OAKVILLE

North Oakville Creeks Subwatershed Study

ANALYSIS REPORT

August 2006

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TABLE OF CONTENTS

LIST OF FIGURES

On or following page

LIST OF TABLES

On or following page

LIST OF APPENDICES

A – Study Terms of Reference
    A1 – IAR Phase I & II Reports
B – List of Background Reports Reviewed
C – TAC – Additional Notes
    C1 – Bus routes and sites visited
    C2 – Initial set of issues provided to TAC for discussion at TAC meeting No. 2 (June 20/02)
    C3 – Information handed out at the Open House
D – Figure B of Community Organization from OPA 198
E – Geology – Additional Notes
    E1 - Figure E.1 Cross-section of location along Burnhamthorpe Rd.
    E2 – MEL1.1 to MEL1.26 bore holes and construction details for minipiezometers & monitoring wells
    E3 - MEL1.34 to MEL1.37 grain size testing results
    E4 – Groundwater testing results
    E5 – Photos E1 – 4 and 4W.1 & 2
F – Water level monitoring data
G – List of Vascular Flora
H – ELC Additional Information
    H1 – Sample ELC data form
    H2 – MNR Wetland description translated into ELC codes
I –Additional Bird Information
    I1 – Background Reports Reviewed
    I2 – List of Bird Species in Study Area
    I3 – Breeding Evidence for Bird Species
J – List of Mammals Observed in Study Area
K – List of Reptiles and Amphibians Observed in Study Area
L – List of Butterfly Species in Study Area
M – Field data form for Aquatic Habitats
N – Characteristics Recorded for the Aquatic Habitats of Surveyed Reaches
O – List of Fish Species for Each Creek and Tributary
P – Results of Fish Sampling
Q – Data Tables Provided by the MNR for Fish Sampling in 2002/2003 in the North Oakville Study Area
R – Sampling Methodology and Details on Benthic Invertebrates
S – References Used to Identify Benthic Invertebrates
T – Benthic Invertebrate Monitoring Form
U – Methodologies and Assessment Criteria for the Indices used for Benthic Invertebrate Sampling
V – Benthic Invertebrate Identification and Enumeration Raw Data
W – Results of the Water Quality Analyses
X – Stream Characteristics
Y – Hydrologic and Hydraulic Modelling Approach
Z – Assumptions and Percent Imperious Values Used for the Future Land Use Types and Categories
AA – Test Catchment Design Case
BB – Analysis of Equivalent Comparison of Each Reach by Storage Based on Runoff and Reach Length
CC – Stream Photos
DD – Erosion Pin Analysis

5.0 IMPACT ANALYSIS/MANAGEMENT REQUIREMENTS

5.1 INTRODUCTION/APPROACH

The characterization of the North Oakville Creeks Subwatershed is outlined in **Sections 4E** and **4W** of this report; the *North Oakville Creeks Subwatershed Study* (Subwatershed Study). This section of the report provides the analysis of areas east and west of Sixteen Mile Creek.

These analyses are based on the field data collected, background information reviewed and hydrologic modelling. The subcatchments are illustrated in **Figure 5.1.1**. This study, particularly the modelling, forms the basis for evaluating subwatershed processes and functions that support and influence subwatershed characteristics, as well as identifying potential impacts of future land use changes.

The process of carrying out the impact analysis included consideration of potential development scenarios. In this case, development scenarios were identified for lands north of Dundas Street. This allows for an assessment of the sensitivity of the catchment areas to change. These scenarios were modelled, primarily from a hydrologic standpoint, according to surface water, water balance, and the potential impacts on stream conditions. This information was also used in the consideration of terrestrial, wetland, and aquatic conditions and associated management requirements to preserve and enhance environmental conditions. Development of these requirements is outlined in this report. The resulting management strategy is presented in the next chapter.

A comprehensive management strategy consists of multiple elements and under no circumstances can a single element, such as stormwater management (SWM), dominate the entire strategy. A broad range of components are necessary to address all processes that influence watershed conditions. The various components that are considered in the development of a strategy include:

- SWM measures to protect flow regime conditions (baseflow, bankfull flow, and flood flows) and water quality;
- The preservation, restoration, and enhancement of terrestrial features for habitat conditions and to protect hydrologic processes;
- The preservation and enhancement of linkages to ensure a sustainable natural heritage system is maintained;
- The preservation of topography and surficial geological conditions that contribute to surface water and groundwater flow conditions;
- The identification and preservation of stream corridors for aquatic habitat, hydrologic processes and water quality;
- The identification, preservation and restoration of selected headwater systems that are important to the stream corridor functions (hydrologic, stream geomorphology, hydrogeologic, aquatic, and terrestrial); and
- The identification of rehabilitation opportunities to increase the resiliency of the stream system.

5.2 IMPACT ANALYSIS - LAND USE SCENARIOS

The current land use is shown on **Figure 5.2.1**. From a hydrologic response perspective, the existing land use is mostly agricultural, with some wetland and remnant upland habitat. Some residential units are located along the roadways such as Dundas Street West, Burnhamthorpe Road West, Sixth Line Road, Bronte Road, and Tremaine Road. Highway 407 constitutes the northern boundary of the study area in an east-west direction.

Future land use changes in the catchment areas will focus on residential and employment land development north of Dundas Street. The future land use scenario (**Figure 5.2.2**) reflects land use patterns proposed by the Town of Oakville in Official Plan Amendment (OPA) 198, and as being developed in the Secondary Plan process.

In each scenario, the significant natural features, including remnant upland habitat, wetlands and stream corridors have been excluded from development for the purposes of analysis.

The potential impacts have been identified and will provide the basis for identification of management requirements for the study area.

5.3 SUBWATERSHED STUDY PROCESS INPUTS

There were a number of inputs that fed into the study process. The main inputs included community, TAC and IAR input and are described in more detail in the following sections.

5.3.1 Community Input

As described in detail in **Section 3.0,** community input into the study process was initiated through a series of meetings held to involve the public in the development of the subwatershed management strategy.

Community input received during the subwatershed characterization and analysis indicated a significant interest in the development of a management strategy for the protection and enhancement of environmental resources. Concerns were expressed regarding the potential impact of future land use changes and the need to manage these changes in a manner that protects the resources in the North Oakville Creeks Subwatershed. This input was taken into account, and was used to aid in the development of the analysis approach.

During this subwatershed study the Town of Oakville was also carrying out a planning process for the future of the lands north of Dundas Street. The process followed included an amendment to the Town's Official Plan (OP), known as OPA 198, to provide for urban use, and development of a Secondary Plan. This information, including subwatershed management needs, developed in this study, is being incorporated into the Secondary Planning Process. As part of that process, a number of environmental issues have been raised, including concerns regarding local groundwater and surface water resources, since a number of the creeks and streams have their headwaters in the lands north of Dundas Street. Community input was also obtained through the Secondary Planning process in the form of public meetings and a design charette.

The concerns and issues raised during Community input have been summarized in **Section 3.0** of this subwatershed report. A number of resource management and servicing issues have been identified through concerns of the local community. These issues are also reflected in the study's Terms of Reference.

The Subwatershed Study is to provide the necessary resource information to assist in the development of the Secondary Planning Process. It will be important to ensure that the necessary information is provided for this process (*i.e.,* implementation recommendations). Similarly these studies are to provide guidance to future servicing studies as part of the Secondary Planning Implementation Process. Current servicing information (*e.g.,* sanitary, water, and roads) is to be considered, as well as corresponding issues.

5.3.2 Technical Advisory Input (TAC) Input

To ensure that the community interests are incorporated into the Subwatershed Study process, a Technical Advisory Committee (TAC) was established (see **Section 3.0**). The TAC meetings covered a review of work to date, as well as preliminary findings and data sharing/data transfer protocols for the background information. Some of the issues within the study area generated by the TAC included terrestrial, creeks & surface water, habitat enhancement and the Trafalgar Moraine. The TAC meeting minutes are contained in **Appendix C**.

5.3.3 Interagency Review (IAR) Input

The IAR Process was initiated by the Town of Oakville to foster a higher level of participation (and easy data transfer) between the agencies involved with the Subwatershed Study and Secondary Planning Processes. The IAR group was comprised of the following participants:

- Ontario Ministry of Municipal Affairs and Housing (MMAH);
- Halton Region; and
- Town of Oakville representatives.

The MNR, Conservation Halton, and the Subwatershed Study team were also included as advisors to the process.

The purpose of the IAR Process was:

> *"To develop options for a common policy system which would be suitable for the urban context of North Oakville and reflect provincial smart growth principles for input to the Subwatershed Study, which in turn will all be input to the Secondary Plan."*

This information was used throughout the analysis phase, and was reflected in the management strategy. **Appendix A** provides the North Oakville Planning Authorities IAR Phase I and II reports (which includes the terms of reference). Policies surrounding the management strategy were developed as part of the Secondary Planning Stage.

5.4 HYDROLOGIC ANALYSIS

5.4.1 General

The assessment of the potential impact of proposed development on the hydrologic cycle for the watercourses within the study area was modelled using the Guelph All-Weather Storm Event Runoff computer simulation model (GAWSER). GAWSER is a physically based deterministic hydrologic model that incorporates the physical understanding of the involved processes. The GAWSER program is routinely used to model precipitation events for short and long-term periods. In addition, the program can simulate spring runoff and snowmelt events.

There were two analytical components to the GAWSER model. The first analysis determined the impact of development on return period peak flow rates, while the second analysis determined the impact on long-term mean annual evapotranspiration, runoff, and infiltration rates. The impact was determined by comparing the results of two hydrologic computer models. One model represented existing land use conditions, and the second model simulated expected future land use conditions as proposed in OPA 198 and the Secondary Planning process when the watersheds are completely built out (without SWM).

Modelling assumptions are discussed in **Section 5.4.3**.

The hydrologic impact analysis was used to compare, on a relative basis, simulated results from an existing conditions model with the results from a proposed development conditions model. The results from the existing conditions model may not accurately reflect real world values. The hydrologic cycle is the result of complex interactions between climate and ever changing land use patterns. Climate and land use patterns can vary significantly from year to year and from one location to another within the study area. Also, models are simplified representations of documented conditions compared to real world conditions. Results from an uncalibrated model can vary from 50 to 100% of recorded data. Calibrated models provide increased accuracy but can still vary from observed data.

5.4.2 Results

Impact analysis results are shown in **Table 5.4.1** and **Table 5.4.2**. **Table 5.4.1** shows peak flow rates for existing and future land use conditions at several locations (*i.e.,* culverts) located throughout the study area. Culvert locations are shown on **Figure 5.4.1**. Peak flow rates were determined for storm events with return periods ranging from 2-year through the Regional Storm. **Table 5.4.2** shows the mean annual runoff, evapotranspiration, and infiltration rates for existing and future land use conditions at various points of interest within the study area.

Generally, peak flow rates (**Table 5.4.1**) within the study area will increase approximately 100% from existing to future land use conditions. For the Regional Storm event, peak flow rates will increase by 25 to 50% over existing land use results. For mean annual values (**Table 5.4.2**), future development will decrease evapotranspiration by about 50%, runoff values will increase by approximately 100%, and infiltration rates over the developed area could decrease by 60%.

The results shown in **Tables 5.4.1** and **5.4.2** are based on assumptions described in **Section 5.4.3**. Changing the assumptions used in the modelling process will cause changes to the results.

5.4.3 Modelling Assumptions

Points of Interest - Were selected primarily along Burnhamthorpe Road, Highway 407 and Dundas Street to provide for an assessment of existing conditions and potential impacts. The locations along Dundas Street also provide for the assessment of potential impacts on downstream conditions.

Precipitation and Temperature Values - For the long-term mean annual analysis, hourly precipitation and daily temperatures were selected from Environment Canada's gauge located at the Royal Botanical Gardens in Burlington. Data recorded from 1962 to 1990 was used in the impact analysis. The gauge was considered to have the most appropriate characteristics for the analysis. The gauge was selected in consultation with Conservation Halton, the Corporation of the Town of Oakville, and the Consultant Study Team. The peak flow rate analysis used rainfall intensity-duration-frequency values, and design storm patterns shown in the Town of Oakville's Development Engineering Procedures and Guidelines Manual (1999).

[Existing Land Use] - Was obtained from aerial photographs and biological investigations conducted during the study. In developing modelling parameters, land use was classified as wetlands, remnant upland habitat, agricultural, residential, or employment lands as shown on **Figure 5.4.2**. Existing land use was taken from aerial photographs maintained by the Regional Municipality of Halton, and dated April 1999, and discussions with Town staff to clarify current uses. The aerial photographs had a scale of approximately 1:6,000

[Future Land Use] – Was abstracted from figures shown in OPA 198 for the first iteration of modelling. The modelling assumed a feature based approach meaning that wetlands, wooded areas and stream corridors would not be developed. This was compared to the land use being developed in the Secondary Planning Process at that time and from a modelling standpoint, the plans produced very similar results. Refer to the *Revised Draft Analysis Report, December 2003* for more details.

The future land use conditions were revised to reflect the most current plan developed through the Secondary Planning Process. The Secondary Plan shows the future land use categories and locations as well as the Natural Heritage System which is discussed in detail under **Sections 6.3.3 and 6.3.4.** The revised future land use model incorporates the future core, linkage and stream corridor areas. **Figure 5.4.3** shows the subcatchment boundaries superimposed over the future land use as per the Secondary Plan. The existing agricultural, residential and employment lands would be redeveloped into a wide spectrum of different land use categories.

The assumptions and percent impervious values used for the future land use types and categories can be found in **Appendix Z**.

[Depressions] - Were reviewed in detail during the study. Both artificial/human made depressions (ponds) and natural depressions were catalogued. The natural depressions include both linear depressions along watercourses and isolated "off-line" pits along the Trafalgar Moraine and throughout the study area. **Table 5.4.3** shows estimated areas and storage volumes for both natural and artificial depressions in each subcatchment (taken from topographic information). Storage volumes were calculated assuming a depth of 0.5 m for natural depressions and 1.0m for artificial depressions. The assumed depth for the natural depressions was determined based on the minimum interpolated relief from the available mapping and field investigations. **Table 5.4.3** shows the natural depression depth (storage volume averaged over the subcatchment area) for each subcatchment. The natural depression depths were not considered great enough to warrant changes to the hydrologic model. The hydrologic model already incorporates storage through input of soil group depression depth and input of a hydrograph storage value.

