frac{\sum n(n-1)}{N(N-1)}$$

Where "n" is the number of individuals within each species, and "N" is the total number of individuals of all species (Simpson 1949).

The results of these metrics are then compared to a set range of 'Potentially Unimpaired' conditions and 'Potentially Impaired' conditions. The OBBN defines impaired as, "showing a biological response to imposed stressors; exhibiting a changed biological community brought about by degradation in water or habitat quality" (Jones et al. 2007). 'Potentially Unimpaired' conditions indicate a low probability of significant anthropogenic impact, and 'Potentially Impaired' conditions indicate a high probability of significant anthropogenic impact, within an aquatic environment. These ranges can be used as measures of the environmental water quality and serve as potential indicators of ongoing environmental impacts. They also provide added context for the results of the benthic assessment. The ranges are based on the results of benthic rapid assessment methodologies developed by the MNRF, the MECP, the Ministry of Municipal Affairs and Housing (MMAH), and the Toronto and Region Conservation Authority (TRCA).

Table 2.6.3 below provides the range of results that can be attributed to the 'potentially unimpaired' and 'potentially impaired' categories within an ecosystem (Vannote et al. 1980).

Table 2.6.3: General Benthic Invertebrate Assessment Ranges

Water Quality Index	Potentially Unimpaired	Potentially Impaired	Source(s)
EPT Richness	>10	<10	David et al. 1998 and Kilgour 2000
Taxa Richness	>13	<13	David et al. 1998
% Oligochaetes	<10%	>10%	David et al. 1998 and Griffiths 1998
% Chironomidae	<10%	>10%	Griffiths 1998
% Diptera	20 - 45%	<20 or >50%	David et al. 1998
Shannon-Wiener Index	>4	<4	Kilgour 1998
Family Biotic Index	<6	>6	Kilgour 1998
Biotic Index	<7	>7	Kilgour 1998

2.6.4 Characterization and Analysis

The existing conditions within the study area and adjacent lands are characterized in the following sections

2.6.4.1 Terrestrial Analysis

Designated Natural Areas

Information on designated natural areas has been obtained from the MNRF LIO database, NHIC, Halton Region, Town of Halton Hills, and Conservation Halton. According to background information collected, there are no locally, provincially, or regionally significant wetlands, Areas of Natural and Scientific Interest (ANSI), or Environmentally Sensitive Areas (ESAs) within the study area or adjacent lands. One unevaluated wetland is mapped by the MNRF in the eastern portion of the study area (Map 1).

Vegetation

In total, 193 species were observed within the study area. No rare vegetation species were observed within the study area. Species observed within each vegetation community are summarized below. The vegetation species list is attached in **Appendix H.3**.

Vegetation Communities

The study area and adjacent lands consist primarily of agricultural fields with meadows located along the two watercourses and some regenerating lands. Natural heritage features, such as woodlands, forest, and wetlands are sparse within the study area. Rural residential areas, industrial, and commercial sites are located along the roadways. A summary of ELC communities identified within the study area is provided in Table 2.6.4. ELC communities are described below and shown on Map 4. Agricultural crops are labelled on this map based on 2020 conditions.

Table 2.6.4: Vegetation Communities Present within the Study Area

Meadow / Thicket	
CUM	Cultural Meadow
CUT	Cultural Thicket
Woodland and Forest	
CUW	Cultural Woodland
FOD	Deciduous Forest
FOD4	Dry-Fresh Deciduous Forest
FOD7-4	Fresh-Moist Black Walnut Lowland Deciduous Forest
Wetland and Open Water	
MAM2-10	Forb Mineral Meadow Marsh
MAS2	Mineral Shallow Marsh
MAS2-1	Cattail Mineral Shallow Marsh
SWT2-2	Willow Mineral Thicket Swamp
OA	Open Water
SWD	Deciduous Swamp
Other	
Ag	Agricultural Cropland (2020 crop identified on Map 4)
Rural Properties	--
Business Sector	--
Light Industrial	--
Cemetery	--

Mineral Cultural Meadow (CUM)

Meadow habitat is present throughout the study area and includes areas of recently cleared land and fallow agricultural land. These communities often contain a high proportion of non-native cool season grasses including Smooth Brome (*Bromus inermis*), Reed-canary Grass (*Phalaris arundinacea*), Timonthy (*Phleum pratense*), Orchard Grass (*Dactylis glomerata*), and Kentucky Bluegrass (*Poa pratensis*). The diversity of forbs includes Canada Goldenrod (*Solidago canadensis*), Tall Goldenrod (*Solidago altissima*), Grass-leaved Goldenrod (*Euthamia graminifolia*), New England Aster (*Symphyotrichum novae-angliae*), Queen Anne's Lace (*Daucus carota*), Teasel (*Dipsacus fullonum*), and Ragweed (*Ambrosia artemisiifolia*), among others.

The meadow communities generally contain a variety of species that provide pollinator habitat including Common Milkweed (*Asclepias syriaca*), which is the host plant for Monarch butterfly (*Danaus plexippus*). Cultural meadow habitat is associated with East Sixteen Mile Creek, where it transitions into a Forb-Mineral Meadow Marsh (MAM2-10) next to the creek. Agricultural fields between 8th Line and East Sixteen Mile Creek have been left fallow and now provide meadow habitat. In 2020, the fields north of East Sixteen Mile Creek were also fallow, although they had not yet established a meadow community. In 2021, these fields are planted with hay, which provided breeding habitat to several Bobolink (*Dolichonyx oryzivorus*) pairs.

Small cultural meadows are associated with farm properties. In part, these are very disturbed sites, containing rubble and gravel where residences have been demolished. East of 10th Line, a large cultural meadow is establishing on a property that contained numerous buildings, barns, and a likely trucking company prior to 2000. The area contains a lot of gravel pavement.

Cultural meadow is also found along Mullet Creek on the east side of the study area, as well as along the HDF MC(5). A small inclusion is mapped of wetland vegetation along the HDF, which is dominated by Lance-leaf Aster (*Symphyotrichum lanceolatum*), and Spotted Joe-Pye Weed (*Eutrochium maculatum*), with abundant Reed-canary Grass (*Phalaris arundinacea*) (MAM2-10).

Mineral Cultural Thicket (CUT)

Three cultural thicket communities have been identified, all of which are in the block of land east of 9th Line. All thickets were previously Ash-dominated woodlots, but the Ash have died due to Emerald Ash Borer (*Agrilus planipennis*). Virtually the only species in these now thicket communities is European Buckthorn (*Rhamnus cathartica*), the non-native and highly invasive shrub.

Cultural Woodland (CUW)

Cultural woodlands, with a canopy <60%, are located along East Sixteen Mile Creek in the western portion of the study area. The area around a former residence off 8th Line contains quite a few trees, including Black Walnut (*Juglans nigra*), Manitoba Maple (*Acer negundo*), Norway Maple (*Acer platanoides*), White Pine (*Pinus strobus*), and White Spruce (*Picea glauca*). Meadow grasses and forbs are found in this area below the trees, as are gravel areas in the vicinity of the former farm buildings.

A small cultural woodland is found in the southwest corner of the study area, located between the cemetery and East Sixteen Mile Creek. This woodlot is dominated by Black Locust (*Robinia pseudoacacia*), with some Black Walnut, and a few other species: Eastern Cottonwood (*Populus deltoides*), Manitoba Maple, Red Oak (*Quercus rubra*), and White Elm (*Ulmus americana*).

Higher quality woodlands are identified as inclusions of the cultural meadow (CUM) adjacent to the upper reaches of East Sixteen Mile Creek. These treed stands are dominated by Black Walnut with associations of Bitternut Hickory (*Carya cordiformis*) and Sugar Maple (*Acer saccharum*). The understory contains a variety of shrubs, and the groundcover is dominated by meadow species, particularly Smooth Brome and a variety of forbs, as described in the meadow community.

Deciduous Forest (FOD)

The forest north of the study area, through which East Sixteen Mile Creek flows, is a deciduous forest which appears to be dominated by Black Walnut and Oak species, along with dead Ash. South of the study area, East Sixteen Mile Creek flows through a deciduous forest that is dominated by Basswood and Bur Oak (*Quercus macrocarpa*), along with occasional Manitoba Maple, Norway Maple, and Black Walnut. Restoration plantings are visible on the southern embankment of Steeles Avenue. Observations of both forests were made through binoculars from the study area boundary.

Dry-Fresh Deciduous Forest (FOD4)

This deciduous forest is dominated by Basswood (*Tilia americana*) with Bitternut Hickory almost as abundant. Bur Oak and Shagbark Hickory are also present in the canopy. The sub-canopy is dominated by Basswood and Ironwood (*Ostrya virginiana*), as well as European Buckthorn. European Buckthorn dominates the understory and groundcover, with no herbs.

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

A Black Walnut dominated forest is located on the north side of East Sixteen Mile Creek. It is noted that this community does not appear to be a plantation or have originated as a plantation. Black Walnut is found in the canopy, sub-canopy, and understory. Hawthorn species (*Crataegus spp*.), Norway Maple, and White Elm are found infrequently in this unit. The understory is comprised of regenerating trees, including Black Walnut, as well as Tatarian Honeysuckle (*Lonicera tatarica*), Basswood, and White Elm. The groundcover is dominated by a variety of grasses, along with a good mix of forbs, such as American Hog peanut (*Amphicarpaea bracteata*), Common Milkweed, and Grass-leaved Goldenrod (*Euthamia graminifolia*). Fresh-Moist Black Walnut Lowland Deciduous Forest is considered significant in Ontario, with a provincial rank of S2S3. Species that prefer moister conditions are found right along the watercourse, including Reed-canary Grass, Spotted Joe-pye-weed (*Eutrochium maculatum*), Nodding Beggarticks (*Bidens cernua*), and Panicled Aster (*Symphyotrichum lanceolatum*). Household refuse / garbage has been dumped within the southern portion of the community, on the edge of the agricultural fields located to the west.

Forb Mineral Meadow Marsh (MAM2-10)

This marsh community is located along East Sixteen Mile Cree, as well as in the Lisgar area, and Mullet Creek. The marsh is dominated by Panicled Aster, with Calico Aster (*Symphyotrichum lateriflorum*), Spotted Joe-pye-weed, Purple Loosestrife (*Lythrum salicaria*), and other forbs.

Mineral Shallow Marsh (MAS2)

Two small shallow marsh communities are located on either side of the laneway leading to the former residence on the far west end of the study area, off 8th Line. The marsh is inundated with the highly invasive Common Reed (*Phragmites australis*).

Cattail Mineral Shallow Marsh (MAS2-1)

A small marsh, dominated by Narrow-leaved Cattail (*Typha angustifolia*) is also located east of 8th Line, associated with a former homestead.

Deciduous Swamp (SWD)

The forest north of the study area, through which East Sixteen Mile Creek flows, contains a deciduous swamp according to MNRF mapping, although species are

unknown, given the distance from the study area and that access was not permitted. Species include Ash and Oak.

Willow Mineral Thicket Swamp (SWT2-2)

Access to this wetland was granted on one occasion to delineate the boundary on the west side. This wetland is dominated by a variety of Willow species (*Salix amygdaloides, S. bebbiana, S. discolor, S. eriocephala, S. petiolaris*), Red-Osier Dogwood (*Cornus sericea*), and Reed Canary Grass. Red-osier Dogwood (*Cornus sericea*) is abundant, along with occasional Trembling Aspen (*Populus tremuloides*). Reed-canary Grass dominates the ground layer. Certain areas are abundant with Broad-leaved Cattail (*Typha latifolia*), and Common Reed dominates the southern portion of the wetland.

Agricultural Crop Land

Crops are labelled on Map 4 as they were noted in September 2020. Fields were planted primarily with corn and soy beans, both inside and outside of the study area. One central field was planted with wheat, and another one, east of 10th Line, was bare (no crop). Alfalfa was growing in two fields in the east part of the study area. It is probable that yearly crops rotate between corn and soy. In 2021, the field north of the western portion of the study area was planted in hay, where it was fallow in 2020.