[Future Watercourse Modifications] – As part of the modelling exercise hydrologic routing was performed to simulate the movement of water down the existing stream channels to account for the attenuation effects on the flood flows. The modelling accounted for both open and closed drainage systems. The modelling was performed with the understanding that portions of the open channel drainage would remain under post development conditions (i.e. red and blue streams discussed in **Section 6.0** of this study report). The results shown in **Table 5.4.1** and **5.4.2** assume that watercourses in each subcatchment would not be modified to accommodate future development. If further watercourses were to be modified or replaced by storm sewers, then peak flow rates shown in **Table 5.4.1** will likely increase.

5.4.4 Model Verification

Generally, model calibration is conducted using locally recorded streamflow and precipitation data. Within the study area, local streamflow and precipitation was only recorded for a short period during completion of the field studies. Although valuable, there was not sufficient data for model calibration purposes.

Calibration adjusts model input parameters to more accurately simulate the observed hydrologic conditions. Model verification compares peak flow rates and volumes of runoff with recorded data from adjacent catchment areas or from within the study area. To date, verification has included a cursory comparison with data recorded in adjacent catchments. Environment Canada operates streamflow gauges in several adjacent catchments. A summary of those gauges is shown in **Table 5.4.4**. Only one gauge in **Table 5.4.4** (East Oakville Creek near Omagh) has natural runoff conditions similar to the watercourses found in the study area. The other gauges record runoff from watersheds where runoff is regulated by reservoirs. The East Oakville Creek gauge has recorded a mean annual runoff of approximately 250 mm, similar to the model results shown for existing conditions in **Table 5.4.2**. Also from the Omagh gauge, unit area peak flow rates for the 2-year event are approximately 0.337 $m^3/s/km^2$, again very similar to the model results. From this cursory verification, the GAWSER model appears to adequately simulate streamflow from the study area.

Table 5.4.4
Summary Of Environment Canada Streamflow Gauges

Bronte Creek at Progreston - runoff is regulated 02HB0		
Drainage Area	124	km^2
Mean Annual Flow (1978 - 1984)	1.47	m^3/s
Mean Annual Runoff Depth (1978 - 1984)	374	mm
Mean Annual Max. Instant. (1977 - 1985)	9.8	m^3/s say 2 year
Unit Area Peak Flow Rate (1977 – 1985)	0.079	m^3/s/km^2
Bronte Creek at Zimmerman – runoff is regulated 02HB011		
Drainage Area	235	km^2
Mean Annual Flow (1964 - 1987)	2.76	m^3/s
Mean Annual Runoff Depth (1964 - 1987)	371	mm
Mean Annual Max. Instant. (1964 - 1987)	24.0	m^3/s say 2 year
Unit Area Peak Flow Rate (1964 – 1987)	0.102	m^3/s/km^2
East Oakville Creek Near Omagh – runoff is natural 02HB004		
Drainage Area	199	km^2
Mean Annual Flow (1958 - 1990)	1.58	m^3/s
Mean Annual Runoff Depth (1958 - 1990)	250	mm
Mean Annual Max. Instant. (1965 - 1990)	67.1	m^3/s say 2 year
Unit Area Peak Flow Rate (1965 – 1990)	0.337	m^3/s/km^2
Oakville Creek Near Milton – runoff is regulated 02HB005		
Drainage Area	95.6	km^2
Mean Annual Flow (1959 - 1990)	1.22	m^3/s
Mean Annual Runoff Depth (1959 - 1990)	403	mm
Mean Annual Max. Instant. (1959 - 1990)	18.7	m^3/s say 2 year
Unit Area Peak Flow Rate (1959 – 1990)	0.196	m^3/s/km^2

5.5 HYDROGEOLOGY AND WATER BALANCE

5.5.1 Analytical Results

Water Budget

The circulation and movement of water between the atmosphere, surface waterbodies and the land surface is called the hydrologic cycle. Water that falls to the ground as precipitation (P) either runs off (R) to a surface waterbody, evapotranspires (ET, a combination of evaporation from ground surface and waterbodies and transpiration by plants) or infiltrates (I) into the ground. The water that infiltrates moves either vertically down to the water table as recharge or flows horizontally in the weathered zone, eventually discharging as interflow to the nearest surface water feature. The rate at which water infiltrates into the ground is controlled by factors such as the permeability and porosity of the earth materials and the size and timing of precipitation events. Soils such as sands and gravels are generally more permeable, enabling water that falls on these soils to infiltrate relatively easily. Clay rich soils, such as those at ground surface in the North Oakville area, are considered to be less permeable, resulting in little infiltration and a predominance of evapotranspiration and run off. **Figure 2.1.1** shows a schematic of the hydrologic cycle.

When long-term averages of P, R, ET, and I are used, there is no net change in groundwater storage (S). On a short-term basis, however, there is a potential for changes in S.

The annual water budget can be stated as:

$$P = ET + R + I + S$$

Precipitation

Based on the 30-year average (1962 – 1990) at the Royal Botanical Gardens station in Burlington, the precipitation in the study area averages 785 mm/yr. This is similar to the 825 mm/yr average annual precipitation value recorded at the Oakville Water Pollution Control Plant. For the purpose of the water budget, the precipitation at the Royal Botanical Gardens was used.

Evapotranspiration

Measurement of evapotranspiration can be difficult and the results are often not easily reconciled. Assuming that about 10 cm of precipitation is needed to annually replenish water storage in the vadose zone, the potential evapotranspiration for the area is estimated at about 640 mm/year, with the actual evapotranspiration being about 550 mm/year (Brown *et al.*, 1980). The actual evapotranspiration represents approximately 70% of the total precipitation.

Infiltration and Recharge

Infiltration, although difficult to measure accurately, can be estimated in several ways. One method used is an assessment of measured baseflow (low flow in the summer or early autumn) in streams within the catchment area. These low flows are considered the groundwater contribution to streamflow and represent that portion of infiltration that returns to the surface water system via flow in the shallow groundwater system and the unsaturated zone.

Using data from the 2002 and 2003 flow monitoring and the calculated area upstream of the monitoring stations, the infiltration in Joshua’s Creek and Fourteen Mile Creek subcatchments north of Dundas Street was estimated. The results are presented in **Table 5.5.1**. It should be noted that all streams other than Joshua’s Creek, East Morrison Creek, Sixteen Mile Creek and Fourteen Mile Creek, are intermittent north of Dundas Street. Consequently, there is no perennial contribution from groundwater to these streams in the area north of Dundas Street. When these streams flow, the water is derived from runoff.

Table 5.5.1
Calculated Infiltration

Location	Low recorded non-zero flow (m^3/day)	Total Contributing Area (ha)	Calculated Infiltration (mm/yr)
Joshua's Creek at Dundas Street	864	938	34
West Fourteen Mile Creek at Dundas Street	864	162	195
East Fourteen Mile Creek at Dundas Street	2160	318	248
Average	-	-	159

The broad range in calculated infiltration is likely as much a function of the monitoring as it is representative of area conditions. For all streams monitored, there were periods when there was no flow, indicating that the groundwater contribution to stream flow, is only on a seasonal or event specific basis. It should also be noted that this is only a small data set collected over a short time period.

This is further reflected by the reduction in shallow vertical gradients measured at the stations where mini-piezometers were installed. During the summer months the magnitude of the gradients decreased, and in some cases temporarily reversed. These fluctuating gradients reflect the changes in groundwater contribution to streamflow seasonally.

Based on the field studies done, the range in infiltration is between 4% and 32% of total precipitation on an average annual basis. The infiltration values calculated from the field data are generally higher than expected for the clayey silt soils found throughout North Oakville. Work done by others (Funk (1979), Ostry (1979), Marshall Macklin Monaghan *et al.* (1992) suggested that infiltration in the Sixteen Mile Creek and Joshua's Creek watersheds ranged from 48 to 110mm/yr, which is about 6 to 14% of precipitation. The infiltration calculated as part of this study correlates better with the lower end of the historical range documented by others.

Another way of estimating infiltration is through hydrologic modelling. These results, presented in **Section 5.4**, indicate an average infiltration rate of about 40 mm/yr. This calculated value suggests that the results from the 2002 and 2003 Joshua's Creek monitoring are likely typical for the area.

The Halton/Wildfield Till is generally a heterogeneous soil with very little bedding or other evidence of layering. Infiltration through the soil matrix is low, given that the hydraulic conductivity of the soil is low (**Section 4.3.2.2**). However, the presence of weathering in the upper portion of the soil profile provides secondary permeability for infiltration and recharge. Considering that soil heterogeneity and anisotropy often results in the horizontal hydraulic conductivity being about 10 times greater than the vertical hydraulic conductivity, only about 10% of water infiltrating into the soil will end up reaching the water table and can be considered recharge. For North Oakville this equates to a recharge of about 5 mm/year. Using an infiltration rate of 40 mm/year the estimated infiltration is 3×10^6 m^3/yr and the recharge to groundwater flow system is estimated at 3.8×10^5 m^3/yr.

Runoff

The runoff simulated with the GAWSER models (**Section 5.4**) for Joshua's Creek, East Morrison Creek and Fourteen Mile Creek watersheds was checked against the regional expectations as a verification of the analyses. The resulting runoff estimates indicate that about 38% of precipitation is runoff. Using a recharge of 5 mm/yr and an average actual evapotranspiration of 550 mm/yr, runoff in the study area, including interflow, is estimated at 230 mm/yr. Thus, the water surplus is calculated at about 235 mm/yr. This is consistent with historical regional estimates of 280 mm/yr (Brown *et al.*, 1980).

Pitted Topography on the Trafalgar Moraine

In the area east of Sixteen Mile Creek, the high ground associated with the crest of the Trafalgar Moraine creates a local surface water and groundwater divide. Between the south slope of the moraine and Dundas Street, runoff from the area created several intermittent streams. Along the narrow crest of the moraine there is a series of shallow depressions or pits that were formed during the advance and melt back of the last glacial ice mass that covered the area. Based on current topographic mapping (1m elevations with 0.5m interpolation) these features are generally less than 1m in depth. **Figure 5.5.2** shows the location of the pits along with other depression storage related features. The major concentration of pits associated with the Trafalgar Moraine occurs between Sixth Line and Trafalgar Road in Oakville.

These pits are located toward the north end of subdrainage area EM2 with a lesser concentration at the north end of subdrainage areas JC7 and EM1. Within each subdrainage area in this part of the study area, the total aerial extent of each pit ranges from less than 0.05 ha to about 2 ha. Some pits retain water permanently, (as evidenced by the permanent standing water and wetland ecosystem associated with them), but most are small, have drainage outlets, and dry up shortly after a precipitation event or the spring freshet. This indicates that most of the water in these pits runs off or evapotranspires. In addition to the natural pits, there are a number of artificial ponds or depressions. All of these features have been examined and their presence accounted for in the hydrologic modelling.

Groundwater Contribution to Stream Health

The contribution of groundwater is an important factor in the overall health of aquatic ecosystems (Hynes, 1983; Danielopol, 1989; Findlay 1995; Jones *et al.*, 1996; Brunke *et al.,* 1997). Groundwater helps to regulate the temperature of streams and can provide thermal refuge at a microhabitat scale for aquatic organisms (Danielopol, 1989). Groundwater can also provide important nutrients which may be lacking in surface runoff (Brunke, 1997; Williams, 1993). Some aquatic organisms use groundwater discharge areas as important microhabitats for critical life stage activities such as spawning (Baxter 1999, 2000; Stoneman *et al.*, 1999).

Groundwater discharge within the study area is limited to sections of the Joshua’s Creek valley (south of Burnhamthorpe Road), part of the Shannon’s Creek catchment (around Dundas Street), the area north of the closed Fourth Line Landfill (south of Burnhamthorpe Road), and the East Sixteen Mile Creek tributary just south of Burnhamthorpe road. These discharges are predominantly seasonal or event based and occur during those times of the year when the water table is closer to the ground surface.

Groundwater discharge was observed at four locations in the study area. The first location was in Reach JC-5 on Joshua’s Creek (see **Figure 5.6.2** for reach location) where a localized discharge was observed in May of 2002. Given the position of this reach, it is suspected that this is a perennial discharge area and that the presence of this groundwater discharge is moderately significant in contributing to overall stream health

Also in the Joshua's Creek watershed, groundwater discharge is suspected in Reach JC-36 (see **Figure 5.6.2** for reach location) immediately north of Dundas Street. No discharge was observed, but water temperature and plant species suggest a potential discharge area. Since this is a relatively small reach, the suspected discharge, which is located in an area consistent with the modelling results in the Halton Region Aquifer Management Plan, is considered highly significant in its contribution to overall stream health.

Although no specific discharges were observed, the Region's model suggests that groundwater discharge can be expected, at least seasonally, in the Shannon's Creek catchment toward the south end of reach SHC-1 just north of Dundas Street, and in the tributary to Sixteen Mile Creek north of Reach SMA-8 just south of Burnhamthorpe Road. See **Figure 5.6.2** for these reach locations. Both areas are relatively flat with some evidence of standing water, at least seasonally, which support the premise that there may be some localized seasonal groundwater discharge.

5.5.2 Potential Impacts and Management Needs

The potential impacts of urbanization on the groundwater flow system include a reduction of infiltration and recharge as a result of the increase in impervious area. The quality of infiltrating water will also change as a result of urbanization. These potential impacts are of greatest concern in areas of both groundwater recharge and discharge north of Dundas Street and in areas already developed to the south.

With regards to areas of discharge, the main discharge areas are mapped in the Joshua's Creek valley between Dundas Street and Burnhamthorpe Road, the area just north of Dundas Street, in the Munn's and Shannon's Creek areas, and the area west of Fourth Line, north of the closed Fourth Line landfill. Areas further to the south have also been identified as discharge areas (Halton Aquifer Management Plan) as the streams rising in North Oakville intersect the bedrock and sustain more perennial flow. The remainder of the area can be considered to have a low recharge potential.

The potential reduction of infiltration in the North Oakville area has been identified through the hydrologic modelling presented in **Section 5.4**. In completing the hydrologic modelling, it is assumed that the future cores and linkage areas will remain largely undeveloped. These areas will continue to recharge and discharge as they currently do, including their contribution to recharging the groundwater flow system in the bedrock. Through the remainder of the developed area the reduction of infiltration, without mitigation, is estimated to be up to 60% of predevelopment infiltration.