Birds

According to the Ontario Breeding Bird Atlas (BSC et al. 2006) a total of 75 bird species are reported from the 10 x 10 km OBBA squares that overlap with the study area. The data found in the OBBA includes those species that have been observed in the area, are known to nest in the area, and/or have exhibited some evidence of breeding in the area. Additional background data documented an additional three species exhibiting breeding evidence (NRSI 2015) and 17 species that did not exhibit signs of breeding evidence (eBird 2021 and iNaturalist 2021). Numerous SAR and SCC have the potential to occur within the study area and adjacent lands based on the results of the background review. A complete list of these species is included in **Appendix H.3**.

A total of 87 bird species were observed during field surveys. Of these, 58 species were observed during breeding bird surveys, of which 54 species exhibited signs of breeding.

Several significant bird species were identified within the study area including Barn Swallow, Bobolink, Eastern Meadowlark, and Eastern Wood-Pewee.

- Barn Swallows were observed foraging throughout the study area (BMB-01, 04-09; MBM-06, 07). They were confirmed to be nesting within the barn and shed located

just east of 9th Line. These structures were removed on July 6, 2021. Confirmed breeding was also noted through the observation of fledged young observed along the East Sixteen Mile Creek corridor, near BMB-04.

- Bobolink were associated with the fallow fields north of East Sixteen Mile Creek, east of 8th Line, in the area of BMB-03 to -04; as well as on the eastern end of the study area in the vicinity of BMB-08 and -09. Bobolink was noted as a probable breeder through the observation of breeding displays and pairs.
- One Eastern Meadowlark was observed on March 17, 2021, within meadow habitat associated with East Sixteen Mile Creek. This individual was on migration and the species is not breeding within the study area as it was not observed again.
- Eastern Wood-Pewee was noted as a probable breeder from the deciduous woodland (FOD) south of Steeles Avenue, just east of 8th Line (BMB-01). It was recorded as a possible breeder from the treed slope from BMB-03 and from the woodland further north along East Sixteen Mile Creek (FOD7-4) at BMB-04.

The marsh bird surveys confirmed marsh bird habitat is not present within the study area or adjacent lands. No marsh birds were identified during marsh bird surveys. The only marsh bird detected during field surveys was a Green Heron (*Butorides virescens*), observed on July 30, 2021, from the East Sixteen Mile Creek corridor.

Winter wildlife surveys carried out during February 2021 also assessed habitat for wintering birds, including raptor species. Meadow / marsh habitat adjacent to East Sixteen Mile Creek has the potential to provide habitat for wintering raptors, however, only small numbers (2 - 3 individuals) of Red-tailed Hawks (*Buteo jamaicensis*) were observed on each site visit, and as such, SWH for raptor wintering is not considered to be present within the study area or adjacent lands.

Owl surveys carried out in April 2021 did not identify any owl species within woodlots. However, a Great Horned Owl was observed within a small woodlot (FOD4) east of 10th Line during winter wildlife surveys in February 2021. Although owls were not observed during owl surveys during April, suitable breeding habitat is present for both Eastern Screech Owl (*Megascops asio*) and Great Horned Owl (*Bubo virginianus*) within the study area and adjacent lands.

Raptor migration was monitored during all suitable spring and fall conditions. As the study area is not located immediately adjacent to Lake Ontario or other features that would concentrate raptor movement, migration activity has been noted to be relatively diffuse. A substantial raptor movement was recorded during a fall survey (September 14, 2020) when a total of 86 raptors were recorded over several hours including Broad-winged Hawk (*Buteo platypterus*), Turkey Vulture (*Cathartes aura*), Red-tailed Hawk,

Bald Eagle (*Haliaeetus leucocephalus*), American Kestrel (*Falco sparverius*), and Merlin (*Falco columbarius*). A Peregrine Falcon (*Falco peregrinus*) was observed within the study area on October 23, 2001. Movement patterns through the study area are expected to be largely dictated by wind patterns and are not generally related to topography or natural features.

Herpetofauna

According to the Ontario Reptile and Amphibian Atlas (ORAA), 16 species and forms of herpetofauna are reported from the vicinity (approximately 10 km) of the study area (Ontario Nature 2019). Numerous SAR and SCC have the potential to occur within the study area and adjacent lands based on the results of the background review. A complete list of these species is included in **Appendix H.3**.

Anurans (Frogs and Toads)

Anurans were surveyed April 26, May 26, and June 24, 2021. The results are provided in **Table 2.6.5.** Breeding anurans were only observed from stations ANR-03 and ANR-04 (Map 2), both associated with East Sixteen Mile Creek, at the downstream and upstream ends within the study area. A total of four species were observed during field surveys, which includes American Toad (*Anaxyrus americanus*), Green Frog (*Lithobates clamitans*), Northern Leopard Frog (*Lithobates pipiens*), and Spring Peeper (*Pseudacris crucifer*).

Table 2.6.5: Anuran Monitoring Results

ANR Station	April 26, 2021	May 26, 2021	June 24, 2021	June 28, 2022
1	*none*	*none*	*none*	*n/a*
2	*none*	*none*	*none*	*n/a*
3	AMTO 2(3), SPPE 2(3)	AMTO 1(1), GRFR 2(6)	AMTO 1(1), GRFR 3	*n/a*
4	NLFR 1(1)	GRFR 1(1)	GRFR 1(2)	*n/a*
5	*none – dry, meadow*	*n/a*	*n/a*	*n/a*
6	*none – dry, meadow*	*n/a*	*n/a*	*n/a*
7	*none*	*none*	-	*none*
8	*none*	*none*	-	*none*
9	*none*	*none*	-	*none*
10	*none*	*none*	-	*none*
11	--	*no water*	*n/a*	*n/a*

Legend

AMTO – American Toad GRFR – Green Frog

NLFR – Northern Leopard Frog SPPE – Spring Peeper

First # indicates call code / level, 2nd #, in brackets, indicates number of individuals.

Call Level 1. Calls can be counted; not simultaneous

Call Level 2. Some simultaneous calls; yet distinguishable

Call Level 3. Calls not distinguishable; overlapping (i.e., “full chorus”); number of individuals is not estimated

As indicated in **Table 2.6.5,** following April surveys, ANR-05 and 06 were discontinued as they were identified to be dry, with no standing water and therefore no suitable habitat for breeding anurans. ANR-11 was added during the May 26 survey to assess amphibian habitat along Mullet Creek but was also found to be dry. Auran surveys at stations 7, 8, 9, and 10 were inadvertently missed in June 2021, so surveys were completed in June 2022.

Salamanders

Habitat for salamanders within the study area and adjacent lands is considered to be minimal or non-existent. Ephemeral pools and other suitable wetland habitat was not observed. No egg masses were observed during the targeted survey in April. No salamanders have been observed during area searches, including flipping of rotting logs, although it is possible that Eastern Red-backed Salamander (*Plethodon cinereus*) is present.

Reptiles

No reptiles were observed during field surveys. One Snapping Turtle (*Chelydra serpentina*) and Eastern Gartersnake (*Thamnophis sirtalis sirtalis*) were reported from the far western property (JLA et al. 2020).

Butterflies and Odonates (Dragonflies and Damselflies)

According to the Ontario Butterfly Atlas (Jones et al. 2020), Ontario Odonata Atlas (OODA 2020), and iNaturalist (2021), 48 butterfly species and 10 odonata species are reported from within the 10 x 10 km atlas square that overlaps with the study area. Numerous SAR and SCC have the potential to occur within the study area and adjacent lands based on the results of the background review. A complete list of these species is included in **Appendix H.3**.

Habitat for butterfly species is anticipated to be present within the East Sixteen Mile Creek corridor and associated woodland, wetland, and meadow communities, as well as in other naturalized areas throughout the study area where nectar sources are present. Odonate species are anticipated to be most strongly associated with East Sixteen Mile Creek as they require aquatic habitats for breeding, although meadow areas throughout the study area may be utilized for foraging.

Targeted insect surveys were undertaken on May 27, June 15, and July 6, 2021. A total of 19 butterfly species and 17 odonate species were observed. Monarch (*Danaus plexippus*), a species of conservation concern, were identified throughout the subject property in open habitats on July 6, 2021.

During the first insect survey on May 26, 2021, a number of common butterfly, odonate, and bumble bee species were recorded. The highest quality insect habitat for pollinators as well as odonata is largely located along the East Sixteen Mile Creek corridor where a number of flowering plants and aquatic habitats are present. Additional insect surveys were completed in June and July.

Mammals

According to the Mammal Atlas of Ontario (Dobbyn 1994) and iNaturalist (2021), 42 mammal species are reported from within 10 km of the study area. Numerous SAR and SCC have the potential to occur within the study area and adjacent lands based on the results of the background review. A complete list of these species is included in **Appendix H.3**.

Mammal surveys to date have focused on winter wildlife and bat habitats. Winter wildlife surveys carried out during February 2021 identified the presence of abundant numbers

of common mammal species. In particular, the East Sixteen Mile Creek corridor was found to have particularly high numbers of mammals including Coyote (*Canis latrans*), Mink (*Mustela vison*), Ermine (*Mustela erminea*), Eastern Cottontail (*Sylvilagus floridanus*), and various small mammal species. This area was found to be an important north-south movement corridor across the study area. Very few White-tailed Deer (*Odocoileus virginianus*) were observed within the study area, likely due to a lack of substantial tree cover and the presence of high numbers of Coyote.

East Sixteen Mile Creek has been impacted by Beaver (*Castor canadensis*), with frequent dams causing areas of pooled water, particularly evident upstream (north) of Steeles Avenue.

Bats

Bat habitat assessments carried out during the leaf-off period in March 2021 identified numerous trees that could provide suitable habitat for roosting bats. Most of these trees were associated with habitats along East Sixteen Mile Creek, although other candidate trees were also identified within the small, isolated forest community (FOD4) located east of 10th line (Map 5). None of the forests / woodlands within the study area were found to have sufficient snag densities to be considered SWH, although several woodlands bordering the study area could not be surveyed since permission to enter had not been given.

A bat leaf-on survey and bat acoustic monitoring was carried out in June 2021 to assess the potential for bat SAR habitat associated with leaf clusters and identify bats species are utilizing habitats within the subject property. The majority of the trees associated with bat habitats were within the East Sixteen Mile Creek corridor and several suitable trees were observed in the isolated forest community (FOD4) located east of 10th line (Map 5). The bat acoustic monitoring was conducted June 16, 2021 using a SM4 acoustic detector and microphone set to record from the full spectrum of bat calls (15 - 120kHz). Transects were walked within the subject property within the East Sixteen Mile Creek corridor and the cultural meadow (CUM) south of FOD4. Recordings were manually classified, and only 30KHz approach phase signals were detected which would either be Big Brown Bat (*Eptesicus fuscus*) or Silver-haired Bat (*Lasionycteris noctivagans*). The following species are reported from the Gilbach property: Big Brown Bat, Eastern Red Bat (*Lasiurus borealis*), Eastern Small-footed Myotis (*Myotis leibii*), Hoary Bat (*Lasiurus cinereus*), Little Brown Myotis (*Myotis lucifugus*), and Silver-haired Bat (JLA et al. 2020). Eastern Small-footed Myotis and Little Brown Myotis are considered Endangered in Ontario and Canada. The Gilbach SWS (JLA et al. 2020) reports 102 calls recorded of Eastern Small-footed Myotis, but notes that suitable breeding habitat is not present within their property. A total of four calls of Little Brown

Myotis were recorded and it was noted that it “is unlikely that Little Brown Myotis is roosting within the Cultural Woodlands on the Subject Lands due to the low call counts, rather they are likely foraging within the wetland communities and/or along the East Branch of Sixteen Mile Creek” (p.407 of pdf document).

2.6.4.2 Aquatic Analysis

Watercourses

Background review of the study area has identified East Sixteen Mile Creek, as well as some additional aquatic features that may be protected and have regulated areas associated with them. Through further review and field studies, two of the features within the study area, and two more within the adjacent lands were identified as watercourses. The other features were identified as HDFs and are discussed in **Section 2.4**

Aquatic Habitats

The majority of the surveyed aquatic features are located within the East Sixteen Mile Creek subwatershed, with the remaining being located within the Mullet Creek subwatershed. The watercourses are mapped through existing sources, are shown on Map 2. All tributaries where property access was granted within the study area at the time of the survey have been surveyed and information has been recorded regarding available fish habitat. Information collected for each tributary is summarized in **Table 2.6.6.**

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<u>East Sixteen Mile Creek</u>

The overall main branch of East Sixteen Mile Creek is a permanent flowing watercourse that provides direct habitat to a variety of fish species. Beavers have built a large number of dams along the watercourse (Map 5), which is influencing the substrates and causing backwatering to occur. A wide floodplain is associated within East Sixteen Mile Creek. Habitat within the creek is provided through pools, riffles, runs, overhanging vegetation, woody debris, and undercut banks. Iron staining was identified throughout the various reaches that were assessed, indicating potential groundwater input. A small area of open water was noted during winter surveys within the FOD7-4 community, adjacent to East Sixteen Mile Creek, indicating a small seep may be present in that location. Water temperatures were taken within East Sixteen Mile Creek during the site visits and are provided in **Table 2.6.6.**

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Table 2.6.6: Temperatures of East Sixteen Mile Creek

	Reach 1		Reach 2		Reach 3	
	Water Temperature	**Air Temperature**	**Water Temperature**	**Air Temperature**	**Water Temperature**	**Air Temperature**
May 7, 2021	12	13	12	14.5	11	14.5
May 10, 2021	12	--	13	--	12.4	--
June 1, 2021	18	23	21	21	22	24
June 2, 2021	17	27	19	28	20	28

Based on the water temperatures compared to the air temperatures that were found during the June sampling, as well as the evidence of iron staining, it is probable East Sixteen Mile Creek has a cool water thermal regime.

Table 2.6.7 provides a summary of the habitat characteristics observed within each of the assessed reaches. The three reaches were chosen to represent East Sixteen Mile Creek. The reaches were not influenced by the beaver dams, as preferred by the OSAP.

Appendix H.4 provides a photolog of the three reaches within Sixteen Mile Creek.

Table 2.6.7: East Sixteen Mile Creek OSAP Watercourse Characteristics

	Reach 1	Reach 2	Reach 3
General Description	Natural channel flowing through a natural floodplain. Low gradient with pools and runs. Fish abundant.	Natural channel flowing through a natural floodplain. Low gradient with pools, riffles, and runs. Fish abundant.	Natural channel flowing through a natural floodplain. Low gradient with pools, riffles, and runs. Fish abundant.
Flowing	Yes	Yes	Yes
Length of Reach (m)	53.0	56.5	65
# of Transects	10	12	12
# of Points per Transect	6	5	5
Groundwater Input	Potential – iron staining	Potential – iron staining	Potential – iron staining
Left Bank Height (m)	0.62 – 1.93	0.15 - 1.27	0.12 – 0.86
Right Bank Height (m)	0.61 – 0.86	0.22 – 0.97	0.34 – 1.19
Wetted Width (m)	4.4 – 7.4	1.6 – 6.0	1.6 – 7.9
Morphology	Meander	Meander	Meander

	Reach 1	Reach 2	Reach 3
Water Depth (cm) Range	1 – 55	1 - 38	1 - 36
Aquatic Vegetation	Terrestrial Plants, Filamentous Algae and Non-filamentous Algae	Terrestrial Plants, Grass, Filamentous Algae and Non-filamentous Algae	Terrestrial Plants, Grass, Filamentous Algae and Non-filamentous Algae
Cover	Embedded and Unembedded round rock, flat rock, banks and macrophytes.	Embedded and Unembedded round rock, flat rock, macrophytes, banks, and wood	Embedded and Unembedded round rock, flat rock, macrophytes, banks, and wood
Instream Habitat	Pools, Undercut Banks, Woody Debris and Overhanging vegetation	Pools, Riffles, Undercut Banks, Woody Debris and Overhanging vegetation	Pools, Riffles, Undercut Banks, Woody Debris and Overhanging vegetation
Substrates	Sand, gravel, pebble, silt, cobble and boulder	Sand, gravel, pebble, silt, cobble and boulder	Sand, gravel, pebble, silt, and cobble
Banks	Stable with high amount of vegetation	Stable with high amount of vegetation	Stable with high amount of vegetation
Dominant Vegetation	Meadow & Scrubland	Meadow	Meadow
Fish Present	Yes	Yes	Yes

Tributary to East Sixteen Mile Creek

This watercourse is located on the western extent of the study area and flows into the main branch of East Sixteen Mile Creek. It is identified as TESMC1 within the Gilbach SWS (JLA et al. 2020). During the habitat assessment and HDF e-fishing on May 7, 2021, this feature was flowing and clear. The channel is defined and the terrestrial vegetation overhangs the channel providing excellent shading. It is likely that the terrestrial vegetation grows within the channel during the summer months, and that this feature is intermittent. Immediately downstream of the confluence with East Sixteen Mile Creek is a beaver dam (Map 5). This beaver dam has caused backwatering into the tributary, and fish were observed within this area. Substrates were primarily silt and detritus with limited substrate sorting.

This feature was also assessed as a headwater drainage feature and more information is provided in **Section 2.4**.

Mullet Creek

This watercourse is located on the western extent of the study area and during the habitat assessment and HDF e-fishing on May 7, 2021, this feature was flowing and

clear. There was a defined channel present alongside the residential property, but the channel became less defined further west (upstream). Substrates within the channel were primarily muck, silt and detritus and vegetation was growing within the semi defined channel. A small pond appears to be present (on mapping) to the north of the study area which was likely providing the flow to this small feature. The watercourse was dry in late May and early June, which indicates this feature has a warm water thermal regime.

This feature was also assessed as a headwater drainage feature and more information is provided in **Section 2.4**.

Fish Community

Fish sampling has been completed by CH and others at several locations along East Sixteen Mile Creek within and in the vicinity of the subject area. Fish sampling has not previously been completed for Mullet Creek or HDFs within the study area.

A list of fish species historically known to occur within the study area and vicinity is presented in **Table 2.6.8**. The historical fish community within the study area consists of a variety of cool and warmwater species and is generally indicative of an intermediately tolerant fish community. **Table 2.6.8** also identifies the species found on June 1, 2021. All species identified with an asterix (*) were observed in all three of the stream reaches in East Sixteen Mile Creek. Based on the results of the electrofishing and the fish species found, East Sixteen Mile Creek has a cool water thermal regime, substantiating the temperature observations.

The DFO Species at Risk distribution mapping (DFO 2020) does not identify any aquatic SAR from within the study area.

Table 2.6.8: Fish Species Reports from East Sixteen Mile Creek within the Study Area

Common Name	Scientific Name	Thermal Regime	SRank	Background Information (Date Observed)
Bluegill	*Lepomis macrochirus*	Warm	S5	12/31/1993
Bluntnose Minnow*	*Pimephales notatus*	Warm	S5	7/25/2019
Brook Stickleback*	*Culea inconstans*	Cool	S4	7/25/2019
Brown Bullhead	*Ameiurus nebulosus*	Warm	S5	7/25/2019
Creek Chub*	*Semotilus atromaculatus*	Cool	S5	7/25/2019
Fantail Darter*	*Etheostoma flabellare*	Cool	S4	7/25/2019
Fathead Minnow	*Pimephales promelas*	Warm	S5	06/10/2003

Common Name	Scientific Name	Thermal Regime	SRank	Background Information (Date Observed)
Finescale Dace	*Chrosomus neogaeus*	Cool	S5	12/31/1996
Golden Shiner	*Notemigonus crysoleucas*	Cool	S5	12/31/1996
Johnny Darter*	*Etheostoma nigrum*	Cool	S5	7/25/2019
Largemouth Bass	*Micropterus salmoides*	Warm	S5	12/31/1996
Mimic Shiner	*Notropis volucellus*	Warm	S5	12/31/1993
Northern Pike	*Esox lucius*	Cool	S5	12/31/1996
Northern Redbelly Dace*	*Chrosomus eos*	Cool	S5	7/25/2019
Pumpkinseed	*Lepomis gibbosus*	Warm	S5	06/10/2003
Western Blacknose Dace*	*Rhinichthys obtusus*	Cool	S5	7/25/2019
White Sucker*	*Catostomus commersonii*	Cool	S5	7/25/2019

Note: * indicates the species was observed June 1, 2021 during fish community surveys in the study area

Electrofishing or dip netting was conducted within the HDFs / aquatic features at culvert crossings along Steeles Avenue that had enough water within the study area.

Reach MC(4)1 reach from Winston Churchill Boulevard to the 90 degree turn was shocked, as well as spot shocking occurred on MC(4)2. No fish were captured or observed during the assessment and reaches further upstream associated with this watercourse / HDF were dry within the study area.

The tributaries associated with East Sixteen Mile Creek, located between 9th Line and 10th Line, as well as the one immediately east of 10th Line were dry at the time of assessment, with the exception of TESMC(1). All culvert crossings were inspected. An online pond is located on HDF TESMC(1)5-1 immediately upstream of Steeles Avenue, as well as a small pool just downstream of Steeles Avenue within TESMC(1). Brook Stickleback was observed in both the pond and the pool.

The tributary to East Sixteen Mile Creek, ESMC(3)2-1, was electrofished from approximately 15 m upstream of the confluence with East Sixteen Mile Creek to a culvert under a small laneway where the water became too low to successfully support fish. No fish were observed within the assessed reach. Fish were observed just downstream to the confluence with East Sixteen Mile Creek in an area of backwater created by a Beaver dam.

Spawning Surveys

A spawning survey was conducted on October 30, 2020, and May 7, 2021 in East Sixteen Mile Creek within the study area. The water temperature was 5.6°C during the fall survey and was 14.5°C during the spring survey. No Trout, redds, or evidence of Trout spawning were observed during either of the spawning surveys within East Sixteen Mile Creek.

Benthic Community

Benthic monitoring stations BTH-001 to BTH-003 are consistent with OSAP Reaches 1, 2, and 3, as shown on Map 2. Sampling conditions are summarized by station in **Table 2.6.9.**

Table 2.6.9: Spring Benthic Sampling Conditions

	Reach 1 BTH-001			Reach 2 BTH-002			Reach 3 BTH-003		
Date	May 10, 2021								
Time (hrs)	0935			1015			1045		
Water Temperature (°C)	12.4			13.0			12.4		
Dissolved Oxygen (ppm, %)	8.8, 96.79			8.2, 85.25			8.5, 89.0		
Conductivity (µS/cm)	600			550			620		
	Riffle 1	**Pool**	**Riffle 2**	**Riffle 1**	**Pool**	**Riffle 2**	**Riffle 1**	**Pool**	**Riffle 2**
Wetted Width (m)	3.2	5.6	2.6	2.3	4.2	3.25	4.2	5.6	4.3
Maximum Depth (m)	0.3	0.5	0.25	0.10	0.15	0.1	0.15	0.25	0.1
Maximum Hydraulic Head (mm)	3	0	3	58	0	5	5	0	5
Dominant Substrate	Gravel	Gravel	Gravel	Gravel	Gravel	Gravel	Sand	Sand	Cobble
Second Dominant Substrate	Cobble	Cobble	Cobble	Cobble	Sand	Sand	Cobble	Cobble	Sand
Total Transect Length (m)	10	10	10	10	10	10	10	10	10
Kick & Sweep Sampling Time (min:sec)	3:00	3:00	3:00	3:00	3:00	3:00	3:00	3:00	3:00

A total of 24 different taxa were identified within the three sampling stations along East Sixteen Mile Creek in spring 2021. These taxa represent 16 different families and 10 orders of benthic macro-invertebrates. The identification and enumeration of benthic invertebrates are provided in tabular format in **Appendix H.5**. Survey results are summarized for stations BTH-001, BTH-002, and BTH-003 in **Table 2.6.10** and are discussed below.