The impacts associated with the changes in the water balance if no mitigation is done could include a lengthening of the period of no flow for intermittent streams. Although some localized changes in the depth to the shallow water table may occur, the calculated change in recharge is expected to result in water table elevation changes that are within the natural water table fluctuation that currently occur. Thus, no measurable regional water table lowering in the shale or discharge to watercourses south of Dundas Street is expected to occur.

The most effective way of mitigating this change is to minimize changes to infiltration as a result of urbanization. Given the low permeability soils in the area, this will be difficult. Since opportunities for infiltration are site specific, more detailed studies on individual land parcels will be needed to identify and take advantage of these infiltration opportunities. As a guiding principle, best efforts and the use of best management practices are a must to minimize the reduction of infiltration.

With respect to groundwater quality, there are two issues. The first is the protection of drinking water supplies during the transition from a rural setting to urban. The second is protecting the quality of groundwater discharging to surface water.

Existing groundwater quality in North Oakville is generally poor. During the urbanization of the area, some residents will remain on groundwater as a drinking water source and their groundwater supplies must be protected. Both the Town of Oakville and the Region of Halton have existing policies that must be considered if a groundwater quality interference situation is detected. Active compliance with these policies addresses the short term. In the long term, the most effective mitigation measure will be hooking the groundwater users to the municipal system. The result will be a sustainable long-term supply of potable drinking water, as well as a reduction in the current withdrawal of groundwater from private wells in the study area.

With respect to long-term groundwater quality, it must be recognized that there is virtually no chance for development of a groundwater based municipal water supply either in North Oakville or further down gradient in the already developed parts of the Town. In addition, there will be no future private down gradient use of groundwater as a drinking water supply source. Thus the focus for groundwater quality is the quality of discharge to watercourses and water bodies.

To address this ecological issue, mitigative measures aimed at balancing recharge volume should also address enhancing the quality of urban recharge, particularly recharge from stormwater management facilities. This can be done by ensuring that there is sufficient travel time through the natural clayey silts, the native shale, or any filter media constructed as part of an enhanced infiltration system. This will assist in the natural attenuation and removal of some typical contaminants. The natural clay rich soils and the underlying shale have a generally low permeability, making them good barriers to contaminant movement.

5.6 STREAM CORRIDOR FUNCTIONS AND STREAM CHARACTERIZATION

5.6.1 General Overview of Stream Characterization

A detailed analysis has been performed to determine the stream characteristics and functions from a:

- hydrogeologic perspective (this section);
- hydrologic, hydraulic and water quality perspective (this section);
- stream morphology perspective (see **Section 5.8**);
- terrestrial resources perspective (see **Section 5.9**); and
- aquatic resources (i.e. fishery) perspective (see **Section 5.10**)

From a hydrogeologic perspective, **Section 5.5** above considers the stream connection to the groundwater system in supporting baseflow discharge and its role in supporting aquatic life. This section describes the hydrologic/ hydraulic analysis of selected stream reaches carried out for delineation of the floodplain, to assess the hydrologic role of the stream corridors. In addition, a water quality control function is considered and presented.

5.6.2 Hydraulic Analysis

The hydraulic analysis included the development of floodlines along selected watercourse reaches. Watercourses were selected based upon the watercourse definition and overall drainage area. The one-half square mile limit was a factor used in the selection of the watercourse reach for developing floodlines, but was not the sole determinant.

Hydraulic modelling was available for Joshua's Creek from previous studies (*Halton Region Conservation Authority*, 1988). This information was used for purposes of this study. The model for Joshua's Creek was extended to include the selected reaches. This included primarily the reaches in the vicinity of Burnhamthorpe Road.

The design flows for the hydraulic model were provided by hydrologic modelling (see **Section 5.4**) The HEC-RAS model was applied to calculate water surface profiles. The approach in applying the model is described in **Appendix Y.** Flood elevations were developed for the full range of design flows (1:2 to Regional). Floodlines were plotted for Regional storm conditions and are illustrated on **Figure 5.6.1.**

5.6.3 Hydraulic Modelling Results

The resulting floodlines for Regional storm event was plotted on Topographic mapping provided by the Town of Oakville. This mapping is at 1 m contour intervals with 0.5 m interpolation. The floodlines are suitable for the purposes at this Subwatershed Study. The topographic mapping, however, does not meet the specifications required for regulatory floodlines. As such, the floodlines will need to be finalized with appropriate mapping prior to use as a regulatory limit.

The calculated floodlines were used in the assessment of flood potential as well as use in the assessment of the hydrologic role of the stream corridors (see **Section 5.6.4**).

Flood Potential/Extent of Flooding

The potential for flood damages to existing buildings is limited to the most westerly tributary of Joshua's Creek downstream of Burnhamthorpe Road, as illustrated in **Figure 5.6.1.** This flooding is at the fringe of the Regional floodlines at minimal depth. Flood potential does not exist for lesser events. Remediation of flood potential at this location can occur in one of two ways.

- During development of the area, most existing properties will likely be redeveloped and current regulations will keep development out of the floodplain. This is the most likely scenario to occur; or
- If this property is not redeveloped, flood potential mitigation can be achieved through berming adjacent to the building or flood proofing.

Stream Geomorphology and Streambank Erosion

The hydraulic analysis provided information on stage – discharge – velocity for the streams along the reaches modelled. The information was incorporated into the geomorphologic consideration of erosion potential stream geomorphology is discussed in **Section 5.8**.

5.6.4 Hydraulic Stream Characterization

Hydrologic Stream Functions

Stream reaches were evaluated based upon their function with respect to hydrologic process. This included their ability to accommodate stormwater runoff, connection to other features with a hydrologic role (*e.g.*, wetlands, storage areas), and function as a headwater stream. The characterization was combined with other physical stream characteristics (*i.e.*, environmental, geomorphologic, and hydrogeologic processes) to provide an overall riparian corridor characterization (see **Section 5.11.2**).

The stream characterization based upon hydrologic function is summarized in **Appendix X.** The factors considered in the evaluation are included in each column and are described as follows:

- Valley present – if a well-defined valley exists, defined storage will be provided during high stages (*i.e.*, overbank flow conditions);
- Hydraulic Conveyance Condition (ability to detail/store streamflow) – the stream reach was evaluated on its ability to provide overbank storage which helps to augment flows during overbank conditions. This was based on a combination of hydraulic analyses (as discussed in the following paragraphs), a review of air photos/topographic information, and field reconnaissance. In stream riparian systems that exhibited wet conditions, it was judged that significant storage was provided. Some of the streams have on-line wetlands or are connected to wetland systems that provide storage during overbank conditions. Some streams, on the other hand, act more as a straight conveyance channel and provide less significant storage for flow attenuation; and
- Linkage to headwater functions – the connection provided to, and role as a headwater stream was considered. If the stream reach is near the uppermost drainage limits and provides a significant connection to storage features (*e.g.*, wetlands, pits, and depressions) it is considered to have a higher hydraulic role for flow attenuation.

Role in Providing Storage

One of the key functional roles considered in this evaluation is the attenuation of flows, or storage provided. Natural stream corridors with a well-defined riparian system provide a role in flow attenuation. This attenuation slows water during overbank flow conditions (*i.e.*, greater than 1:1.5 – 1:2 year events). This leads to reduced peak flow rates and reduced erosion rates. If the riparian system is well vegetated, the storage of flows will also act to remove pollutants.

The evaluation of this storage function was based upon the hydraulic analysis results as well as review of air photos/topographic information and field reconnaissance. The hydraulic modelling provided the data necessary to compare the storage by each reach.

To provide an equivalent comparison of each reach, the storage by reach was normalized based on runoff volume (to remove drainage area effects), and reach length. The analysis is outlined in **Appendix BB**.

The associated relative hydraulic conveyance condition (ability to detrain stormwater) is summarized in **Appendix BB**.

Water Quality Improvements

The ability for a stream corridor to provide ability to provide a water quality control function was another factor considered in the evaluation process. Water quality improvement is provided through the existence of a well developed buffer system and vegetated riparian system. To provide good ability to improve water quality, the buffer would contain a mix of trees and low growing vegetation (*e.g.*, grasses, shrubs). This will assist in both buffering the stream from adjacent lands and removing pollutants during high flow stages.

Overall Hydrologic Ranking

The overall hydrologic ranking is provided in **Appendix X** and illustrated in **Figure 5.6.2**. A high, medium, or low ranking (H-M-L) is assigned through a combination of the factors considered (water quality improvement, presence of valley, relative hydraulic conveyance, and linkage to a headwater), as described above.

5.6.5 Hydrogeologic Ranking

The hydrogeologic conditions within the catchments, is discussed in **Section 5.5** of this report. This includes overall water balance from a runoff perspective as well as relationships between hydrogeology and stream function. The relative hydrogeologic processes relative to stream conditions was considered, evaluated and summarized in **Appendix X** with respect to flow type within the stream groundwater discharge, interpreted groundwater contribution to stream flow and the resulting overall hydrogeologic contribution to stream health.

5.7 ANALYSIS OF WATER QUALITY IMPACTS

Urban land uses generate residual and waste material from a range of individual and group activities. Each type of land use has unique characteristics that result in the generation of pollutants and runoff volume. Density or intensity of the land use and percent imperviousness also play a part.

Pollution Sources in Urban Areas

- Vehicular traffic accounts for much of the build-up of contaminants on road surfaces. Wear from tires, brake and clutch linings, engine oil and lubricant drippings, combustion products and corrosion, all account for build up of sediment particles, metals, and oils and grease. Wear on road surfaces also provides sediment and petroleum derivatives from asphalt.
- Lawn and garden maintenance in all types of land uses including residential, industrial, institutional, parks, and road and utility right-of-way accounts for additions of organic material from grass clippings, garden litter, and fallen leaves. Fertilizers, herbicides, pesticides can all contribute to pollutant loads in runoff.

- Air pollution fallout of suspended solids accounts for build-up of sediments contaminated from traffic, industrial sources, and wind erosion of soils.
- Municipal maintenance activities including road repair and general maintenance (road surface treatment, salting, and dust control).
- Industrial and commercial activities can lead to contamination of runoff from loading and unloading areas, raw material and by-product storage, vehicle maintenance, and spills of petroleum products.
- Illegal connections of sanitary services to storm sewers can cause contamination with organic wastes, nutrients, and bacteria.
- Illegal disposal of household hazardous wastes can introduce waste oil and a multitude of toxic materials to storm sewers.
- Transportation spills from accidents can occur on heavily traveled arterial streets and highways.
- Construction activity can introduce heavy loads of sediment from direct runoff, construction vehicles and wind-eroded sediment.
- Pet feces and litter introduce organic contamination, nutrients and bacteria.
- Runoff from residential driveways and parking areas can contain driveway sealants, oil, salt, and car care products.

Pollutant Impacts

The receiving water quality impacts of municipal discharges vary depending upon the quality and quantity of the wastewater and the assimilative capacity of the receiving waterbody. Control measures implemented in newer developments mitigate or prevent many of these impacts. Potential water quality concerns resulting from stormwater include:

- Bacteria from fecal material in pet and wildlife litter and sanitary wastes from illegal connections causing beach closures;
- Nutrient enrichment, from nitrogen and phosphorous compounds, which can lead to nuisance growths of algae in the receiving waterbody;
- Deposits of contaminated sediments, which can lead to degradation of benthic (bottom-dwelling) organisms and restrictions on dredging;
- Toxicity from ammonia, metals, and organic compounds present in the runoff and overflows and potential human endocrine disruption from pesticides;
- Oxygen depletion potential (‘oxygen demand’ or BOD) of the wastewater from biodegradable organic material, which can lead to oxygen deprivation of the organisms in the receiving waterbody;
- Temperature changes due to an influx of water warmed by the ‘heat island’ effect of roads and buildings;
- Aesthetic impacts from floatable matter and sediments (*i.e.,* litter, grass clippings, sanitary items, soil erosion, etc.); and
- Contamination of groundwater with soluble organic chemicals, metals, nitrates and salt.

5.7.1 Water Quality Background

Sections 4E.10 and **4W.10** describe the water quality in the watersheds with existing land uses. Water samples were taken at various locations shown in **Figures 4W.10.1** and **4E.10.1**. The results are summarized**.** Generally, water quality is mildly impaired with bacteria, some metals and total phosphorus exceeding the Provincial Water Quality Objectives (PWQO). Chloride and nitrate exceed guideline levels being considered by Environment Canada for protection of aquatic life. A Canadian water quality guideline for the protection of aquatic life was adopted in 2003 for nitrates. Given that there are fishery resources in the tributaries and downstream of the development areas, the effects of development need to be mitigated or prevented. Ontario Government policies outlined below give some guidance on the approach to be followed concerning water quality and developments.

- *The Ministry of Environment Water Management Policies, Guidelines and Provincial Water Quality Objectives* (MOE, 2003) outlines the approach to be taken regarding water quality. For surface water quality, the goal is to ensure that the surface waters of the Province are of a quality which is satisfactory for aquatic life and recreation. The PWQO are a set of narrative and numerical criteria designed for the protection of aquatic life and recreation in and on the water. In assessing water quality conditions, a comparison can be made between the water quality and the PWQO. One of the following two cases would apply:

    - Policy 1: In areas which have water quality better than the PWQO, water quality shall be maintained at or above the objective.
    - Policy 2: In areas where water quality presently does not meet the PWQO, water quality shall not be further degraded and all practical measures shall be undertaken to upgrade the water quality to the objectives.

- *Stormwater Management Practices Planning and Design Manual* (MOE, 2003). This document has guided SWM practice and design since an earlier version was released in 1994. The key provision of sizing SWM systems based on achieving levels of protection for protection of aquatic life based on sedimentation of total suspended solids (TSS) is being retained in the updated versions. Once a level of protection target is established for a watershed, the design requirements are clear, with choices provided to select alternative methods for meeting the objectives. The three levels[1] are:

    - Enhanced, with 80% long-term suspended solids (SS) removal;
    - Normal, with 70% long-term SS removal; and
    - Basic, with 60% long-term SS removal.