Table 2.6.10: Calculated Benthic Invertebrate Metrics by Sampling Station (Spring 2021)

Benthic Invertebrate Metrics	BTH-001	BTH-002	BTH-003
Taxa Richness	22	17	19
Sensitive Groups			
EPT Taxa Richness	4	4	3
% EPT	11.2	14.7	9.0
Tolerant Groups			
% *Oligochaetes*	0.0	0.0	0.0
% *Diptera*	32.8	23.8	20.4
% *Chironomidae*	23.6	18.9	17.1
Functional Feeding Groups			
% Collector-Filter	23.6	30.5	19.9
% Collector-Gatherer	51.3	56.0	68.4
% Predators	3.0	0.0	2.4
% Scrapers	9.8	6.9	5.3
% Shredders	12.4	6.3	4.0
Diversity and Biotic Indices			
Shannon-Wiener Index	2.7	2.6	2.6
Family Biotic Index	5.28	5.77	6.1
Family Biotic Index Water Quality	Fair	Fairly Poor	Fairly Poor
Biotic Index	6.2	6.3	6.6
Biotic Index Water Quality	Fair	Fair	Fairly Poor
Simpsons Diversity Index	0.92	0.91	0.90

Legend: Potentially Unimpaired Potentially Impaired

Taxonomic Richness was relatively consistent across all monitoring stations, with the resulting richness falling within the Potentially Unimpaired range across all three monitoring stations. This consistency also extended to the proportion of Sensitive Taxa, with similar richness and proportion of EPT observed across all monitoring stations,

falling within the Potentially Impaired range suggesting a high proportion of the benthic invertebrate community is composed primarily of more tolerant taxa. This is further supported by the high proportion of *Diptera* observed across all monitoring stations. The proportion of Tolerant Taxa across all three monitoring stations generally falls within the Potentially Unimpaired range for the proportion of *Oligochaetes* and *Diptera*, however the high proportion of *Chironomidae* falls within the Potentially Impaired range, which further supports the assumption that the benthic invertebrate community is comprised primarily of members of highly tolerant taxa.

The dominant functional feeding group observed across all three monitoring stations is represented by the Collector-Gatherers, comprising between 51.3% and 68.4% of the benthic invertebrate community. This functional feeding group is primarily comprised of members of the highly tolerant family *Chironomidae*. The Shannon Wiener (H') Index measures diversity, taking into account the number of species and their evenness. The H' Index falls between 2.6 and 2.7 across all monitoring stations, falling within the Potentially Impaired range across all monitoring stations most likely as a result of the uneven distribution of species across all monitoring stations. Overall, the H' Index calculations indicate a moderate benthic taxonomic richness and species evenness across all monitoring stations.

In general, the Family Biotic Index (FBI) values ranged from 'Fair' to 'Fairly Poor' within East Sixteen Mile Creek, falling within the Potentially Unimpaired range at monitoring stations BTH-001 and BTH-002, and the Potentially Impaired range at monitoring station BTH-003. The Biotic Index (BI) values within East Sixteen Mile Creek ranged from 'Fair' to 'Fairly Poor' within the Potentially Impaired range across all monitoring stations. The results of both the FBI and the BI suggest that the benthic invertebrate communities within East Sixteen Mile Creek are comprised primarily of high and moderately tolerant taxa, consistent with the proportion and richness of sensitive and tolerant taxa. NRSI's findings are similar to the benthic community data that was provided by CH from monitoring stations along East Sixteen Mile Creek.

2.6.5 Significance and Sensitivity

This section provides an overview of the important natural heritage features within the study area and adjacent lands, an analysis of policies related to these features, and recommended buffers. This information, informed through a review of available background information, as well as results of field surveys of aquatic and terrestrial habitats, has been used to refine the boundary of the natural environment features in the study area. Analysis of the significance and sensitivity of existing natural features has been used to identify those features and habitats that are sensitive to disturbance. Results of this analysis are intended to protect or enhance the form and function of the

natural heritage features within a Natural Heritage System and ensure that these features are protected from future development and land uses.

2.6.5.1 Significant Wetlands

Wetland boundaries as surveyed by the SWS Team are shown on Map 4. Wetlands on the Gilbach property (Special Policy Area) were staked and surveyed with an OLS on October 10, 2019. As requested by Conservation Halton (ref: Appendix A; Conservation Halton Comment 18b), wetland boundaries staked for the *Scoped Subwatershed Study Northeast Corner Steeles Avenue and 8th Line* (JLA et al. 2020) were incorporated into the Phase 2B Scoped SWS. The tableland wetlands on the Gilbach property are being dealt with through the site specific Scoped Subwatershed Study being completed as part of the development application for that property.

A fulsome wetland evaluation process through the Ontario Wetland Evaluation System (OWES) was initiated, however through subsequent discussion between the Town of Halton Hills and its study partners (i.e., the Region of Halton and Conservation Halton), it was agreed that the evaluations would not be completed as this would have an impact on many lands outside of the Phase 2B Scoped SWS study area due to the large size of the wetland catchment areas (Map 3). Rather, wetlands within the East Sixteen Mile Creek and Mullet Creek catchment areas are provided a 30 m buffer, consistent with buffers widths applied to provincially significant wetlands.

The Forb Mineral Meadow Marsh communities (MAM2-10) within the study area are dominated by a variety of forbs including Panicled Aster (*Symphyotrichum lanceolatum*), Calico Aster (*Symphyotrichum lateriflorum*), Spotted Joe Pye Weed (*Eutrochium maculatum*), and Reed Canary Grass (*Phalaris arundinacea*). In the east, the Willow Mineral Thicket Swamp (SWT2-2) is the only wetland that was previously reported from the study area. This wetland is dominated by a variety of Willow species (*Salix amygdaloides, S. bebbiana, S. discolor, S. eriocephala, S. petiolaris*), Red-Osier Dogwood (*Cornus sericea*), and Reed Canary Grass.

Two small wetlands were surveyed east of 9th Line. These wetlands, referred to as the Lisgar Wetlands, are within a separate drainage area catchment (Map 3) that generally extends far to the southeast. The two small Lisgar Wetlands are separated from the larger catchment area by Highways 401 and 407, which create a significant divide and barrier to any connections further south. Within the East Sixteen Mile Creek catchment area, the MNRF advised that Highway 401 provides such a significant barrier, that the catchment area should be cut off at the highway. Similarly, the Lisgar Wetlands are not connected to any wetlands south of the two highways. These wetlands will require more detailed study at the SIS stage to assess the wetlands as per the Conservation Authorities Act, to confirm each wetland:

(a) is seasonally or permanently covered by shallow water or has a water table close to or at its surface,

(b) directly contributes to the hydrological function of a watershed through connection with a surface watercourse,

(c) has hydric soils, the formation of which has been caused by the presence of abundant water, and

(d) has vegetation dominated by hydrophytic plants or water tolerant plants, the dominance of which has been favoured by the presence of abundant water

The further study of these vegetation communities will feed into the assessment of HDFs in this area, specifically TESMC1a, TESMC(1)2-1a, TESMC(1)3-1a, and TESMC(1)5-1 (refer to Drawing FG-3).

The Lisgar Wetlands are “borderline” in that they exhibited both upland and wetland vegetation in almost equal proportions. More detailed vegetation work and soil assessments in these two wetland units will determine whether these areas need to be protected. Regardless, these areas are not provincially significant as they are separated from other wetlands by Highways 401 and 407 and do not exhibit any significant features or functions. The Lisgar Wetlands are 0.11 ha and 0.54 ha in size.

The Lisgar Wetlands were also evaluated with regards to Regional significance, in accordance with Halton Region’s Official Plan, Policy 276.5. The Lisgar Wetlands are not regionally significant as they are outside the RNHS and they do not appear to make an important ecological contribution to the RNHS. Regional significance should be assessed further at the SIS stage through more detailed study.

Coordination with Hodero / Gilbach Property

As noted above, the Gilbach site (formerly Hodero) lies within the Premier Gateway Phase 2B study area boundary. Notwithstanding the site's designation as Phase 2B Employment Area, through an Ontario Land Tribunal settlement associated with ROPA 47, the subject lands have allowance to seek the following permissions:

- submit a local Official Plan Amendment application to obtain development permissions, provided the amendment demonstrates the site can be integrated into the approved Phase 1B Secondary Plan, which applies to the lands across from the site, west of Eighth Line.
- incorporate the subject lands in the pre-2021 Urban Area planning phase.

Gilbach (Halton Hills) Inc. has submitted an application for an Official Plan Amendment to allow the subject lands to be included within the Phase 1B Secondary Plan in order to allow a range of entertainment and hospitality related uses, including a waterpark and hotel, at 8079 Eighth Line (Premier Gateway Employment Area). The Official Plan Amendment application would serve to identify the subject lands as being within the "Phase 1B Employment Area" and designate the site as a Special Policy Area to allow for the proposed range of uses.

A Scoped Subwatershed Study specific to that property has been completed to establish the environmental and stormwater management requirements for the property accordingly (JLA et al. 2022). Subsequent to the completion of the draft Phase 1 report in June 2021, the Premier Gateway Scoped Subwatershed Study Team was informed that the Scoped SWS Team for the Gilbach site had previously consulted with Conservation Halton and Halton Region July 23, 2020 regarding requirements for evaluating wetlands on that property. Through this consultation and based upon the findings from the Scoped SWS submitted for the Gilbach property, it was concluded that the wetlands which were evaluated as part of that Scoped SWS did not meet the criteria for Provincial Significance, and that the wetland boundaries surveyed for the property were approved. A copy of the July 23, 2020 meeting minutes, as provided by the Gilbach Scoped SWS Team, is included in **Appendix H.7** for reference.

2.6.5.2 Significant Woodlands

Woodland and forest cover within the study area and adjacent lands is sparse. The Town OP, policy B1.3.5, states that all woodlands 0.5 ha or larger are an important natural heritage feature and candidate Significant Woodland. Significant Woodlands are considered Greenlands B within the Town's Greenlands System.

The ROP, policy 277, identifies woodlands 0.5 ha as significant if they meet one or more of the following criteria:

1. The Woodland contains forest patches over 99 years old.
2. The patch size of the Woodland is 2 ha or larger if it is located in the Urban area, or 4 ha or larger if it is located outside the Urban Area but below the Escarpment Brow, or 10 ha or larger if it is located outside the Urban Area but above the Escarpment Brow.
3. The Woodland has an interior core area of 4 ha or larger, measured 100 m from the edge, or
4. The Woodland is wholly or partially within 50 m of a major creek or certain headwater creek or within 150m of the Escarpment Brow.

“Major creek and certain headwater” are defined in ROP policy 256.2 as “all watercourses within a Conservation Authority Regulation Limit […] and those portions of a watercourse that extend beyond the limit of the Conservation Authority Regulation Limit to connect a woodland considered significant based on criteria under Section 277(1), 277(2) or 277(3) and/or wetland feature within the Regional Natural Heritage System.”

The larger woodland associated with East Sixteen Mile Creek in the western portion of the subject property (FOD7-4) is significant, as well as the woodlands north and south of the study area boundary (FOD), associated with East Sixteen Mile Creek. The cultural woodlands (CUW) associated with East Sixteen Mile Creek are not considered significant due to their small size and in part due to their disturbed nature. Significant Woodlands are shown on Map 5. Refer to the Gilbach property Scoped SWS (JLA et al. 2020) for further information on the woodlands located within the Special Policy Area.

The small woodland, FOD4, located east of 10th Line, is dominated by Basswood (*Tilia americana*) and Bitternut Hickory (*Carya cordiformis*). Three cultural thicket communities located in the block of land east of 9th Line are dominated by European Buckthorn (*Rhamnus cathartica*) and do not require protection.

Additional analysis on woodland significance was provided to the Town through a memo, dated January 20, 2023, which is attached in **Appendix H.8**.

2.6.5.3 Significant Valleylands

The East Sixteen Mile Creek valleyland is considered significant based on guidance provided in the Natural Heritage Reference Manual (OMNR 2010). The significant valleyland generally follows the long-term stable top of slope and includes overlapping woodlands, other than the disturbed woodlands associated with the former residence on the Gilbach property. The Significant Valleyland is depicted on Map 5.