Although TSS is considered a pollutant in that excessive amounts can affect critical life stage activities of resident fish, there is no PWQO for this parameter. However, many of the contaminants found in urban runoff, such as heavy metals, petroleum hydrocarbons, PAHs (polynuclear aromatic hydrocarbons) are associated with SS. This is the basis for using TSS as a surrogate parameter for control in the Ministry of the Environment (MOE) SWM manual. This parameter, along with total phosphorus, will be used in the analysis tool discussed in the next section.

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[1] These levels correspond to Level 1 (enhanced), Level 2 (normal) and Level 3 (basic) protection as used in the 1994 version of the Manual.

Other contaminants in urban drainage will be included in the management plan are as follows:

- Nitrate: This soluble nutrient is not removed with TSS. It is anticipated that the existing amounts observed are likely from discharges from septic tank systems to the groundwater that appear in baseflow, or from fertilizer applications running off agricultural lands. It is expected that with urbanization and the installation of sanitary services, septic tank systems will be removed. As the land use changes to urban, the agricultural fertilizer applications will stop. Best Management Practices (BMP) for reducing fertilizer use in the urban area will be recommended as part of the management plan; and
- Chloride: These are present as part of the background from the mineral soils, the underlying bedrock and from the application of road salt. With urbanization and the addition of more roads and parking lots, additional applications can be expected. Chloride is soluble and is not removed by SWM ponds.

Environment Canada declared road salt toxic by adding road salt to the Priority Substances List of the *Canadian Environmental Protection Act* (1999). Road salts are used in Canada as de-icing and anti-icing chemicals for winter road maintenance, with some use as summer dust suppressants.

Environment Canada (Canada Gazette, April 3, 2004) issued a Code of Practice for the Environmental Management of Road Salts, under the *Canadian Environmental Protection Act* (1999). The Code of Practice was developed in consultation with a multi-stakeholder working group for road salts. It recommends that road authorities develop salt management plans to implement Best Management Practices in storage and application of road salts and disposal of snow containing road salt. The notice states that “The environmental impact indicators listed in Annex A, the guidance for identifying vulnerable areas provided in Annex B and the data gathering and reporting provisions in Annex C of this Code should be considered during the development and implementation of the salt management plan.” . The Government of Canada is not banning the use of road salts or proposing any measures that would compromise or reduce road safety. The Region adopted a Road Salt Management Plan in 2003 that addresses many of the requirements of the later notice. The Plan includes the Region and the 4 local municipalities, including Oakville. The Region should update the Road Salt Management Plan to reflect the Code of Practice issued by Environment Canada, in particular to identify watercourses and groundwater locations vulnerable to salt damage.

5.7.2 Water Quality Loading Model

A spreadsheet model was developed for this study to estimate loads of pollutants derived from runoff in North Oakville, originally applied to the City of Kingston (TSH *et al.,* 2003). The model takes land uses and estimates runoff co-efficients for each land use which, along with an estimate of annual rainfall, gives a runoff volume for each area. An event mean concentration (EMC) for each land use is applied to the runoff to obtain an annual loading rate for two parameters, Total Suspended Solids (TSS) and Total Phosphorus (TP). The significance of these parameters is discussed below:

- TSS is used as the basis for SWM facilities design in the *Storm Water Management Planning and Design Manual*, with the Levels of Protection for fisheries made equivalent to specific performance for long-term TSS removal; and
- Phosphorus is an ideal parameter to consider cumulative impacts of development on the watershed, both because of its impact on stimulating excessive algal growth causing

reduced dissolved oxygen and impaired aesthetics. Because TP consistently exceeds the PWQO in the North Oakville Creeks Subwatershed, a control target can be adopted based on the *MOE Surface Water Management Policy 2*.

The loadings can then be reduced by control measures and a revised overall pollutant load calculated for all the management areas. The quantitative review of the loadings derived from changes in land use and implementation of control measures can provide input to planning decisions on development and control measures.

5.7.3 Land Use

Land uses for each management area were derived from Geographical Information System (GIS) maps provided by the Town of Oakville. The existing land use designations are provided in **Table 5.7.1**, and future land use in **Table 5.7.2**.

Table 5.7.1
Existing Land Use

Land Use and Subwatershed Areas	Total	Wetland	Agriculture	Wood	Res/Com
	Ha	ha	ha	ha	ha
1. Joshua's Creek	1055.34	23.54	822.61	130.32	78.88
2. East Morrison Creek	340.63	8.99	254.47	42.15	35.02
3. West Morrison, Munn's, Shannon's, and Osenego Creeks	418.19	10.65	327.18	39.90	40.46
4. East Sixteen Mile Creek	592.66	5.23	253.49	257.72	76.22
5. Sixteen Mile Creek	336.93	6.93	294.88	23.66	11.45
6. McCraney, Taplow, and Glen Oak Creeks	202.36	2.11	194.90	4.83	0.52
7. Fourteen Mile Creek	1135.62	14.73	960.91	123.73	36.25
Total	**4081.72**	**72.16**	**3108.45**	**622.30**	**278.80**

Note that only 276 ha, or about 7%, of the land is considered currently developed (not including highways and roads).

Table 5.7.2
Future Land Uses

Land Use and Subwatershed Areas	Total	Wetland	Agriculture	Wood	Residential	Ind/Com
	ha	ha	ha	ha	ha	ha
1. Joshua's Creek	1046.59	22.26	257.82	119.23		274.55
2. East Morrison Creek	336.48	8.45	19.60	43.59	246.03	18.80
3. West Morrison, Munn's, Shannon's, and Osenego Creeks	4Fourteen.13	15.50	62.70	46.24	239.67	133.24
4. East Sixteen Mile Creek	585.13	4.01	5.27	255.44	274.18	46.23
5. Sixteen Mile Creek	344.28	10.02	169.95	46.28	60.21	134.23
6. McCraney Creek, Taplow Creek, and Glen Oak Creek	202.45	1.61	43.43	1.50	53.89	45.89
7. Fourteen Mile Creek	1132.82	15.90	713.94	119.64	2.55	280.79
Total	**4061.86**	**77.76**	**1272.71**	**631.92**	**876.52**	**933.72**

Note: Differences in land use between Tables 5.7.1 and 5.7.2 area are attributed to exclusion of some road areas in the Future Land Uses table.

5.7.4 Runoff and Water Quality

The estimates of runoff coefficients and the EMCs for TSS and TP for each land use are presented in **Table 5.7.3.** TSS values range from 10 mg/L to 150 mg/L, with TP levels two orders of magnitude less ranging from 0.12 to 0.36 mg/L. The total annual rainfall for Oakville used in the model is 800 mm.

Table 5.7.3
Runoff Coefficients and Parameter Concentrations

	Impervious Area		**Pervious Area**			**Event Mean Concentrations**	
Land Use Type	**Impervious Area %**	**Runoff Coefficient**	**Pervious Area %**	**Runoff Coefficient**	**Combined Runoff Coefficient**	**Suspended Solids - mg/L**	**Total Phosphorus mg/L**
Wetland	1	0.95	99	0.1	0.109	10	0.12
Agriculture	3	0.95	97	0.275	0.295	100	0.2
Woodlot	3	0.95	97	0.15	0.174	70	0.2
Residential/ Commercial	30	0.95	70	0.25	0.460	91	0.36
Residential Med. Density	50	0.95	50	0.3	0.625	91	0.36
Ind/Comm	80	0.95	20	0.3	0.820	70	0.3
Baseflow						10	0.06

Source: http://www.halton.ca/ppw/PlanningRoads/Transp/RoadSalt/default.htm

5.7.5 Control Measures

Three types of control measures can be applied in the model:

- A source control BMP such as street sweeping, catch basin cleaning or fertilizer use reductions. This is applied as a reduction in the EMC on a land use basis;
- Infiltration measures, such as ex-filtration systems in the conveyance system, bioinfiltration or end-of-pipe measures. This is applied as a reduction in runoff flow volume with an equivalent reduction in loading; and
- End-of-pipe water quality control measures, such as wet ponds, dry ponds, wetlands, or oil-grit separators (OGS). These are applied as a reduction in loading related to the efficiency of the measure for that parameter. Where multiple facilities service a land use type in a management area, an area-weighted efficiency is calculated.

All measures can be applied to only a portion of the land use area. In this study, only end-of-pipe measures have been evaluated in the scenarios described below. Other control measures can be assessed in further applications of the model.

Efficiencies of the end-of-pipe measures are given in **Table 5.7.4.**

Table 5.7.4
Control Measure Efficiencies

North Oakville SWM Plan

LEVEL	**TOTAL SUSPENDED SOLID REMOVAL %**	**TOTAL PHOSPHORUS REMOVAL %**
Wet Pond Level 1	80	65
Wet Pond Level 2	70	57
Wet Pond Level 3	60	50
Dry Pond	40	20
OGS	60	30

Source: *Toronto Wet Weather Flow Management Master Plan* (July, 2003)

5.7.6 Management Scenarios

The loading scenarios modelled consist of “Base Scenario” and “Existing Land Uses Development”. The following scenarios are provided for comparison purposes. Loadings and runoff volume are estimated in **Table 5.7.5.**

Table 5.7.5
Base Scenario - Existing Development

Management Area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Total Runoff Volume 1000 m^3	2,389	781	968	1,219	763	462	2,540	9,123
Runoff percent of Precipitation	28.84	29.23	29.49	26.21	28.85	29.08	28.49	28.47
Runoff as mm	226.4	229.4	231.5	205.7	226.5	228.3	223.6	223.5
TSS Load - tonnes/yr	229.2	74.6	93.0	108.5	74.4	45.8	246.6	872.2
TP Load - tonnes/yr	0.522	0.176	0.216	0.288	0.159	0.093	0.528	1.981

Scenario 1 - Future Development Uncontrolled

This shows the change in land use is affected by increasing runoff volumes by 75%, TS and TP loadings indicated in **Table 5.7.6.** Note that runoff volume increases from 28.5% of rainfall to 50% as a result of increased imperviousness of roadways, parking lots, and roof surfaces. The TSS load and TP loads increase by 53% and 141% respectively, due to the increase in runoff and the change in concentration of the runoff.

Table 5.7.6
Future Scenario 1 - Development with Uncontrolled Stormwater

Management Area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Total Runoff Volume 1000 m^3	4375.36	1,440	2,255	2,007	1,625	664	3,652	16,019
Runoff percent of Precipitation	52.81	53.86	68.70	43.15	61.44	41.79	40.96	49.99
% Increase over Base	83.1	84.3	133.0	64.6	113.0	43.7	43.8	75.6
Runoff as mm over each area	414.59	422.83	539.28	338.69	482.32	328.06	321.55	392.45
TSS Load - tonnes/yr	361.47	127.1	186.1	168.9	131.3	55.0	304.7	1334.5
% Increase over Base	57.7	70.4	100.1	55.7	76.4	19.9	23.6	53.0
TP Load - tonnes/yr	1.343	0.493	0.724	0.646	0.458	0.205	0.912	4.780
% Increase over Base	157.3	180.1	234.8	124.7	188.5	120.9	72.8	1411.3

Scenario 2 - Future Scenario with SWM

This gives results with the same land uses as shown for Scenario 1, but with SWM ponds included for the new urban developments to enhanced level of control for enhanced fishery protection (80% TSS removal and 65% TP removal) (**Table 5.7.7**). This is considered appropriate for possible consideration as a control level to be implemented in at least some of the catchments given the type of fishery present and the concern for TP loadings to the Lake Ontario shoreline of Oakville. Note that with controls, the TSS levels are reduced somewhat over the pre-development condition, while the TP levels are still marginally above the pre-development condition.

Table 5.7.7
Future Scenario 2 - Development with Stormwater Controlled To Level 1

Management Area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Total Runoff Volume 1000 m^3	4375.36	1440.29	2255.20	2007.29	1425.07	663.87	3651.61	14,019
Runoff percent of Precipitation	52.81	53.86	68.70	43.15	61.44	41.79	40.96	49.99
% Increase over Base	83.1	84.3	133.0	64.6	113.0	43.7	43.8	75.6
Runoff as mm over each area	414.59	422.83	539.28	338.69	482.32	328.06	321.55	392.45
TSS Load - tonnes/yr	129.37	32.4	52.5	54.3	61.4	19.2	202.6	551.8
% Increase over Base	-43.6	-56.5	-43.6	-49.9	-17.5	-58.2	-17.8	-36.7
TP Load - tonnes/yr	0.570	0.187	0.281	0.273	0.220	0.085	0.557	2.174
% Increase over Base	9.3	6.1	30.2	-4.9	38.8	-8.1	5.4	9.8

5.8 STREAM MORPHOLOGY

A fluvial geomorphological assessment of the catchments was performed to assess any potential impacts or effects from proposed development on the stream systems of the study area. The assessment included calculating drainage densities for the low order or headwater tributaries, rapid stream assessments, reach delineation and characterization, and a meander belt width determination for each reach. This information was then used to identify sections of stream that were representative of conditions within the study area and derive erosion thresholds for such reaches. Based on the integration of all of this information, a constraint matrix was derived. The enhancement potential for each reach was also identified.

5.8.1 Headwater Function/Evaluation

Stream Classification

Each of the tributary channels that form part of the drainage network in the catchments was classified using rapid stream assessments. As reported in **Sections 4E** and **4W**, these assessments provide a relative indication of stream health and stability, in addition to identifying the active geomorphic processes affecting each channel. This, in turn, offers insight into the sensitivity of a channel to changes in land use and flow regime. To facilitate the rapid assessment, streams were divided into reaches (**Figures 4E.8.1** and **4W.8.1)**. It should be noted that the channels shown in **Figures 4E.8.1** and **4W.8.1** were delineated for the purposes of the geomorphic assessment. A reach displays similarity with respect to its physical characteristics such as channel form, function and valley setting. Reach delineation considers sinuosity, gradient, local geology, hydrology, land use, degree of valley confinement and vegetative controls (PARISH Geomorphic Ltd., 2001b). The sensitivities of each system are addressed further in the threshold analysis discussion (**Section 5.8.3**).

Each of the reaches defined for North Oakville were assigned an Overall Geomorphology Classification in **Appendix X**. High Geomorphic Classifications were given to reaches that were determined to be high quality resources based on channel form and function. Medium Geomorphic Classification refers to channels which may or may not have a well defined morphology but do maintain geomorphic function and have the potential to be rehabilitated. Channels that were first order streams and characterized as swales were given a Low Geomorphic Classification because they lacked defined banks and beds. These were based on the nine stream characteristics (also in **Appendix X**) which were qualified through stream walks and RGA and RSAT observations.

While most of the reaches were moderately degraded, they present good opportunities for stream enhancement due to the quality of the surrounding environment. However, through completing this assessment process, several tributaries were easily identified as being more sensitive and providing more physical functions to the overall channel system. The ultimate result was a categorization of each tributary into an overall geomorphic rating, which can then be adapted and applied to the management strategy with respect to the amount of protection required.

Drainage Densities

The North Oakville area comprises the headwaters of several watersheds. These headwater areas include numerous low-order channels which can easily be altered by land use changes such as urbanization. The calculation of drainage densities is useful in evaluating basin functions and provides an opportunity to assess the cumulative effects of land use change on low-order tributaries. To provide insight into the basin functions within the headwaters of North Oakville, drainage densities were calculated for the headwater subcatchments. Drainage density (*i.e.,* total stream length per unit area) provides a rapid measure that reflects the factors controlling surface runoff (Chorley, 1969). Controlling factors of drainage density can be grouped as direct and indirect. Climate and geology provide a direct control while indirect factors include (but are not limited to) basin area, shape and relief. For example, areas with poor drainage, due to relatively impermeable soils, should have higher drainage densities due to lack of infiltration. For comparison, drainage densities were calculated for the headwater tributaries of two other local subwatersheds which both share similar climate and geology. **Table 5.8.1** provides subcatchment drainage density calculations for the North Oakville Creeks Subwatershed. As illustrated in **Table 5.8.2**, results of the drainage density comparison show that the regional average drainage density for the North Oakville Creeks Subwatershed falls just slightly above those noted in other headwater systems.

In general, the results indicated that most of the low order headwater streams of North Oakville fell into two main categories: low order, low gradient swales and steep gully channels. The former grouping was associated primarily with agricultural land use but also formed in more naturalized areas. These channels had poorly defined bed morphology and were often previously straightened. The latter category of streams, meanwhile, tended to feed the larger systems such as Joshua’s Creek and Sixteen Mile Creek. Streams in this category were often associated with exposure of underlying bedrock or till, and were characterized by well developed, steep valleys.

While many of the low order tributaries within the study area are ephemeral swales influenced by agricultural land use, the role of these channels in the overall function of the system should not be discounted. Swales play an important role in the conveyance of sediment and the retention and conveyance of flow within a drainage network. Consequently, although each individual swale may not make a significant contribution to the subwatershed system, the cumulative impact of swales is extremely significant. Although many of the minor swales were designated a low rating from a geomorphic standpoint, a portion of these swales may be maintained through drainage density targets based on the regional average. The results of the tributary evaluation can be combined with the hydrologic and aquatic information in order to develop an overall classification system for stream management.

Table 5.8.1
Subcatchment Drainage Densities for North Oakville Creeks Subwatershed

Subcatchment	Drainage Area (km^2)	Stream Length (km)	Drainage Density (km/km^2)
EM1	1.88	12.09	6.45
EM2	0.15	2.15	14.72
EM3	0.29	4.60	15.71
EM4	1.11	4.34	3.92
ES1	0.49	7.40	14.96
ES2	0.39	3.66	9.33
ES3	0.17	2.29	13.42
ES4	0.83	12.39	14.89
ES5	1.68	6.95	4.13
ES6	1.34	10.91	8.16
ES7	0.26	1.96	7.61
ES8	0.46	2.19	4.77
ES9	0.23	0.49	2.09
FM1001	1.49	5.36	3.59
FM1002	0.29	1.85	6.32
FM1003a	0.98	3.93	4.00
FM1003b	0.27	1.11	4.05
FM1004	0.22	0.64	2.97
FM1005	0.09	0.76	8.82
FM1006	0.23	1.75	7.58
FM1007a	0.51	0.99	1.94
FM1007b	0.18	1.24	6.82
FM1007c	0.66	2.75	4.17
FM1007d	0.27	1.92	7.00
FM1008	0.05	0.48	9.02
FM1009	0.60	2.37	3.94
FM1010	0.81	10.76	13.31
FM1011	0.07	0.48	6.69
FM1104	0.55	3.05	5.53
FM1105	0.44	2.85	6.55
FM1106	0.12	0.32	2.72
FM1107	0.18	2.41	13.29
FM1108	0.46	5.15	11.14
FM1109	0.23	1.43	6.36
FM1110	0.44	2.14	4.81
FM1111	0.99	6.62	6.72
GO1114	0.52	3.54	6.75
JC1	0.14	1.85	12.89
JC10	0.49	5.58	11.46
JC11	0.09	2.12	23.35
JC12	0.23	1.59	6.90
JC13	0.28	2.15	7.56

Table 5.8.1
Subcatchment Drainage Densities for North Oakville Creeks Subwatershed

Subcatchment	Drainage Area (km^2)	Stream Length (km)	Drainage Density (km/km^2)
JC14	0.48	1.94	4.01
JC15	0.39	1.95	4.97
JC16	0.77	7.95	10.29
JC17	1.14	6.60	5.77
JC2	0.06	0.74	11.63
JC3	0.18	1.39	7.76
JC4	0.17	1.06	6.29
JC5	0.37	4.42	11.95
JC6	0.33	3.88	11.87
JC7	0.99	6.11	6.18
JC7b	0.64	5.90	9.21
JC8	0.37	2.59	7.00
JC8b	0.28	2.12	7.62
JC9	1.52	6.52	4.29
MC1	0.64	4.60	7.19
MC1012	0.32	2.17	6.87
MC1114	0.90	6.47	7.17
MC2	0.25	0.66	2.62
OC1	0.39	2.91	7.53
SC1	0.97	4.93	5.06
SM1020	1.18	7.98	6.77
SM1021	0.27	0.62	2.31
SM1117	0.92	5.32	5.76
TC1115	0.33	2.45	7.50
WM1	1.47	11.40	7.77
WM2	0.56	2.20	3.90

Table 5.8.2
North Oakville Creeks Subwatershed Drainage Density Comparison

	Subwatershed Drainage Densities		
	North Oakville	**Sheldon Creek**	**Sawmill Creek**
Average	7.58	6.34	4.78
Range	1.94-23.34	3.43-11.66	3.93-5.64

Meander Belt Widths

A meander belt width defines the area that a watercourse currently occupies or can be expected to occupy in the future. Meander belt width delineation is commonly used as a planning tool in order to protect private property and structures from erosion due to fluvial action or geotechnical instability (Parish Geomorphic Ltd., 2001a). Within a subwatershed context, studies require the general identification of meander belt widths to facilitate the planning process (**Tables 5.8.3** and **5.8.4**). For the purposes of this study, meander belt widths were measured using digital and topographic mapping (scale of 1:5000). **Figure 5.8.2** shows the meander belt widths for the various reaches. For unconfined channels, limits of the meander belt are defined by parallel lines drawn tangential to the outside bends of the largest amplitude meander in the planform for each reach. In the majority of cases, the meander belt width for a channel is smaller than the floodplain. In general, the lower order headwater tributaries all had minimal corridor widths of 25m due to their unconfined, poorly developed nature. Meander belt widths increased in the downstream direction as streams widened and increased their sinuosity, creating better developed floodplains and increasing sediment storage.

Table 5.8.3
Meander Belt Widths for Reaches East of Sixteen Mile Creek

North Oakville Creek		Reach	Meander Belt Width (m)
Sixteen Mile Creek	***A***	SMA-1	25
		SMA-2	45
		SMA-3	25
		SMA-4	40
		SMA-5	20
		SMA-6	45
		SMA-7	35
		SMA-8	15
		SMA-9	15
	B	SMB-1	30
		SMB-2	35
		SMB-3	45
		SMB-4	35
	C	SMC-1	35
		SMC-2	35
		SMC-3	25
Shannon’s Creek		SCH-1	25
		SCH-2	25
Munn’s Creek		MUN-2	35
		MUN-3	25
Morrison Creek	***West***	MOC-W1	45
		MOC-W2	35
		MOC-W3	30
		MOC-W5	30
		MOC-2	20
		MOC-4	45
		MOC-6	35
Joshua’s Creek		JC-1	45
		JC-2	45
		JC-3	35
		JC-4	35
		JC-5	35
		JC-6	30
		JC-7	20
		JC-8	25
		JC-9	25
		JC-12	20
		JC-13	30
		JC-14	25
		JC-19	30
		JC-20	20
		JC-20A	20
		JC-22	40
		JC-27A	30
		JC-36	30

Table 5.8.4
Meander Belt Widths for Reaches West of Sixteen Mile Creek

North Oakville Creek		**Reach**	**Meander Belt Width (m)**
Fourteen Mile Creek	***West***	14W-1	40
		14W-1A	40
		14W-2	40
		14W-3	40
		14W-4	30
		14W-9	30
		14W-9a	20
		14W-10	20
		14W-11	20
		14W-11a	20
		14W-12	25
		14W-14	15
		14W-16	15
		14W-17	15
		14W-17a	15
Fourteen Mile Creek	***East***	14E-1	40
		14E-2	40
		14E-2a	30
		14E-3	40
		14E-3a	40
		14E-6	40
		14E-7	40
		14E-8	20
Sixteen Mile Creek	***West***	16W-1	30
		16W-2	40
		16W-3	40
		16WA-1	45
		16W-8a	20
Glen Oak Creek		GO-1	15
McCraney Creek		MC-1	55
		MC-4A	20

5.8.2 Monitoring

As part of the detailed field assessment, control cross-sections were established at JC-3, JC-13, SMA-4, MOC-4, 14W-1, 14W-7 and 16WA-1. Locations for the detailed work were decided based on results from the rapid stream assessment in combination with the goal of providing measurements from a range of channel types and broad spatial coverage of the study area. These sites have since been revisited and the control cross-sections and erosion pins re-measured. Data gathered from monitoring the control cross-sections allows for the identification of changes in channel form and overall cross-sectional area over time. This information provides insight into long-term trends in channel geometry.

At monitoring cross-section JC-3 (**Figure 5.8.3)**, there was a general increase in cross-sectional area due to channel lowering across the bar and pool. Little evidence of channel widening was observable. As such, the changes noted at JC-3 were not excessive and may simply be associated with local channel adjustment (*i.e.,* bar development). At JC-13 (**Figure 5.8.4**), little change in cross-sectional area or form was observed. Consequently, neither channel widening or lowering had occurred. At SM-4 (**Figure 5.8.5**) there was minimal infilling between June of 2002 and July of 2003, and there was no evidence of channel widening. Unfortunately, the monitoring cross-section at MOC-4 was lost and needed to be re-established. Overall, the monitoring sites showed little change in cross-sectional area or form over the period of monitoring.

West of Sixteen Mile Creek, the monitoring cross-section on 14W-1 (**Figure 5.8.6**) indicated very little overall change with the exception of some minor changes in the left bank. While results for the detailed site on 14W-7 (**Figure 5.8.7**) initially appear to indicate aggradation, the change is too uniform and more likely reflects a difference in tape tension across the transect. Consequently, this cross-section has experienced little change. At 16WA-1 (**Figure 5.8.8**), meanwhile, channel adjustment resulted in an overall decrease in cross-sectional area over the monitoring period.

Erosion pins provide information regarding rates of bank erosion. Bank erosion rates are a product of channel migration and channel widening. Erosion pins were installed along the length of each detailed field site in combination with the control cross-sections (**Appendix DD**). Overall, erosion rates were generally low, ranging from no change to 12 cm/yr. Results from North Oakville east of Sixteen Mile Creek indicate that erosion is the primary geomorphic process affecting the sites, with the highest rates noted at JC-3. This fits well with the observations made at the control cross-section which suggests the occurrence of local channel adjustment. Results from the detailed field sites west of Sixteen Mile Creek confirm that little change has occurred over the monitoring period. At both 14W-1 and 14W-7, only one pin recorded change in the form of deposition at 0.12 and 0.08 m/yr, respectively. At 16WA-1, erosion was recorded along the right bank at a rate of 0.04 m/yr near the monitoring cross-section. In general, these measurements indicate that the channels are reasonably stable with respect to both cross-section and planform.

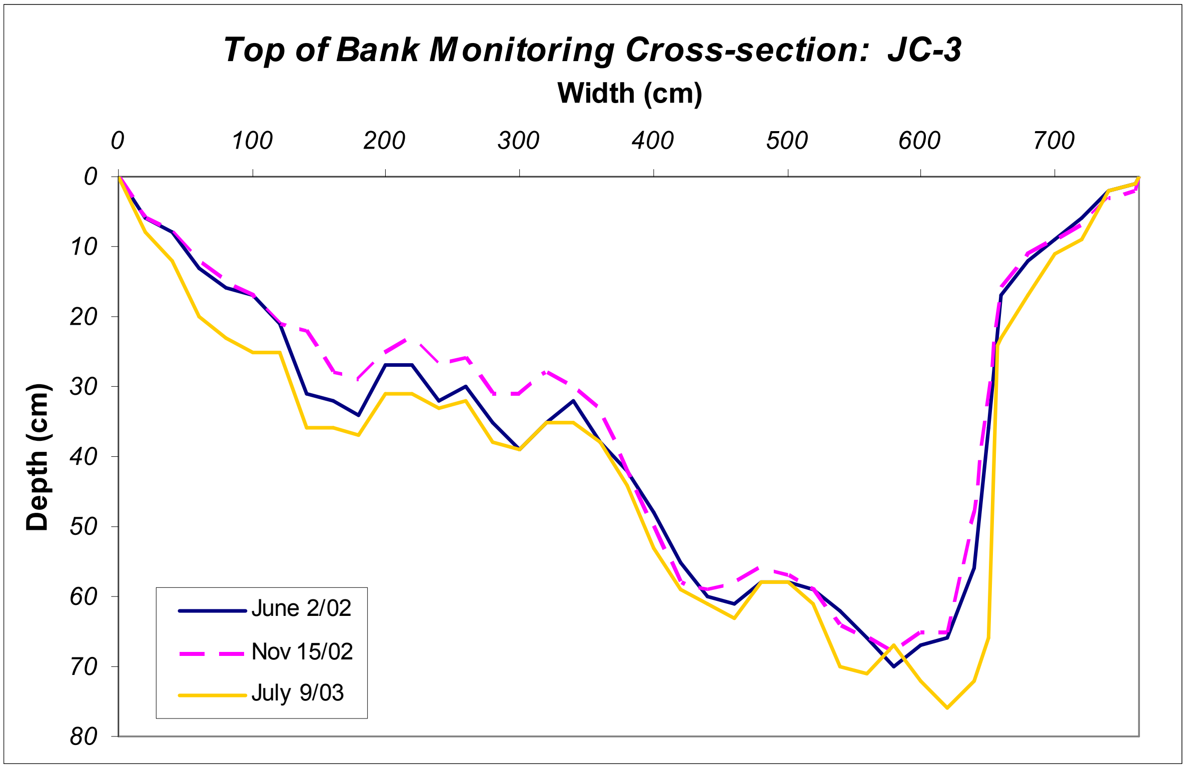


Figure 5.8.3 Monitoring Cross-Section Results for JC-3.