2.6.5.4 Significant Areas of Natural and Scientific Interest

There are no provincially significant Areas of Natural and Scientific Interest (ANSI) within the study area or adjacent lands. The closest ANSIs are located a minimum 10 km to the west and south (Halton Forest North Life Science ANSI, Milton Heights Earth Science ANSI, and Trafalgar Moraine Earth Science ANSI).

2.6.5.5 Significant Wildlife Habitat

The following Significant Wildlife Habitat (SWH) was identified within the study area, which falls in Ecoregion 7E:

— Turtle Wintering Area (Candidate)

- Reptile Hibernaculum (Candidate)
- Rare Vegetation Community (Confirmed): Fresh-Moist Black Walnut Lowland Deciduous Forest (FOD7-4)
- Turtle Nesting Area (Candidate)
- Habitat for Species of Conservation Concern: Terrestrial Crayfish (Confirmed), Eastern Wood-pewee (Confirmed)

Information on these SWH types is provided in **Appendix H.2**. Confirmed SWH is shown on Map 5.

Seasonal Concentration Areas

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

Suitable habitat for Turtle Wintering Area SWH is present within the study area and has been identified as candidate habitat. A Snapping Turtle was observed within East Sixteen Mile Creek during the Gilbach property SWS in 2019, although no turtles were observed by NRSI despite extensive field surveys. Deep water pools within the East Sixteen Mile Creek provide suitable overwintering habitat and would be considered the SWH.

Suitable reptile hibernaculum features are present throughout the study area associated with old barn and building foundations. Although snakes were not observed through field surveys, a Gartersnake was observed on the Gilbach property through that SWS (JLA et al. 2020). As intensive snake hibernaculum surveys were not undertaken through this study, this SWH type is identified as candidate.

Rare Vegetation Communities

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

The Fresh-Moist Black Walnut Lowland Deciduous Forest (FOD7-4) is considered significant in Ontario, with a provincial rank of S2S3.

Specialized Wildlife Habitat

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

Habitat adjacent to the East Sixteen Mile Creek may provide marginal turtle nesting habitat where bare soil is present (e.g., gravel laneways, exposed soils, etc.). No turtles were observed during extensive field surveys by NRSI biologists, but one Snapping Turtle is reported from the Gilbach property as was observed from within the creek in 2019 (JLA et al. 2020). Turtle Nesting Area SWH is identified as candidate from the East Sixteen Mile Creek corridor.

Habitat for Species of Conservation Concern

Confirmed habitat for SCC is considered SWH (OMNR 2000).

Confirmed Terrestrial Crayfish habitat is present within the cultural meadow (CUM) and marsh (MAM2-10) associated with Mullet Creek, on the east side of the study area where two crayfish chimneys were observed. Habitat for Terrestrial Crayfish comprises the ELC polygon in which it is found, and as such, the entire polygon has been mapped as SWH (Map 5).

Eastern Wood-Pewee was noted from several woodlands in the western portion of the study area. Where it was identified as a probable breeder, south of the study area east of 8th Line, SWH for this species was confirmed. SWH for this species was not identified where Eastern Wood-Pewee was identified as a possible breeder, although these areas are considered candidate habitat. Specifically, candidate habitat is identified as the Black Walnut Lowland Forest (FOD7-4), the cultural woodlands (CUW) associated with East Sixteen Mile Creek, and the deciduous woodland (FOD, SWD) north of the study area along this same creek corridor.

Animal Movement Corridors

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

2.6.5.6 Wildlife Movement Corridors

Although not considered SWH, movement corridors for wildlife provide an important function of connecting ecologically important habitats and allowing wildlife to safely traverse the landscape between these areas. Winter wildlife surveys were utilized to help inform important movement corridors that are being utilized by wildlife. During these surveys, the vast majority of wildlife movement was concentrated along the East Sixteen Mile Creek corridor in a north-south direction. Wildlife such as Eastern Coyote were observed crossing Steeles Avenue beneath the bridge at East Sixteen Mile Creek. Wildlife movement throughout the rest of the study area was found to be relatively diffuse, including within the location of Mullet Creek. However, some wildlife were found to follow the creek in this location and also cross Winston Churchill Boulevard via the large box culvert. Eastern Coyote was found to be the most common mammal species utilizing these linkages between higher quality habitats, with good numbers of Mink and Ermine, as well as a variety of small mammals. Very few White-tailed Deer were identified as utilizing these habitats. These movement corridors have been protected within the proposed NHS.

2.6.5.7 Species at Risk

A number of regulated SAR have the potential to occur within the study area and adjacent lands based on the results of the background review and the existing habitat present. Bobolink, Eastern Meadowlark, Eastern Small-footed Myotis, and Little Brown Myotis have been identified within the study area. Barn Swallow was also noted, as it was Threatened at the time of the surveys, however this species was downlisted in January 2023 to Special Concern by COSSARO.

Bobolink is a Threatened species both provincially (MECP 2021) and federally (Government of Canada 2021). This species prefers open country habitat such as large meadows, fallow fields, hay fields, or pasture (OMNR 2000) and was identified during breeding bird surveys within meadow habitat adjacent to East Sixteen Mile Creek as ‘probably’ breeding (Map 5). Although these fields are smaller than what is typically utilized by this species, the presence of adjacent agricultural and meadow marsh communities provides additional supporting habitat that is attractive to Bobolink. Bobolink were also noted from the same area and as probable breeders through the Gilbach SWS (JLA et al. 2020).

Eastern Meadowlark is a Threatened species both provincially (MECP 2021) and federally (Government of Canada 2021). Cultural meadows within study area provide suitable habitat for this species, consistent with habitat for Bobolink. Eastern Meadowlark, however, were not observed to be breeding in the area. This species was observed within an open field west of 9th line on March 27, 2021, as an early migrant,

but was not observed during subsequent breeding bird surveys. The Gilbach SWS (JLA et al. 2020) did identify Eastern Meadowlark as probable breeders from this area.

Eastern Small-footed Myotis was reported from the Gilbach property through that localized SWS (JLA et al. 2020). 102 calls of this species were recorded, but suitable breeding habitat was identified as not present. A total of four calls of **Little Brown Myotis** were recorded from the Gilbach property, which were noted to be foraging along the East Sixteen Mile Creek (JLA et al. 2020). The bats are likely using East Sixteen Mile Creek as a travel corridor as well. Suitable bat maternity roosting trees were observed within the East Sixteen Mile Creek corridor and in the woodland east of 10th Line (FOD4), as identified on Map 5. The Gilbach SWS also identified many suitable bat habitat trees (refer to Figure 7 of that study, p.295), however these were ruled out as providing roosting habitat for this species due to the low call counts (JLA et al. 2020). Both bat species are considered Endangered in Ontario and Canada.

2.6.5.8 Aquatic Resources

Benthic sampling results from surveys in 2021 were coupled with benthic community data provided by CH from monitoring stations along East Sixteen Mile Creek. Based on the results of the benthic sampling and various metrics of species richness / biotic indices, the benthic communities within this East Sixteen Mile Creek are considered 'fair to fairly poor'.

Fish species community data was provided by CH from monitoring stations along East Sixteen Mile Creek, and fish community sampling was completed within three reaches in 2021 to further classify and characterize the aquatic habitat. Based on the results of the fish community sampling and water temperature assessment within East Sixteen Mile Creek, the thermal regime is coolwater.

Based on the lack of flow, lack of fish, and the feature being dry in late May and June, the thermal regime for Mullet Creek is warmwater.

The PPS (2020), Policy 2.1.6 prohibits development and site alteration in fish habitat except in accordance with provincial and federal requirements.

The MNRF classifies fish habitat into three types, as identified in **Table 2.6.11**. The watercourses within the study area have not been classified by the MNRF. Based on background information provided and the site visit completed by NRSI, East Sixteen Mile Creek is identified as coolwater Type 1 Fish Habitat. Mullet Creek tributary, based on the background information and the site assessments, is classified as warmwater Type 3 Fish Habitat. Type 1 watercourses provide a high constraint to development. Type 2 and 3 watercourses typically provide a medium constraint to development.

Table 2.6.11: MNRF Classification of Fish Habitat Types

Classification Type	Description
Type 1	Habitats have high productive capacity, are rare, in space and/or time, are highly sensitive to development, or have a critical role in sustaining fisheries (e.g., critical spawning and rearing areas, migration routes, overwintering areas, habitats occupied by sensitive species).
Type 2	Habitats are moderately sensitive to development and, although important to the fish population, are not considered critical (e.g., feeding areas for adult fish, unspecialized spawning habitat). These areas are considered ideal for enhancement or restoration projects.
Type 3	Habitats have low productive capacity or are highly degraded, and do not currently contribute directly to fish productivity. They often have the potential to be improved significantly (e.g., a portion of a waterbody, a channelized stream that has been highly altered physically).

East Sixteen Mile Creek provides a high constraint to development. Mullet Creek has been identified as providing a medium constraint to development. HDFs have currently all be identified as providing a low constraint to development. The HDF assessment will determine management recommendations for each HDF.

2.6.6 Summary of Findings

The Regional NHS was refined based as part of the Phase 1 SWS process on the data collected at the time within the study area (Map 6). The NHS comprised wetlands, watercourses, fish habitat, Significant Woodlands, and also reflected the floodplain adjacent to East Sixteen Mile Creek and Mullet Creek. The NHS also incorporated linkages that would assist in ensuring that important natural heritage features within the study area and adjacent lands remain connected to one another and the broader NHS.

3 INTEGRATION SUMMARY

The results of the study area characterization have been used to develop an integrated assessment of the study area constraints and management opportunities specific to the area natural features and systems, watercourses, stormwater and water resource systems. The following provides details regarding the approach toward developing the integrated assessment and the findings from the application of this approach to the study area.

3.1 Approach

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.

3.1.1 Water Resources Systems

3.1.1.1 Governing Policies and Definitions

The components of the water resource system are defined by Provincial Policy, specifically the 2020 Growth Plan for the Greater Golden Horseshoe and the 2017 Greenbelt Plan. The following sections summarize the governing policies and components of the water resource system, as well as the component information available to compile the mapping.

The requirement for a Water Resource System (WRS) is set out by the PPS and includes the identification of features and functions which are necessary for the ecological and hydrological integrity of a watershed and include:

— Groundwater features

— Hydrological functions

— Natural heritage features and areas

— Surface water features including shoreline areas

Although not identified as part of the WRS explicitly, the PPS also directs planning authorities to maintain linkages and related functions among components of the WRS. With the basic direction set out in the PPS, interactions and relationships between an NHS and WRS are identified through the inclusion of natural heritage features and areas.

Section 4.2.1 of the Growth Plan for the Greater Golden Horseshoe provides the following requirements for defining the water resource system:

1 "Upper- and single-tier municipalities, partnering with lower-tier municipalities and conservation authorities as appropriate, will ensure that *watershed planning* is undertaken to support a comprehensive, integrated, and long-term approach to the protection, enhancement, or restoration of the *quality and quantity* of water within a *watershed.*

2 *Water resource systems* will be identified to provide for the long-term protection of *key hydrologic features*, key hydrologic areas, and their functions.

3 *Watershed planning* or equivalent will inform:
   a the identification of *water resource systems*
   b the protection, enhancement, or restoration of the *quality and quantity* of water
   c decisions on allocation of growth
   d planning for water, wastewater, and stormwater *infrastructure*

4 Planning for large-scale *development* in designated *greenfield areas*, including *secondary plans*, will be informed by a *subwatershed plan* or equivalent.

5 Municipalities will consider the Great Lakes Strategy, the targets and goals of the Great Lakes Protection Act, 2015, and any applicable Great Lakes agreements as part of *watershed planning* and coastal or waterfront planning initiatives."

Further, the Growth Plan for the Greater Golden Horseshoe provides the following definitions for Key hydrologic features and key hydrologic areas:

Key hydrologic features: "Permanent streams, intermittent streams, inland lakes and their littoral zones, *seepage areas and springs, and wetlands*."