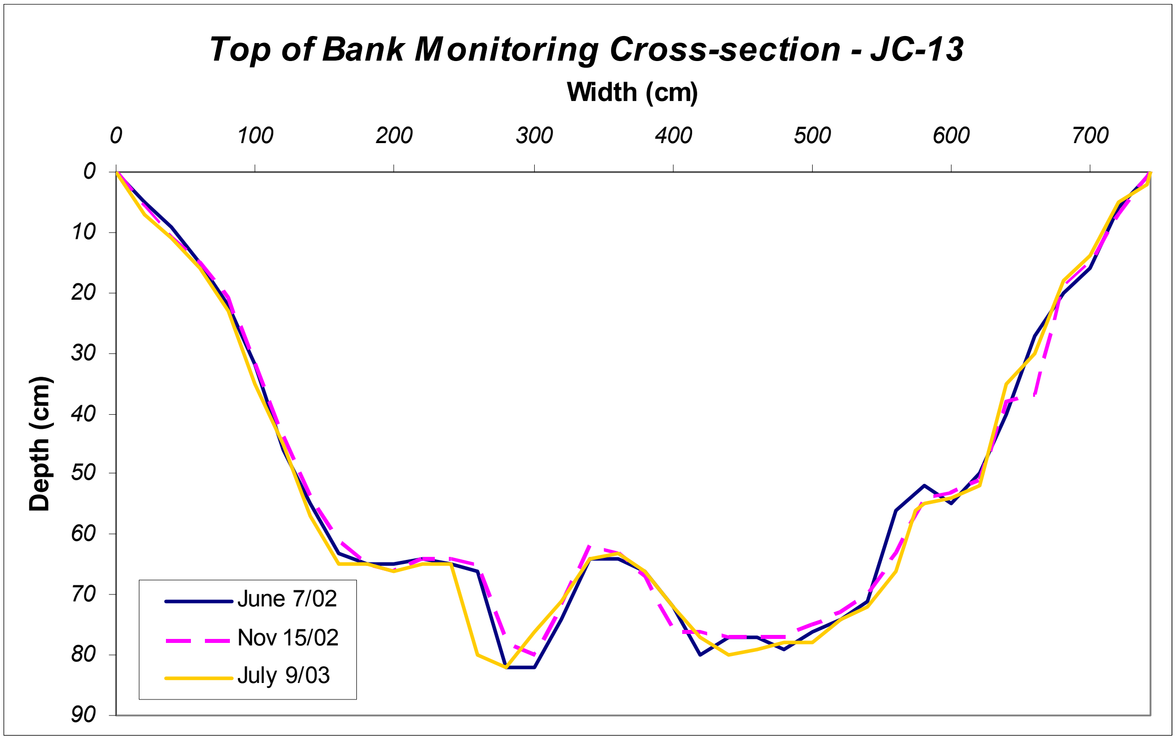


Figure 5.8.4 Monitoring Cross-Section Results for JC-13.

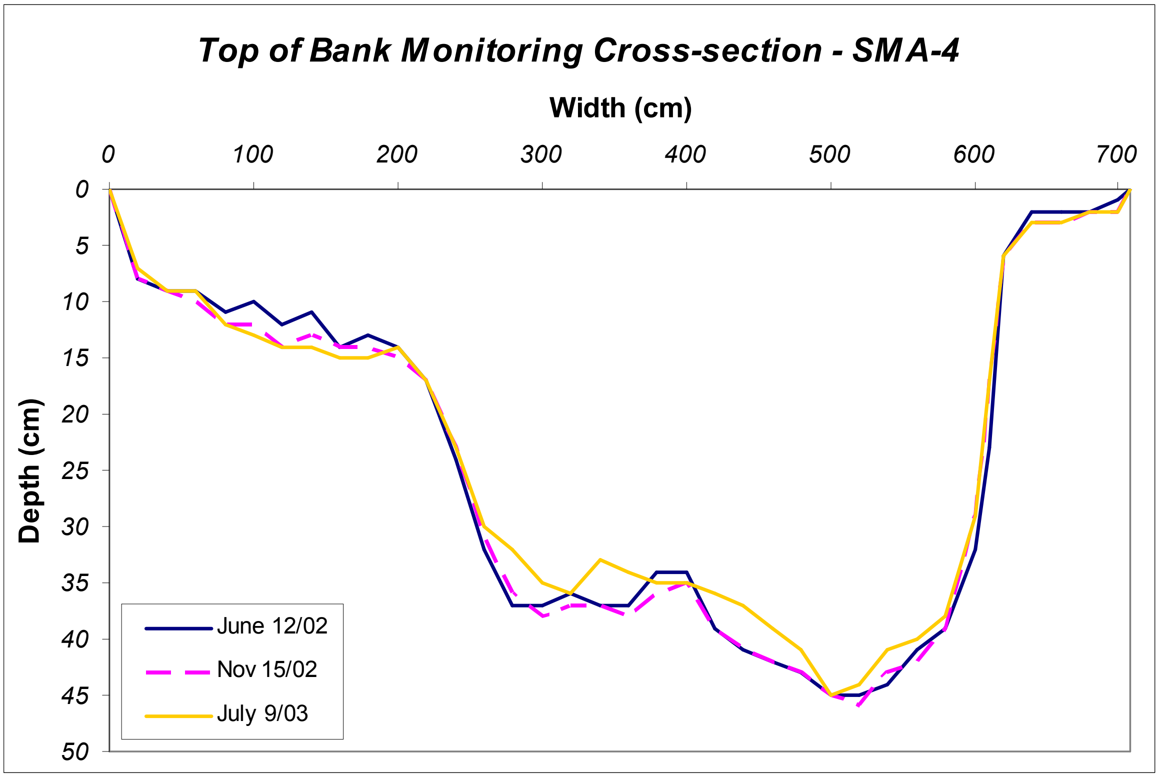


Figure 5.8.5 Monitoring Cross-Section Results for SMA-4.

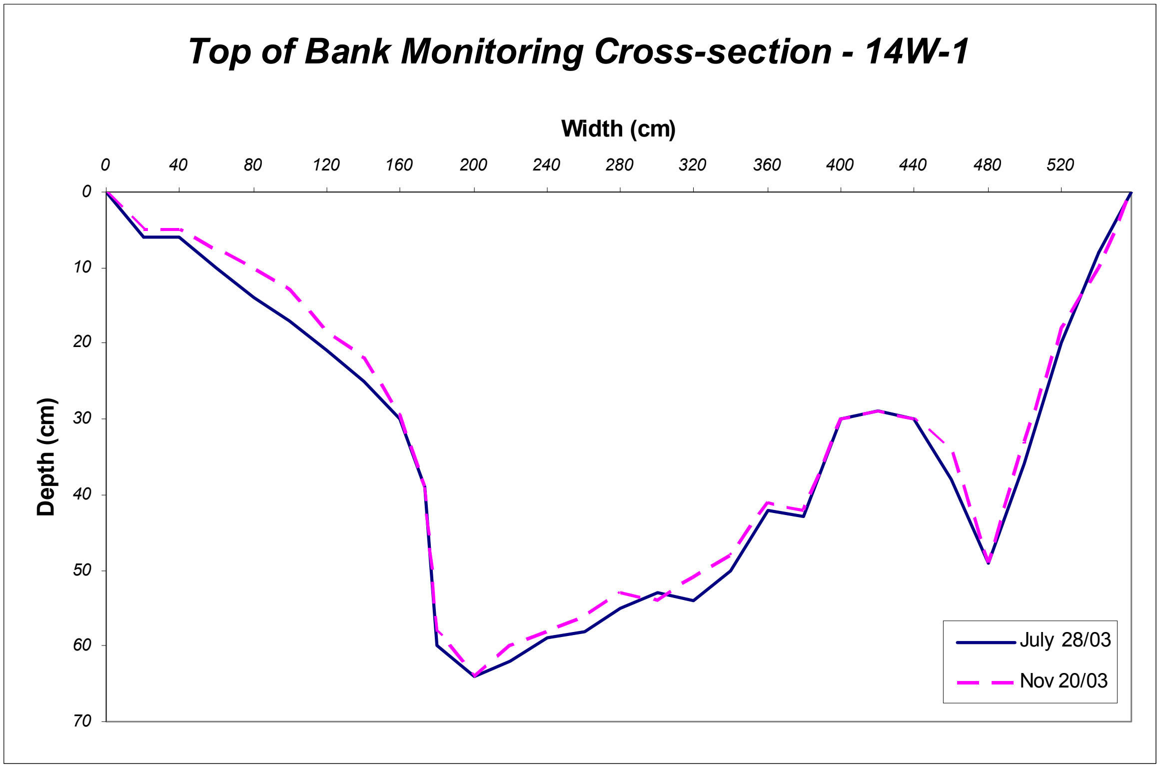


Figure 5.8.6 Monitoring Cross-Section Results for 14W-1.

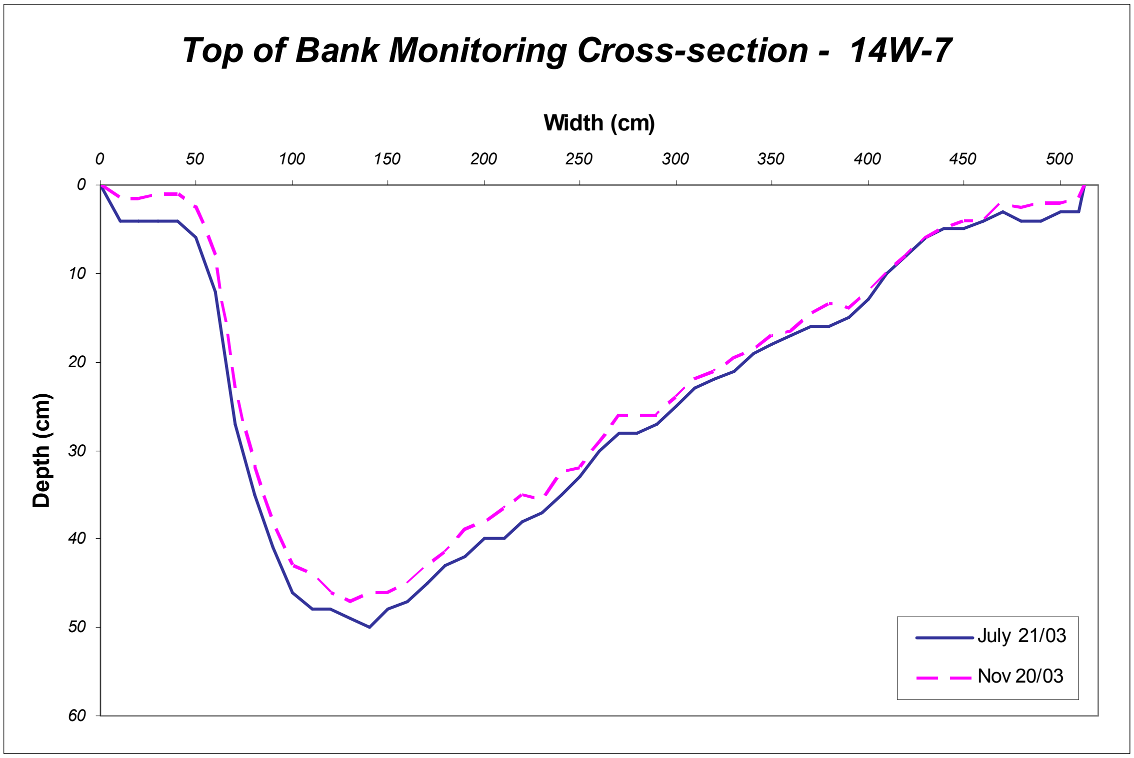


Figure 5.8.7 Monitoring Cross-Section Results for 14W-7.

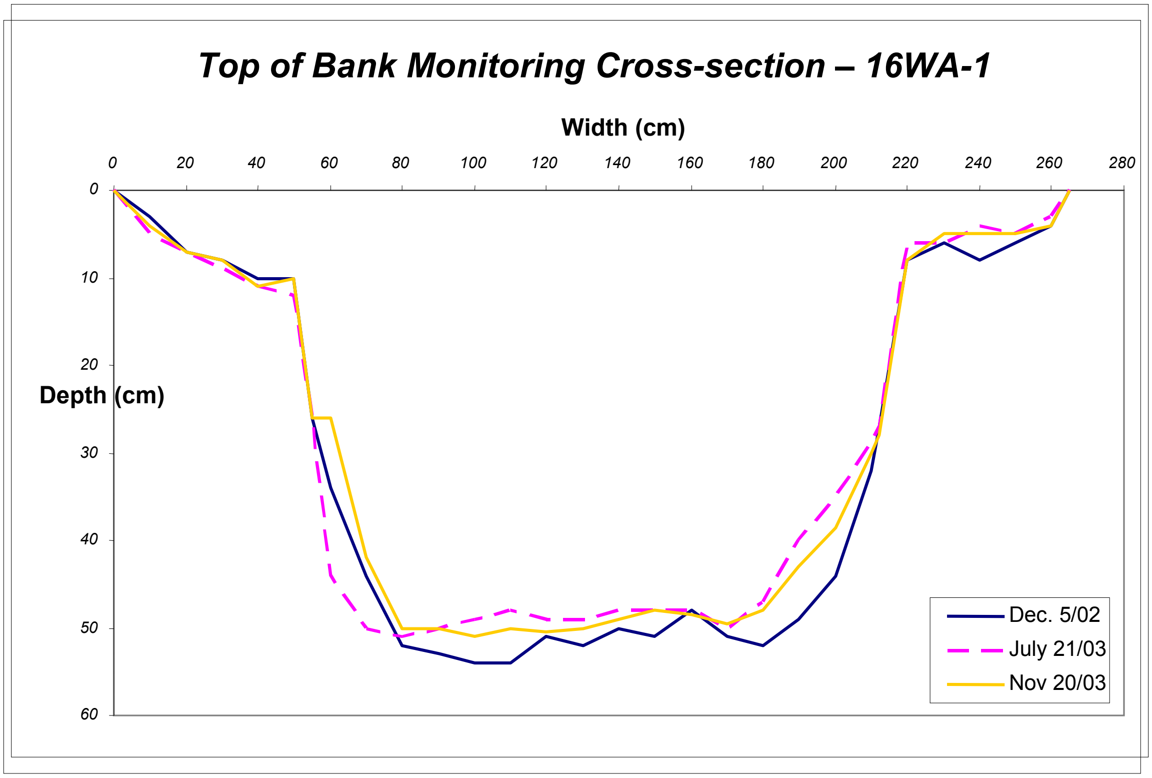


Figure 5.8.8 Monitoring Cross-Section Results for 16WA-1.