Key hydrologic areas: "*Significant groundwater recharge areas, highly vulnerable aquifers, and significant surface water contribution areas* that are necessary for the ecological and hydrologic integrity of a watershed."

The above policies and definitions are noted to be consistent with the requirements and definitions in Section 3.2.3 of the Greenbelt Plan for water resource systems. Characterization of Water Resources Systems.

Surface Water and Groundwater Interactions

The hydrogeologic setting within, and adjacent to, the Study Area is characterized by lower permeability surficial sediments generally consisting of clays of the Halton Till and silty sands. These sediments tend to reduce recharge, lateral and vertical groundwater flow and associated groundwater discharge. If sufficient groundwater gradients exist and more permeable discrete pathways exist within the Halton Till and silty sands, groundwater discharge may occur. Discrete sand lenses are known to exist within the Halton Till and a basal sand is interpreted on the bedrock surface in some boreholes. A thicker, channelized gravelly sand deposit is interpreted at depth in boreholes along 10th Line. While no bedrock valleys or flowing wells are interpreted for the current Study Area, a bedrock valley infilled with more permeable sediments exists in the Premier Gateway Phase 1B study area located southwest of the current Study Area in the Hornby area. This suggests that hydrostratigraphic conditions are present within the regional setting for strong upward gradients and potential connections to local stream reaches near the current Study Area. Groundwater discharge to streams may occur locally where discrete sand lenses and thin or fractured till intersect the watercourses. Discharge will also occur seasonally as the groundwater table rises. Potential groundwater discharge areas are noted in **Section 2.1.4.3**, particularly along the reach of East Sixteen Mile Creek within the Study Area.

It is expected that the more regional groundwater system may provide for discharge potential within the Study Area where the overburden thickness is less than 3 m and the shallow fractured bedrock and/or sand and gravel at the bedrock contact is more continuous.

Site Servicing and Stormwater Management

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

3.1.2 Watercourse Characterization and Functions

1 Land use changes such as the removal of headwater drainage features or vegetation and increases in imperviousness, typically increase flow discharges and diminish the development of resisting forces.

Headwater drainage features may be 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.

2 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.

3 The incorporation of the erosion hazard delineation and associated setbacks into the stream corridor allows the lateral migration of the channel across its floodplain (meander belt), and potential slope processes to occur (long term stable top of slope), 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 long-term stable top of slope, and associated setbacks represent a constraint to development and land use planning.

3.2 Application

The approach and policy guidance outlined above has been applied to the study area to identify key hydrologic features and areas, establish constraint rankings for the area watercourses, and develop a preliminary NHS. The following provides details in this regard.

3.2.1 Key Hydrologic Features and Areas

As noted above, the wetland within the portion of the Study Area in the Mullet Creek Subwatershed lies within an internally draining subcatchment and is thus supported by runoff from the catchment area particularly during smaller storm events. The subcatchment draining to this feature has been considered a key hydrologic area,

The Sixteen Mile Creek East Branch and the Mullet Creek represent the most significant hydrologic features through the study area. Details regarding the significance of these features and other drainage features within the Study Area are provided below in **Section 3.2.2**.

The Key Hydrologic Areas from a groundwater perspective are SGRAs and HVAs. The only SGRA that is mapped within the Study Area is a small localized SGRA (see Figure 6.12 of HHSPC 2017) that appears to be associated with the ice contact gravels mapped at surface along Steeles Avenue, between 9th Line and 10th Line (Figure GW-4). A localized HVA is present under the eastern extent of the area underlying Mullet Creek as mapped in the Credit Valley Source Protection Area Assessment Report (Figure 4.2 of CTCSPC 2015). Background discussion on SGRAs and HVAs is presented in **Section 2.1.4.3**.

3.2.2 Watercourses and Headwater Drainage Features

Stream morphology is a key aspect in developing watercourse and headwater drainage feature management recommendations and opportunities. However, it is a collaborative and integrated process that requires input from each study discipline. An integrated approach has been developed and applied in the current study. Refer to **Section 3.2.2.1** for more detail on the development of this methodology and its application. Through the application of this drainage feature classification methodology, appropriate constraints and management recommendations have been determined for watercourses and HDFs, respectively.

Watercourse Feature Constraints – Classification

Stream management is to be approached on a reach or feature basis as these units display relative homogeneity with respect to form, function, and habitat. Key management practices, in terms of stream morphology, are recommended according to the geomorphic constraint ranking. Management strategies may include several options, or specific guidance. A summary of the geomorphological components of the constraint ranking / classification management strategy for watercourses is provided below.

High Constraint - Red Classification (Solid Red Line on Map)

- Definition: These corridors contain a defined active channel with well-developed channel morphology (i.e., riffle-pool), material sorting, floodplain development, 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, except for select locations where rehabilitation may be of benefit to the system. They have usually been deemed high-quality systems that could not be re-located and replicated in a post-development scenario.
- Management: Watercourse to be protected with meander belt in current form and location. Minor modification through rehabilitation / enhancement may be acceptable in select locations where it is a benefit to the system, or to allow for critical servicing as permitted by regulatory agencies. Options:
  - Do nothing: Corridors must remain where they are in the landscape. Delineate meander belt or erosion hazard corridor depending on valley classification. Determine additional regulatory setbacks as required.
  - Channel adjustments may be permitted at select locations given sufficient rationale (e.g., addressing an immediate high-risk erosion hazard, or an essential infrastructure for servicing issue such as road crossings or channel lowering). Natural channel design to be implemented for any adjustments.
  - Degraded (channelized and straightened) portions may by realigned using natural channel design if realignment does not negatively impact rehabilitation.

Medium Constraint - Blue Classification (Solid Blue Line on Map)

- Definition: These reaches have well-defined morphology (defined bed and banks, evidence of erosion / sedimentation, and sorted substrate). These reaches 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: Watercourse to be protected with applicable meander belt and setbacks. Realignment may be acceptable when deemed appropriate for restoration and enhancement or to address an essential infrastructure for servicing issue. Options:
  - Do nothing: Leave the corridors in their present condition and develop outside of their boundaries: Delineate appropriate meander belt or erosion hazard corridor depending on valley classification. Determine additional regulatory setbacks as required.

- 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). Natural channel design to be implemented for any adjustments. Channel adjustments may be permitted for essential infrastructure for servicing (e.g., road crossings or channel lowering). All proposed works are to include sufficient rationale and be approved by regulatory agencies.
- 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 (i.e., natural channel design). In the event that these reaches are re-located, the corridor width (meander belt width / hazard corridor) associated with each reach must, at a minimum, be maintained. For reaches that have been straightened, appropriate surrogate reaches or empirical methods should be applied to determine the meander belt corridor. Natural channel design to be implemented for any realignment or adjustments.
- For features with realignment opportunities around roads, consideration should be made to select appropriate locations for realignment with respect to the road location, and to reduce the number of road crossings, where appropriate. This should reduce overall environmental impacts from roads. Such changes require approval by regulatory agencies.

It should be noted that, within some reaches, the constraint ranking for another discipline may dictate the outcome (e.g., surface water, fisheries, terrestrial). Several features are protected by virtue of their location within a significant valley or terrestrial feature.

Headwater Drainage Feature Management Recommendations

The classification and evaluation methodology presented in **Table 3.2.1** has been used to characterize and provide management recommendations for individual HDFs. The approach first applies the guidelines set by TRCA / CVC (2014) to determine a feature classification ("**HDFA Management**"), which may then be carried forward to "**Final Management**" or tailored to the landscape based on site opportunities, or other constraints that the protocol may not capture (e.g., feature protection based on location within a significant terrestrial feature). The following briefly summarizes feature function and management strategies for HDFs.

Protection feature (mapped as red-white dashed lines)

- Important Functions: e.g., swamps with amphibian breeding habitat; perennial headwater drainage features; seeps and springs; SAR habitat; permanent fish habitat with woody riparian cover.
- Protect in place and maintain contributions to and from feature, to be incorporated into the NHS. Channel adjustments may be permitted at select locations given sufficient rationale, and as approved by Regulatory Agencies.

Conservation feature (mapped as solid yellow lines)

- Valued Functions: e.g., seasonal fish habitat with woody riparian cover; marshes with amphibian breeding habitat; or general amphibian habitat with woody riparian cover.
- Realignment permitted provided important ecological functions are maintained, including linkage functions if the existing feature provides a linkage function. Conservation features providing important linkage functions may be incorporated into the NHS. Also, realignment may be permitted within existing buffer areas, provided that the feature realignment / creation supports the objectives of the buffer.

Mitigation feature (mapped as solid green lines)

- Contributing Functions: e.g., contributing fish habitat with meadow vegetation or limited cover
- Maintain function to downstream features. These features are typically highly modified but provide some downstream function (e.g., supply of sediment and/or water, or seasonal fish habitat). Some complexities like the function of tile drains, where important, can be replicated through SWM, while fish habitat may be replicated within another nearby feature, or downstream in the floodplain (e.g., pond creation).

No management required (mapped as green-dashed lines)

- Limited Functions: e.g., features with no or minimal flow; cropped land or no riparian vegetation; no fish or fish habitat; and no amphibian habitat.
- Feature can be removed from the surface without any implication to the system.

3.2.2.1 Watercourse and Headwater Drainage Features – Integrated Assessments

The integration principles outlined in the preceding section have been applied to develop a constraint ranking for the watercourses and headwater drainage features (HDF) within the study area. Each watercourse has been assigned a ranking of high, or medium on a reach-by-reach basis, based upon various environmental factors and considerations, with individual rankings per discipline. A final constraint ranking was then established, conservatively, by utilizing the most limiting constraint observed for the feature, which may be suggested by all, few, or even one discipline. The findings of the assessment will ultimately provide guidance regarding the management opportunities and requirements for each watercourse feature within the study area. If during this integrated watercourse classification, a watercourse was found to be of low ranking (i.e., does not warrant High or Medium constraint), then it was re-evaluated as an HDF.

As mentioned in **Section 2.4.4.5** the constraint ranking classification and evaluation methodology is based on a classification system that was developed and applied to earlier subwatershed studies in Milton, Ontario. This system provides a standard system to classify all surface water features (watercourses and HDFs) whereby each feature was assessed by contributing disciplines (i.e., hydrology, geomorphology, hydrogeology, fisheries, and terrestrial ecology), with a constraint ranking of “high”, “medium” or “low” provided by each. Low rated features are typically headwater drainage features. This system incorporates the *Evaluation, Classification and Management of Headwater Drainage Features Guideline* (TRCA / CVC, 2014), and the resulting HDF classes, as determined by the 2014 HDF Guidelines, represent an integrated multi-discipline assessment of individual HDF segments.

In general, this evaluation approach builds upon the recommendations from TRCA / CVC protocols and includes management recommendations for watercourses, with corresponding colour coding / symbolism to represent each feature type, constraint ranking / classification, and corresponding management recommendation. **Table 3.2.2** provides further details regarding evaluation approach, and of feature and constraint definitions and corresponding management strategies. This classification system was collaboratively reviewed and agreed to by the sub-TAC in a meeting held on September 25, 2020 and has undergone minor revisions through subsequent comment / response review with Conservation Halton.

For HDFs, the evaluation has been completed first by following the 2014 HDF Guidelines to determine the management recommendation. Then, through an understanding of existing and proposed site conditions, features that require further

consideration have been flagged. Further consideration is required in these cases to determine “final” recommendations that may differ from the outcome of the HDF Guidelines.

Table 3.2.1 and **Drawing FG-4** presents the integrated watercourse constraint ranking for each watercourse and HDF reach within the study Area and **Table 2.4.7** (ref. Section 2.4.4.5) presents the HDF evaluation, recommendations, and rationale.