5.8.3 Channel Thresholds

The collection of detailed field information is pertinent to modelling erosion thresholds. An erosion threshold represents the point at which sustained flows will tend to entrain and transport sediment. The calculations performed to determine critical discharge for bed materials were based on formulas for critical shear stress. Selection of appropriate thresholds was, in part, dictated by indicators of active processes (*e.g.,* widening or entrenchment), and channel substrate. Multiple analytical methods (*e.g.,* critical shear and threshold velocity models) were applied to the data to define threshold flows for the bed and banks of the sensitive reaches. The model results were examined for convergence and compatibility with field observations to provide appropriate and meaningful erosion thresholds.

Shear stress equations for non-cohesive materials were applied to the bed materials (Chow, 1959; Miller *et al.*, 1977; Fischenich, 2001). The erosion thresholds were based on the threshold for the D_{50} (median grain size). If a large portion of the bed material was cohesive and the erosion threshold associated with cohesive component was greater than the threshold associated with the D_{50}, then the cohesive materials estimated shear strength was used to provide a characteristic threshold. These thresholds were based on tables provided in Chow (1959) and Fischenich (2001). The shear stress equation from Miller *et al.* (1977) was applied to sites with non-cohesive bed materials. This was the case for all the erosion thresholds provided. If there was evidence of excessive bank erosion, a threshold related to the bank material was also calculated. The relative proportion of bank shear stress to the maximum shear stress was calculated. Threshold depths were based on this proportion. The lower of bank and bed threshold (or more conservative measure) was used to define the critical threshold for the channel. In this case, similarity in bed and bank materials and the prevalence of till or stiff clay in the banks meant that bed shears were always the more conservative.

As many of the models are based on a simplified cross-sectional geometry, a single characteristic riffle cross-section was extracted from each detailed site for threshold analysis. The depth and the corresponding simplified geometry were used to produce a meaningful threshold. In all cases, a comparison between the flow competence (based on non-cohesive strength) and bankfull velocity indicates that the bed is fully mobilized around bankfull flows. This implies that sediment can be entrained below bankfull flows and that any increase in discharge within these systems will lead to increased transport and would likely exacerbate channel erosion. Development of the North Oakville area will alter the sediment and flow regimes of the systems downstream of Dundas Street. Consequently, an appropriate performance target must consider these downstream reaches and should be identified based upon the most conservative threshold for each system. If thresholds for the reaches downstream of Dundas Street prove more conservative than those stated for the study area, the downstream threshold would then provide the overall performance target for the system. **Table 5.8.5** provides both bankfull characteristics and erosion threshold parameters.

Table 5.8.5
North Oakville Creeks Subwatershed Erosion Threshold Values

PARAMETER	14W-1	16WA-1	14W-7	MOC-4	SMA-4	JC-13	JC-3
Average Bankfull Width (m)	3.81	1.87	2.65	3.14	4.58	2.92	4.99
Average Bankfull Depth (m)	0.34	0.26	0.17	0.26	0.26	0.24	0.31
Bankfull Gradient (%)	0.18	0.66	0.52	0.60	0.55	0.65	0.70
Bed Material D_{50} (m)	0.00006	0.0036	0.0036	0.0000052	0.0029	0.00083	0.0056
Bed Material D_{84} (m)	0.015	0.035	0.011	0.0053	0.027	0.0085	0.044
Manning's n at Bankfull	0.035	0.035	0.035	0.033	0.033	0.030	0.032
Average Bankfull Velocity (ms^{-1})	0.59	0.95	0.63	0.96	0.92	1.04	1.18
Average Bankfull Discharge (m^3s^{-1})	0.76	0.46	0.28	0.78	1.09	0.73	1.82
Flow competence (ms^{-1}) @ D_{50}	–	0.36	0.54	0.018	0.32	0.18	0.44
Flow competence (ms^{-1}) @ D_{84}	0.69	0.73	0.61	0.43	0.90	0.53	1.13
Tractive Force at Bankfull (Nm^{-2})	6.00	16	8.88	15.30	14.03	15.30	21.29
Critical Shear (Nm^{-2})	4.80[†]	7.70[*]	7.70[*]	7.20[*]	2.11	4.80[†]	4.08[†]
Stream Power per Unit Width (Wm^{-2})	13.50	29.75	14.52	14.63	12.84	15.88	25.08
Critical Depth (m)	0.27	0.12	0.15	0.12	0.04	0.07	0.06
Method	**Chow (1959)**	**Chow (1959)**	**Chow (1959)**	**Chow (1959)**	**Miller**, *et al.* **(1977)**	**Chow (1959)**	**Chow (1959)**

[†] Loose to consolidated sandy clay to clay [*] Moderately compact clay-rich materials

5.9 TERRESTRIAL RESOURCES

This analysis of terrestrial resources includes wetland and upland vegetation features. In **Sections 4E.9** and **4W.9**, areas of contiguous natural vegetation ('habitat units') were used as the basis for species inventories. These units, in conjunction with open fields, hedgerows, and landscaped areas, were used to record plant and wildlife species at the catchment level. The following discussion includes analyses at the habitat unit level, as well as habitat-types such as wetlands, upland forest, and early successional areas.

A number of different systems are available to characterize and in many cases, and provide guidance to the analysis of vegetation features (especially wetlands and woodlands). Pertinent references include the *Provincial Policy Statement* (especially with respect to significant woodlands, and significant wildlife habitats), the Halton Region ESA and Significant Woodland criteria. Generally these systems, and others, are based on many similar factors, and strive to rank or create a hierarchy of habitat areas based on criteria. Based on a review of these documents, a series of factors were identified and are discussed below relative to the vegetation and wildlife characteristics within the study area.

Table 5.9.1 includes a summary of all of the habitat units identified in **Sections 4E.9** and **4W.9** based on the following factors.

Presence of Designated Area

This factor focuses on habitat units that have been identified through other systems. The first is ESA by Halton Region. At this time, none of the areas in the study area have been identified as ESA with the exception of the Sixteen Mile Creek Valley (see discussion below under Sixteen Mile Creek ANSI). The Region of Halton is currently undergoing an update study of the ESAs within the Region, but at the time of preparing this report this update had not been completed for the study area.

In 2003, the MNR identified a Candidate Life Science ANSI called the Oakville-Milton Wetlands and Uplands Candidate ANSI, which is comprised of 11 separate woodland areas, comprising a total of 290ha. A number of these overlap with the habitat units used in this study (those east of Sixteen Mile Creek; see **Table 5.9.1**). The ANSI units to the west of Sixteen Mile Creek are found north of Highway 407 and are therefore not included in this study area. As well, the MNR (2003) identified the woodlands associated with the Sixteen Mile Creek valley as part of a larger ANSI that extends to the north of Highway 407 as well as south of Dundas Street. The Sixteen Mile Creek ANSI (and ESA) basically coincides with Habitat Unit #3. Habitat Units #5, 8, 9, 10, 11, 12, 13, and 16 overlap with the eastern portion of the Oakville-Milton Wetlands and Uplands Candidate ANSI.

The final habitat unit is the Provincially Significant Wetlands (PSW). As discussed in **Sections 4E.9** and **4W.9**, extensive mapping of wetlands has occurred as part of the Subwatershed Study as well as by staff of the MNR. At the time of preparing this report none of the wetlands in the study area have been formally evaluated by the MNR.

Size

Size is a common factor used in numerous Natural Heritage evaluations. This factor is often cited in combination with shape. Although frequently used when analyzing woodland habitats, these factors also apply to other habitat types such as meadows.

This factor generally includes total area as well as a measure of the amount of potential interior habitat. The extent that edge effects extend into a forest stand varies depending on a number of factors including the character of the existing forest edge, extent of buffering as well as the nature of the edge effect in question. Forest interior functions have been variously stated to be found at differing distances from the forest edge. A number of documents have recommended that forest interior habitats can be found 100, 200, or 300m from the edge. The amount of actual interior habitat is also an important factor.

Woodland size and shape are considerations in the analysis of the woodlands. This relates to the provision of forest interior and the minimization of edges. Dramstad *et al.* (1996) explain the optimum patch shape as having a rounded core for the protection of resources, with some curvilinear boundaries and fingers for species dispersal and interception. Riley and Mohr (1994) give certain shape parameters to correspond with woodlot areas. Generally the forest must be more than 100m wide in all directions for there to be any interior habitat. For woodlands less than 4ha in size, shape is less of an issue, since there is no interior habitat present.

Numerous studies have been completed that have identified the value of larger blocks of woodland in terms of sustainability and provision of habitats. The larger blocks of woodland are necessary to provide the sheltered microclimate that is found within the interior of these woodland stands. Because certain edge effects (such as predation) can extend up to 600m into a forest, Riley and Mohr (1994) present the notion of "mega-woodlands" that are 400ha or larger. Such woodlands, they state, contain enough forest interior to sustain populations and landscape variability. Some others, however, such as Burke (1999), argue for even larger woodlands, reporting that ovenbirds require woodlands larger than 500ha in order to maintain their populations and Environment Canada (2004) recommends that 30% of all watersheds should be in forest with some larger than 200ha. The MNR 'Big Picture Project' (2003) also recommends the inclusion of 200ha woodland patches. No woodlands of this size are found in the study area, with exception of Habitat Unit 3, which is a little over 200ha large. It also extends to the north and south of the study area, making it even larger.

Woodland areas as small as 0.5ha are often identified as the smallest unit, for example in the Halton Tree Cutting Bylaw. Woodlands of this size are shown in the Region of Halton's most recent mapping for their OP review. The MNR (2003) provided mapping of forest cover within the Subwatershed Study area that showed woodland patches of 0.5 ha or larger. The vegetation mapping undertaken as part of his study was fine scaled and ensured that habitat patches of 0.5ha (and in many cases smaller) were identified. In some limited cases, smaller woodland areas mapped by the MNR or the Region of Halton coincided with hedgerow or landscaped areas not mapped in the Subwatershed Study.

Context is often cited as an important consideration. For example, in the *Provincial Policy Statement*, the significance of a habitat area (especially woodland) is considered in light of the existing forest cover within the municipality. Similarly the Halton Region Significant Woodland size criterion differs for lands in urban versus rural areas.

Sizes of the habitat units ranged from the smaller units such as #15 (1.5 ha), and #18 (2.3 ha) to the four largest units: #8 (71.8ha), #21/22 (put together for this characterization, 68.3ha), #16 (46.2ha), and #21 (44.6ha). Habitat Unit 3 (Sixteen Mile Creek) has an area of 215.6ha.

For the most part, the woodland units in the catchments are fairly regular in shape (*i.e.*, rectangular or square shaped). However, in some cases narrow "fingers" of habitat are found. This is particularly noted for Habitat Unit #8 where the eastern end of this area consists of a number of fairly narrow patches. In Unit #16, there are a number of square-shaped blocks connected by narrow woodland areas.

Based on the shape and area of the woodlands, none of the habitat units other than Unit 3 (Sixteen Mile Creek) had forest interior beyond 300 m from the forested edges. Unit #8 had 2.1ha of interior habitat beyond 200m from the edge. Units 1, 2, 5, 8, 9, 11, 12, 13, 14, 16, and 21/22 had interior habitats beyond 100m from the edge. However, of these 11 units, only 3 had interior areas greater than 4 ha (*i.e.,* #8, 16, and 21/22). Although Unit #21/22 is large, it includes considerable areas of early succession thicket which were not included in the analysis of potential forest interior. The largest potential forest interior habitats were found in Habitat Unit #8. Habitat Unit #8 was also one of the few areas that provided more than 4 ha of potential forest interior habitat (at 100 m from the edge only).

These forest interior metrics are in common usage, however recent researchers have found that a network of smaller wooded areas may provide some sustainable habitat for birds that might otherwise require larger single woodlands. Based on the field surveys conducted as part of these studies. A number of forest interior bird species and plant species were noted from the woodlands in the study area despite some of the smaller woodland areas.

Non-wooded, open habitats such as grassland communities provide habitat for a variety of species of wildlife including birds, mammals and insects. Tallgrass communities once covered a significant part of southern Ontario's landscape (Rodger, 1998), however 99.5% of this habitat has been destroyed (Bakowsky and Riley, 1994). As a result, many of the species associated with grasslands have experienced severe population declines. For example, 60% of all grassland landbirds in the lower Great Lakes / St. Lawrence Plain (Bird Conservation Region 13) are conservation priority species (Ontario Partners in Flight, 2005). Grassland habitats constitute the habitat with the largest number of bird species listed as endangered, threatened, or of special concern (Vickery *et al.,* 1994). The decline in native grassland habitats has resulted in many grassland species using structurally similar open habitats such as hayfields and abandoned farm fields and meadows.