Table 3.2.1: Watercourse Constraint Evaluations and Rankings

Watercourse Reach ID	Surface Water	Groundwater	Fluvial	Terrestrial	Fisheries	Net Constraint Ranking	Rationale / Comments
MC(4)1	Medium	Low	Medium	Medium	Medium	Medium	Artificially constrained (has been historically straightened). Highly impacted by historical and current land uses, mostly dry.
MC(4)2	Medium	Low	Medium	Medium	Medium	Medium	Artificially constrained (has been historically straightened). Highly impacted by historical and current land uses, mostly dry.
ESMC(3)	High	High	High	High	High	High	Permanently flowing, sinuous, within confined valley, fish present

Table 3.2.2: Premier Gateway Watercourse and Headwater Drainage Feature Classification and Management

Discipline	Proposed Definition	Proposed Management Strategy
Red Stream Classification (solid red lines). These features are high constraint watercourses that have attributes (e.g., floodplains, unstable banks) that attract Conservation Halton regulations. They must remain open and protected in their present condition and location, with the exception of select locations where rehabilitation may be of benefit to the system.		
Surface Water	These corridors contain a well-defined channel within a well-defined and established valley system, with large contributing drainage areas (i.e., 200 ha or more, but may be less).	Watercourse and corridor to be protected in current form and location, with applicable regulatory setbacks and ecological buffers.
Geomorphology	These corridors contain a defined active channel with well-developed channel morphology (i.e., riffle-pool), material sorting, floodplain development, 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, except for select locations where rehabilitation may be of benefit to the system. They have usually been deemed high-quality systems that could not be re-located and replicated in a post-development scenario.	Watercourse to be protected with meander belt in current form and location. Minor modification through rehabilitation / enhancement may be acceptable in select location where it is a benefit to the system. Options • Do nothing: Corridors must remain where they are in the landscape. Delineate meander belt or erosion hazard corridor depending on valley classification. Determine additional regulatory setbacks as required. • Channel adjustments may be permitted at select locations given sufficient rationale (e.g., addressing an immediate high-risk erosion hazard, or a critical servicing issue such as road crossings or channel lowering) • Natural channel design* to be implemented for any adjustments. • Degraded (channelized and straightened) portions may by realigned using natural channel design*, if realignment does not negatively impact rehabilitation.
Fisheries	Permanently wetted (flowing or standing water over most of watercourse length) that is generally associated with continuous or seasonal groundwater discharge, or with wetland storage and/or pond flows. Fish community (or the potential for) is present and natural habitat is usually fully developed. Either habitat and/or flow source characteristics may be difficult to replicate or maintain. -and/or- Habitat occupied by species at risk.	Watercourse to be protected / enhanced in current form and location. Minor modification through rehabilitation / enhancement may be acceptable in select location where it is a benefit to the system. Options • Preserve the existing drainage feature and groundwater discharge or wetland in-situ. Key features of this are: 1) Maintain existing water source: e.g., incorporation of shallow groundwater and base flow protection techniques such as infiltration treatment; examine need to incorporate groundwater flows through infiltration measures (i.e., third pipes, etc.) to ensure no net loss or, if appropriate, potential gain. 2) Drainage feature must connect to downstream watercourse / habitat. 3) 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. • Channel adjustments may be permitted at select locations given sufficient rationale (e.g., addressing an immediate high-risk erosion hazard, or a critical servicing issue), and habitat features can be restored. Natural channel design* to be implemented for any adjustments. • Degraded (channelized and straightened) portions may by realigned using natural channel design* if realignment does not negatively impact rehabilitation potential. For example, a more rigorous investigation may be required to ensure realignment does not result in a reduction in groundwater inputs.
Terrestrial	The watercourse segments that are within terrestrial features that are of high ecological quality; are determined to be provincially, regionally, and/or locally significant; and/or are determined to provide critical habitat functions for wildlife (e.g., consistent with criteria for Significant Wildlife Habitat).	Watercourse to be protected/enhanced in current form and location.
Red HDF Classification (dashed red-white lines). These features, classed as [1]Protection, must remain open and, in general, remain protected in their present condition and location. They may have attributes that attract Conservation Halton regulations.		
Surface Water	These are drainage features for which the application of the HDF Guidelines (TRCA / CVC, 2014) result in a "Protection" management strategy.	For drainage features in this category, follow the HDF management guidelines for "Protection".
Geomorphology	same as above (TRCA / CVC, 2014 guidelines to be followed)	same as above. (TRCA / CVC, 2014 guidelines to be followed) -But- Regulatory setbacks do not include erosion hazards in the case of HDFs. Buffers may be required as determined through subsequent studies.

Discipline	Proposed Definition	Proposed Management Strategy
Fisheries	same as above (TRCA / CVC, 2014 guidelines to be followed)	same as above (TRCA / CVC, 2014 guidelines to be followed)
Terrestrial	The drainage feature reach segments that are within terrestrial features that are of high ecological quality; are determined to be provincially, regionally, locally significant, and/or are determined to provide critical habitat functions for wildlife (e.g., consistent with criteria for Significant Wildlife Habitat).	Drainage feature to be protected / enhanced in current form and location.
Blue Stream Classification (solid blue lines). These features are medium constraint watercourses that have attributes (e.g., floodplains, unstable banks) that attract Conservation Halton regulations. They must remain open but they can be realigned using natural channel design.*		
Surface Water	In general, these reaches have relatively smaller contributing drainage areas (i.e., between 50 ha and 200 ha), and typically are not located within defined valley corridors. There may be instances where contributing areas are be less than 50 ha or greater than 200 ha.	Watercourse to remain open. Realignment may be acceptable. Reconstructed watercourse and corridor would be protected by applicable regulatory setbacks and ecological buffers.
Geomorphology	These reaches have well-defined morphology (defined bed and banks, evidence of erosion / sedimentation, and sorted substrate). These reaches 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.	Watercourse to be protected with applicable meander belt and setbacks. Realignment may be acceptable when deemed appropriate for restoration and enhancement or to address an essential infrastructure for servicing issue. Options • Do nothing: Leave the corridors in their present condition and develop outside of their boundaries: Delineate appropriate meander belt or erosion hazard corridor depending on valley classification. Determine additional regulatory setbacks as required. • 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). Natural channel design* to be implemented for any adjustments. All-proposed works are to include sufficient rationale and be approved by regulatory agencies. • Re-locate and enhance existing conditions. Channelized watercourses (for example), a are not typically 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 where the system requires such a design (i.e., natural channel design*). In the event that these reaches are re-located, the corridor width (meander belt width / hazard corridor) associated with each reach must, at a minimum, be maintained. For reaches that have been straightened, appropriate surrogate reaches or empirical methods should be applied to determine the meander belt corridor. Natural channel design* to be implemented for any realignment or adjustments. • For features with realignment opportunities around roads, consideration should be made to select appropriate locations for realignment with respect to the road location, and to reduce the number of road crossings, where appropriate. This should reduce overall environmental impacts from roads. Realignment of features to accommodate roads requires consultation with CH or CVC on a case-by-case basis. Overall improvement to existing conditions must be demonstrated.
Fisheries	Seasonally wetted (flowing or standing water) that is generally associated with seasonally high groundwater discharge or seasonally extended contributions from wetlands / ponds (no perennial flow). May provide an extended seasonal migration route for fish. Fish community (or the potential for) is present for an extended seasonal period. Potential permanent refuge fish habitat may be provided by naturally occurring storage features such as channel pools, wetlands, and other water bodies.	Watercourse to remain open. Realignment may be acceptable if habitat features and/or flow source can be maintained, replicated, or enhanced. Options • Watercourse remains open and in place, while maintaining (or replicating if appropriate) existing flow source from seasonal groundwater, surface or wetland flows. • Watercourse may be realigned using natural channel design* techniques to provide habitat features to maintain or enhance overall fish productivity of the reach. Existing seasonal groundwater, surface, or wetland flows must be maintained (or replicated if appropriate), and drainage feature must connect to downstream habitat.

Discipline	Proposed Definition	Proposed Management Strategy
Terrestrial	Watercourse segment that is within terrestrial features that are determined to be of low or moderate ecological quality; are determined to be not provincially, regionally, and/or locally significant; and/or are determined to not provide critical habitat functions for wildlife (e.g., consistent with criteria for Significant Wildlife Habitat). -and/or- Watercourse segment that is determined to provide significant linkage function for wildlife (as per Significant Wildlife Habitat).	Follow management strategies outlined for fisheries and fluvial, and ensure that the corridor is sufficiently wide and has appropriate restored habitat that supports movement of wildlife.
Yellow Classification (solid yellow lines). These features are HDFs classed as [1]Conservation, must remain open but can be realigned using natural channel design. They do not have attributes that attract Conservation Halton regulations. The classification and management of terrestrial functions will result from being classed [1]Maintain or Replicate Terrestrial Functions.*		
Surface Water	These are HDFs for which the application of the HDF Guidelines (TRCA / CVC, 2014) result in a "Conservation" management strategy.	For HDFs in this category, follow the HDF management guidelines for "Conservation".
Geomorphology	same as above	same as above
Fisheries	same as above HDFs classed as "Conservation" may provide an ephemeral aquatic linkage[2] that flows for a very short period (typically in the early spring) that may provide a migration route for fish to move upstream to a valued permanent water storage feature, over a period of hours to a few days. [2]An ephemeral aquatic linkage does not provide habitat in which fish may take up residence, though fish may become trapped in minor features and persist for a while until they perish.	same as above
Terrestrial	HDF classification guidelines result in a “Maintain Terrestrial Linkage – Terrestrial Functions” management strategy.	Follow HDF management guidelines for “Maintain Terrestrial Linkage – Terrestrial Functions”
Green Classification (solid green lines). These features are HDFs classed as [1]Mitigation, and do not have attributes that attract Conservation Halton regulations. They need not remain open, but their function to the watershed system must be maintained or replicated.		
Surface Water	These are HDFs for which the application of the HDF Guidelines (TRCA / CVC, 2014) result in a "Mitigation" management strategy.	For HDFs in this category, follow the HDF management guidelines for "Mitigation".
Geomorphology	same as above	same as above
Fisheries	same as above	same as above
Terrestrial	HDF classification guidelines result in a “Replicate Terrestrial Linkage – Terrestrial Functions” management strategy.	Follow HDF management guidelines for “Replicate Terrestrial Linkage – Terrestrial Functions”
Green Classification (dashed green lines). These are HDFs classed as [1]No Management Required.		
Surface Water	These are HDFs for which the application of the HDF Guidelines (TRCA / CVC, 2014) result in "No Management Required".	For HDFs in this category, follow the HDF management guidelines for "No Management Required".
Geomorphology	same as above	same as above
Fisheries	same as above	same as above
Terrestrial	same as above	same as above

Note: [1]Based upon the Evaluation, Classification and Management of Headwater Drainage Features Guidelines (TRCA / CVC, 2014).

* Natural channel design principles are to be applied based on the physical requirements of the system, or an appropriate reference. This should not suggest that pool-riffle streams are designed in every situation.

Notes on the application of the above classification system.

This new classification system retains components of a "Red, Blue, Green" system, that was used to classify and assign management recommendations to drainage features in the Town of Milton over the past almost 20 years, for the purpose of classifying and managing regulated watercourses. It also adopts the methods in the document Evaluation, Classification and Management of Headwater Drainage Features Guidelines (TRCA / CVC, 2014) for the classification and management of Headwater Drainage Features (HDFs) which are typically not regulated. Consequently, to apply this new combined system, watercourses and HDFs must each be assigned a management strategy following somewhat different methods. For watercourses, each discipline evaluates and classifies the watercourse segment separately, with the management strategy determined by the highest classification that was assigned among the disciplines. For HDFs, the resulting classifications for hydrology, riparian conditions, fish and fish habitat, and terrestrial, are used in a decision (yes/no) flow chart to arrive at the appropriate management strategy.

3.2.3 Buffers and Natural Heritage System

3.2.3.1 Buffer Analysis

Vegetation protection zones (i.e., buffers) are required through the Region of Halton Official Plan adjacent to key features. The buffers selected for the natural features within the study area incorporate the most restrictive policies from the guidance documents listed below. In general, this includes the application of 30 m buffers from all wetlands, Significant Woodlands, and watercourses, as well as a 10 m buffer from non-significant woodlands. The application of these buffers is in line with the policies of the Growth Plan for the Greater Golden Horseshoe (2020) which assigns a 30 m buffer to all Key Hydrologic Features / Key Natural Heritage Features. These buffers have been included within the limits of the preliminary Draft Phase 1 NHS, discussed below.

Conservation Halton's Policies and Guidelines for the Administration of Ontario Regulation 162/06 and Land Use Planning Policy Document (2020):

- 30 m from Bankfull Channel (Coldwater / Coolwater / Warmwater Sportfish watercourses)
- 15 m from Bankfull Channel (Warmwater Baitfish watercourses)
- 30 m from Provincially Significant Wetlands
- 30 m from wetlands that are ≥2ha

Halton Region Official Plan (2018):

- *The extent of the buffer and activities that may be permitted within it shall be based on the sensitivity and significance of the Key Features and watercourses and their contribution to the long-term ecological functions of the Regional Natural Heritage System as determined through a Sub-watershed Study, an Environmental Impact Assessment or similar studies that examine a sufficiently large area.* (Policy 220.1.1)
- Within the Greenbelt Plan Area requires a minimum vegetation protection zone of 30 m wide for wetlands, seepage areas and springs, fish habitat, permanent and intermittent streams, lakes, and significant woodlands, measured from the outside boundary of the Key Feature (Policy 139.3.7(5)).
- As a guidance document to the Region, the Phase 3 Sustainable Halton Report 3.02 (North-South Environmental 2009) recommend 30 m buffers from natural heritage features.

Growth Plan (2020):

- 30 m from key hydrologic features (i.e., permanent streams, intermittent streams, inland lakes and their littoral zones, seepage areas and springs, and wetlands), fish habitat, and significant woodlands (Policy 4.2.4.1.c).

The Town of Halton Hills Official Plan (2020) does not define recommended buffers from natural heritage features.

3.2.3.2 Natural Heritage System

The RNHS provides a systems approach aimed at protecting the form and function of the NHS for the long term (Halton Region 2018). The boundaries of the RNHS may be refined through field verifications completed as part of site-specific studies (policy 116.1 of the ROP).

As pertaining to the study area, policy 115.3 of the ROP (Halton Region 2018) lists the components of the RNHS as the following:

- key features, including:
  - significant habitat of Endangered and Threatened species
  - significant wetlands
  - significant woodlands
  - significant valleylands
  - significant wildlife habitat
  - fish habitat
  - enhancements to key features, including Centres for Biodiversity
  - linkages
  - buffers
  - watercourses
  - wetlands

The RNHS also includes regulated floodplains and certain parts of agricultural areas outside of key features (ROP policy 115.4).

The Town's OP (2017) identifies a Greenlands System in accordance with the requirements of the Region of Halton OP (2018). The intent of the Greenlands System is to "maintain, as a permanent landform, an interconnected system of natural and open space areas that will preserve areas of significant ecological value" (Section B1).

The RNHS has been refined to include the features specified above (with the exception of SAR habitat) and is shown on Map 6 relative to the existing RNHS / Greenlands System. The proposed (Draft Phase 1) NHS boundary includes recommended buffers, which in most cases is 30 m from significant natural features (wetlands, watercourses, Significant Woodlands) and 10 m from non-significant woodlands (CUW, FOD4). In some places, the flood lines have formed the extent of the NHS boundary (e.g., along East Sixteen Mile Creek). Within the location of Mullet Creek, two options for an east-west connection to the existing wetland (SWT2-2) and FOD4 community are shown. Option 1 includes a 60 m wide linear connection to the south that follows an existing HDF [MC(5)/MC(6)]; based upon comments from the Town of Halton Hills, it is understood that this area is planned to be used as a park in the future. The NHS in this location has been straightened to provide a square development block, since this feature is considered ‘Mitigation’. Option 2 shows an east-west connection of equal width, further to the north along the study area boundary. Both of these options provide a suitable linkage between natural features (woodland / wetland) to the west and Mullet Creek to the east.

BIBLIOGRAPHY

- AMEC Earth and Environmental, 2011. Mount Pleasant Subwatershed Study, Phase 1 Characterization and Integration, City of Brampton.
- AMEC Foster Wheeler Environment & Infrastructure (AFW). 2016. Premier Gateway Scoped Subwatershed Study, Phase 1: Study Area Characterization (Draft), Town of Halton Hills. February 2016.
- AMEC Foster Wheeler Environment & Infrastructure (AFW). 2020. South Milton Urban Expansion Area Subwatershed Study – Draft Final.
- Bird Studies Canada, Environment Canada's Canadian Wildlife Service, Ontario Nature, Ontario Field Ornithologists and Ontario Ministry of Natural Resources. 2006. Ontario Breeding Bird Atlas Database. http://www.birdsontario.org/atlas/aboutdata.jsp?lang=en
- Bird Studies Canada. 2009. Marsh Monitoring Program Participant's Handbook for Surveying Amphibians. 2009 Edition. Published by Bird Studies Canada in Cooperation with Environment Canada and the U.S. Environmental Protection Agency. February 2009.
- Bond, I.J., Liberty, B.A. and Telford, P.G. 1976. Paleozoic geology, Brampton, southern Ontario; Ontario Division of Mines, Map 2337, 1:50 000.
- Cadman, M. 2021. Ontario Eastern Screech-Owl Survey. Ontario Breeding Bird Atlas.
- Chapman, L.J. and Putnam, D.F. (1984). The Physiography of Southern Ontario, 3rd ed. Ontario Geological Survey Special Volume 2.
- Conservation Halton. 2020. Policies and Guidelines for the Administration of Ontario Regulation 162/06 and Land Use Planning Policy Document. April 27, 2006 (last amended, November 26, 2020).
- Cornell Lab of Ornithology. 2020. eBird Database. https://ebird.org/home California Academy of Sciences and the National Geographic Society. 2020.
- CTC Source Protection Committee (CTCSPC). 2015. Approved Updated Assessment Report: Credit Valley Source Protection Area. July 2015.
- Department of Fisheries and Oceans (DFO). 2019. Aquatic Species at Risk Map. Last Updated August 23 2019. https://www.dfo-mpo.gc.ca/species-especes/sara-lep/map-carte/index-eng.html.

- Dillon Consulting. 2000. 401 Corridor Integrated Planning Project, Town of Halton Hills, Scoped Subwatershed Plan. March 2000.
- Dobbyn, J.S. 1994. Atlas of the Mammals of Ontario. Don Mills, Federation of Ontario Naturalists.
- Gao, C., Shirota, J., Kelly, R. I., Brunton, F.R., van Haaften, S. 2006. Bedrock topography and overburden thickness mapping, southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 207. ISBN 1-4249-2550-9.
- Government of Canada. 2021. Species at Risk Public Registry. Last updated June 8, 2021. https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html.
- Halton-Hamilton Source Protection Committee (HHSPC). 2017. Assessment Report, Halton Region Source Protection Area. October, 2017.
- Halton Region. 2018. Official Plan for the Halton Planning Area Regional Municipality of Halton. Office Consolidation June 19, 2018.
- Hydrology Consultants. 1983. Hydrogeological Investigation for the Rural Community of Hornby, Town of Halton Hills, The Regional Municipality of Halton. Project PR-718. July 1983.
- Imhof, J. 1997. Salmonid Spawning Survey: Methodology. Trout Unlimited Canada.
- iNaturalist. 2020. https://www.inaturalist.org/.
- Jennifer Lawrence & Associates Inc., MGM Consulting, Savanta, Geo Morphix, DS Consultants, Minnow Environmental (JLA et al). 2020. Town of Halton Hills – Halton Region, Scoped Subwatershed Study, Northeast Corner of Steeles Avenue and 8th Line Final Report (Final Submission). November 2022.
- Jones, C., Somers, K.M., Craig, B., and Reynoldson, T.B. 2007. Ontario Benthos Biomonitoring Network: Protocol Manual. Ontario Ministry of the Environment, Environmental and Reporting Branch. Queen's Printer for Ontario, Toronto.
- Lee, H.T., W.D. Bakowsky, J. Riley, J. Bowles, M. Puddister, P. Uhlig and S. McMurray. 1998. Ecological Land Classification for Southern Ontario: First Approximation and its Application. Ontario Ministry of Natural Resources, Southcentral Science Section, Science Development and Transfer Branch. SCSS Field Guide FG-02.
- Macnaughton, A., Layberry, R., Jones, C. and Edwards, B. 2020. Ontario Butterfly Atlas Online. Toronto Entomologists' Association. Last updated February 2020. http://www.butterfly.ontarioinsects.org/atlas/.

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

— Oak Ridges Moraine Groundwater Program (ORMGP). 2018. Oak Ridges Moraine Groundwater Program Website [Oakridgeswater.ca].

— Ontario Geological Survey 2010. Surficial geology of southern Ontario; Ontario Geological Survey, Miscellaneous Release— Data 128 – Revised.

— Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). 2021. AgMaps Geographic Information Portal. Last Updated May 18, 2021. http://www.omafra.gov.on.ca/english/landuse/gis/portal.htm.

— Ontario Ministry of the Environment, Conservation and Parks (MECP). 2021. Permit to Take Water Database. Last Updated May 31, 2021. Downloaded June 1, 2021.

— Ontario Ministry of the Environment, Conservation and Parks (MECP). 2020. Water Well Information System. Dataset downloaded September 24, 2020.

— Ministry of the Environment, Conservation and Parks (MECP). 2021. Species at risk in Ontario. Last Updated November 9, 2020. https://www.ontario.ca/page/species-risk-ontario#section-10.

— Ontario Ministry of Municipal Affairs and Housing (OMMAH). 2020. A Place to Grow: Growth Plan for the Greater Golden Horseshow. Queen's Printer for Ontario, 2020. https://files.ontario.ca/mmah-place-to-grow-office-consolidation-en-2020-08-28.pdf.

— Ontario Nature. 2019. Ontario Reptile and Amphibian Atlas. Last Updated December 1, 2019. https://ontarionature.org/programs/citizen-science/reptile-amphibian-atlas/.

— Ontario Ministry of Natural Resources and Forestry (MNRF). 2021. Ontario Digital Terrain Model (Lidar-Derived). Lidar DTM Halton 2018 Package D. Last Update: 2019-08-30.

— Ontario Ministry of Natural Resources and Forestry (MNRF). 2020. Make a Map: Natural Heritage Areas.https://www.lioapplications.lrc.gov.on.ca/Natural_Heritage/index.html?viewer=Natural_Heritage.Natural_Heritage&locale=en-CA.

— Ontario Ministry of Natural Resources and Forestry (MNRF). 2014. Ontario Wetland Evaluation System: Southern Manual. 3rd Edition, Version 3.3.

— Ontario Odonata Atlas Database. 2020. Natural Heritage Information Centre, Ontario Ministry of Natural Resources and Forestry.

— Regional Municipality of Halton (RMOH). 1995. Halton Aquifer Management Plan – Phase 1 Report Background Hydrogeology. February 1995.

— R.J. Burnside & Associates Limited, 2016. 2015 Hydrogeological Assessment, Milton Phase 4 Lands, Milton, Ontario.
— Stanfield, L (Editor). 2017. Ontario Stream Assessment Protocol. Version 10. Fisheries Policy Section. Ontario Ministry of Natural Resources. Peterborough, Ontario.
— Stanfield, L. (Editor). 2013. Ontario Stream Assessment Protocol. Version 9. Fisheries Policy Section. Ontario Ministry of Natural Resources. Peterborough, Ontario.
— Terraprobe Ltd. (Terraprobe). 2006. Private Well Monitoring Report, Steeles Avenue Project, Halton Hills, Ontario, File No. PR-2174. January 2006.
— Town of Halton Hills. 2020. Town of Halton Hills Official Plan. Adopted March 2008, Office Consolidation December 31, 2020.

Personal Communication

— DeFields, E. Personal communication (email) between Nathan Miller (NRSI) and Emma Fields (Conservation Halton) re: marsh bird surveys/habitat. May 31, 2021.