The literature on minimum habitat areas for open country birds parallels the research on forest bird species. Many grassland species will not use habitat patches below critical minimum areas even if such areas contain suitable habitat (Van Dyke *et al.*, 2004; Brennan and Kuvlesky, 2005; Johnson and Igl, 2001; Peterjohn, 2003; Bollinger and Gavin, 2004; and Renfrew *et al.,* 2005; Herkert, 1994). As noted above for woodlands, patch-size preference studies have found that the level of habitat fragmentation in the study area may have a considerable influence on patch utilization (Donovan *et al.,* 1997). As well, the type of edge habitat around the grassland (Forman *et al.,* 2002) and abundance of the bird species in the region (Johnson and Igl, 2001; Herkert, 1994) have an influence. Variability in the area-sensitivities reported for particular species in different regions is thought to be a function of regional abundances and may be a local phenomenon (Davis, 2004).

The area required by a particular species can be affected by surrounding land use, edge effects, presence of trees and shrubs, type of vegetative cover, abundance of that species, regional scale fragmentation of habitats and other factors. An additional consideration is the difference between territory size and area requirements. Territory size for many grassland passerines is typically between 1-3ha; however many area-sensitive species have been found to occur only in habitat patches many times greater than their territory size (Vickery *et al*., 1994). General guidelines suggest that grassland reserves should be a minimum of 100ha (Johnson and Winter, 1999) or preferably 200ha to support a diverse grassland fauna (Vickery *et al.,* 1994). However, since Ontario has less grasslands, smaller reserves can play an important role in maintaining grassland species. A number of less sensitive birds have been found to nest in fields approximately 20 to 30ha, but most prefer over 50ha. In general, area sensitive open country birds were found to require a minimum of 50ha, but many prefer as much as 100ha (Environment Canada, 2004; Mass Audubon, 2003). However, grasslands 30ha in size provide habitat for most Ontario grassland mammals (Environment Canada 2004). Raptors require between 10 and 15ha of open country for hunting and wintering, respectively (Mass Audubon, 2003).

Efforts on a regional scale to provide a greater number of smaller patches of differing habitat structure in conjunction with at least one larger patch should be pursued to maintain or increase numbers of grassland birds.

For the most part, thicket or savannah habitats found adjacent to woodlands have been included within the habitat units. This is also the case with some existing meadow habitats. A large meadow habitat is found on the landfill, and another large one is found in the northeast corner of the study area (in the Joshua's Creek catchment). In cases where these habitats are not included in a habitat unit, plant and wildlife species noted from these areas are summarized under the catchment area (under fields, landscaped and other).

Part of Riparian/Drainage System

The relationship between habitat patches and surface/groundwater resources is frequently noted in natural heritage system evaluations. Vegetative cover associated with drainage courses, upland vegetation in proximity to wetlands, and natural cover influences on groundwater resources have been studied by a number of researchers. The relationship of vegetative cover on fluvial processes, erosion, and aquatic habitats are discussed elsewhere in this report. The role of wetlands in terms of hydrology is also discussed elsewhere in this report.

Virtually all of the habitat units were found associated with either drainage courses (based on stream reaches delineated as part of the aquatic/fluvial geomorphology assessment) and/or wetland pockets. Units 9, 10, and 12 were noted to include numerous small wetland pockets.

Groundwater relationships are discussed in **Section 5.5** of this report and are not widespread. Localized groundwater features are found within wooded portions of Joshua Creek

Number of Native Plants and Wildlife

The number of native plant species and wildlife is often used as an indicator of habitat diversity. This is generally a simple tally of native plant species as well as birds, mammals, reptiles, amphibians and other taxa. The abundance of non-native species is also used as an indicator of disturbance.

Table 5.9.1 summarizes the number of native plants and wildlife recorded in the habitat units. The coverage of some of the smaller units likely was less than some of the larger well-studied areas, which may influence the species tallies. Notably high species diversity was found in units 1, 8, 9, 16, and 21/22.

Presence of Rare Species

A summary of rare plants and wildlife is provided in **Sections 4E.9** and **4W.9**. Tables summarizing the presence of rare plant and wildlife species are included in **Appendix EE.** These lists not only include the woodland areas, but also include significant species reported from hedgerows, fields, landscaped and other areas within each subwatershed.

Number of Vegetation Types and Relative Area

This factor focuses on the diversity of vegetation types and presence/relative abundance of mature types (based on Ecological Land Classification (ELC) definitions).

The types and extent of vegetation communities within each habitat unit are shown on the vegetation map (**Figure 4.9.1**). Some of the habitat units (*e.g.,* #15, 18) were comprised of single vegetation types. On the other hand, several units contained over 5 types (especially #1, 2, 7, 8, 9, 10, 11, 12, 13, 16, and 21/22). All habitat units include mature forest.

Presence of Rare Vegetation Community

Vegetation community rarity has become more consistent when standardized methods for describing and categorizing vegetation communities are used. The ELC system was used during this study, which allows comparison of the vegetation to lists of significant vegetation communities developed by the Natural Heritage Information Centre (Bakowsky, 1996).

Two upland communities, Dry-Fresh Oak-Hickory Deciduous Forest Type (FOD 2-2) and Dry-Fresh Hickory Deciduous Forest Type (FOD 2-3), are considered uncommon in Ontario.

A variety of significant wetland communities are known from the study area as well. The MNR identified 3 provincially rare and 19 locally rare wetland types in the North Oakville – Milton Wetlands and Uplands Candidate ANSI (MNR, 2003c). These are listed in **Table 4E.9.7**. Of these, all provincially significant wetland types are represented within the study area, within Habitat Units #12, 13, 14, 16, and 22. Of the locally rare wetland communities, 17 are represented within the study area, many of which are small wetland pockets generally found within larger wooded blocks. The two communities that are not found in the study area are Small's spike rush graminoid shallow marsh and slender willow thicket swamp. Of the locally significant wetland communities within the study area, three types are not found within the habitat units. These are river bulrush graminoid shallow swamp, watermeal herbaceous shallow marsh, and star duckweed herbaceous shallow marsh. The majority of the other wetlands are represented by numerous examples within the habitat units.

Character of Surrounding Habitats/Land Uses

As expected in this highly agricultural landscape, all of the units are surrounded by active agricultural lands and some abut residential areas, commercial developments and roadways (including Highway 407).

Regional Municipality of Halton Significant Woodlands

Treed areas within the North Oakville study area were studied on vertical and oblique air photos to determine whether or not they would be considered woodlands, as per ROPA 25 (2006) which states that:

> "Woodland means land with at least: 1000 trees of any size per ha, or 750 trees over 5cm in diameter per ha, or 500 trees over 12cm in diameter per ha […]. For the purpose of this definition, all measurements of the trees are to be taken at 1.37m from the ground and trees in regenerating fields must have achieved that height to be counted."

Woodlands must be 0.5 ha or larger in size to be considered candidates for assessment as significant woodlands.

Actual tree counts were conducted in woodlands on public lands to determine whether woodlands could be identified with certainty based on air photo and oblique air photo interpretation. Woodlands studied in the field had between 3000 and 5250 trees per hectare, well in excess of the 1000 trees needed to be defined as woodland. Only one forest cannot be considered a woodland based on the Region's definition. This is the small forested area along a western branch of Sixteen Mile Creek, just north of Dundas Street (FOD7-1) (see **Figure 4W.9.1**).

Based on this exercise it was concluded that the woodlands mapped in this study based on air photos and field surveys would be defined as woodlands under the Regional definition.

The PPS and Region of Halton provide some guidance for the analysis of woodlands in the study area. As defined by the Provincial Policy Statement (1997, 2005), a significant woodland is an area that is "ecologically important in terms of features such as species composition, age of trees and stand history; functionally important due to its contribution to the broader landscape because of its location, size or due to the amount of forest cover in the planning area; or economically important due to site quality, species composition, or past management history". The Region of Halton, in its OP Amendment 25 (2004), lists four criteria used to evaluate whether or not a woodland is significant. These criteria are as follows:

- Woodlands consisting of trees more than 99-years old;
- Woodlands 2ha or greater in area in Urban Areas (of which North Oakville is a part);
- Woodlands having a minimum 4ha core area at a distance of at least 100m from the perimeter; and
- Woodlands wholly or partially within 50m of a major creek or certain headwater creek, or within 150m of the Niagara Escarpment Brow.

Treed areas that were determined to be woodlands as per Halton Region's definition were assessed based on the Region's significance criteria (see above), other than age. Age of the trees was not assessed as part of this Subwatershed Study. Woodland area was determined through GIS analysis of the ELC mapping of the study area. Forest interior area was also calculated using GIS and a setback of 100 m from the forest edge using the same ELC maps. For this analysis "major creek or certain headwater creek" was conservatively deemed to be one identified in the stream corridor evaluation as either a high or medium constraint stream (see **Section 6.3.4**).

Based on woodland area, interior forest area, and distance from a high or medium constraint stream, 21 out of 28 woodlands would be significant under the Region's system. The woodlands that would not be significant are as follows (also refer to **Table 5.9.2** and **Figures 4W.9.1** and **4E.9.1**):

Unit 2.2	A 0.85ha rectangular woodland located between Habitat Units 2 and 3, approximately 500m south of Highway 407
Unit 9.1	A 1.34 ha woodland located within the eastern portion of Habitat Unit 9, separated from the larger portion of the Habitat Unit by cultural meadow
Unit 15.0	A 0.96ha woodland located east of Trafalgar Road and south of Burnhamthorpe Road East
Unit 17.0	A 1.4ha woodland forming part of Habitat Unit 17
Unit 22.0	A 1.39ha woodland forming part of Habitat Unit 22.

Based on field and air photo work done for this study, the woodlands found not to be significant are not anticipated to achieve significance based on age.

Table 5.9.2 highlights the significance criteria by woodland, as well as giving information on the habitat communities. The values provided in this table are for the woodlands only, as opposed to metrics provided for entire Habitat Units in **Table 5.9.1**.

5.9.1 Identification of Terrestrial and Wetland Constraints

Based on the characteristics of the existing terrestrial and wetland vegetation communities and species found within these areas (see discussion above), a number of patterns of significance were identified. It is recommended that constraints be identified based on these patterns as follows:

- Features currently identified as ANSI or candidate ANSI areas. This includes the Sixteen Mile Creek Valley which is currently designated a regionally significant ANSI, but is currently under review by the MNR as a provincially significant ANSI, as well as a number of woodlands east of the Sixteen Mile Creek which are part of the Oakville-Milton Wetlands and Uplands Candidate ANSI;
- In addition to the above, mature upland woodlands, associated with the defined valleys (Fourteen Mile Creek and Joshua's Creek,). Sixteen Mile Creek is included above;
- In addition to the above, mature upland woodlands that provide potential forest interior habitats (*i.e.,* >100m from the existing edge);
- Other terrestrial habitats (*i.e.,* savannah, thicket, meadow) that are found adjacent to the above, that may contribute to the functioning of these areas;
- Wetland areas. Three general types of wetlands are found within the study area:
  1. Wetlands associated with woodlands. These would fall into one of the first two constraint categories (*i.e.,* woodlands);
  2. Wetlands that are online with watercourses and would therefore overlap with the aquatic habitat considerations; and
  3. Isolated wetland pockets in fields which are scattered, but in some cases may be associated with the drainage network.

Sections 4.9E and **4.9W** discuss all of the natural features identified through the characterization process. The selected features noted above are shown on **Figure 5.9.1**.

Linkages

As noted in **Sections 4E.9** and **4W.9**, the existing woodlands within the Subwatershed study area are not well inter-connected by forested connections. The landscape is predominantly active agriculture with little open field habitat. The issue of habitat connectivity has been discussed in some background reports (see LGL, 2000).

Linear habitats either associated with riparian habitats or other upland features may provide an intrinsic habitat function as well as other ecological and human values (see Riley and Mohr, 1994). In addition to providing intrinsic habitat, the role of these features in providing important avenues for the movement of plant and wildlife species is noted. Some researchers have recognized that some linkages may have disadvantages such as increased immigration of undesirable non-native species of plants and animals into previously isolated habitats, or increased edge and interior-edge effects such as predation (see Brownell and Larson, 1995; Merriam, 1992).

As part of the analysis of current linkages in the study area, a number of background studies which focused or included examinations of linkage characteristics were reviewed. The factors that were used in these background studies were investigated and compared to assist in identifying suitable factors for evaluating linkages.

Ecological linkages must be considered with an understanding of the species that are anticipated to use the connection. Some species, called 'passage species' use linkages for brief passage between habitat patches (Beier and Loe, 1992; Stephenson, 1999). In this case the connection must at least provide suitable conditions to motivate species to enter and use the area. 'Corridor dwellers' may require several days or even generations to pass through the connection (Beier and Loe, 1992), and individuals must therefore be able to live in the connection for extended periods.

In a document entitled *Fauna Species Scoring and Ranking System*, the Toronto Region Conservation Authority (2003) provided a ranking of the mobility for wildlife species known from the Greater Toronto Area (GTA). This ranking is based on species life histories and habitat characteristics in the GTA and can provide some guidance in terms of identifying 'suites' of species for consideration in habitat connections. The TRCA ranking of mammal, bird, reptile and amphibian species fall into five categories:

- Unlimited mobility, species is highly mobile with no habitat restrictions;
- Mobile with availability of 'stepping stone' habitat, hedgerows, or other cover;
- Mobile provided there is continuity of specific habitat type;
- Restricted by limited physical capacity and external threats or very specific habitat requirements; and
- Restricted by limited physical capacity and external threats and very specific habitat requirements.

All but two species recorded from the study area fall within the first three categories (fairly mobile species). Hairy-tailed Mole and Mudpuppy score a "5" on the mobility scale, meaning they are very restricted in their movement. Hairy-tailed Mole was recorded from one source only (Stantec *et al*., 2004) with no locational information from within the study area. Mudpuppy is only known from the Ontario Herpetofaunal Atlas (Oldham and Weller, 2000). A fair number of the amphibian and reptile species reported from the study area were ranked as being 'mobile provided there was continuity'; the majority of other species were less restricted in mobility.

Based on a review of the literature, it was determined that four factors were consistently used to assess linkages: length/width, composition of the potential linkage feature, character of the surrounding habitats (matrix) and presence and size of discontinuities. As well, in assessments of linkages, there is a consistent emphasis on the importance of identifying 'end' habitats for the linkages to actually function as habitat connections.

Although width of corridor strongly depends on other factors including length, habitat, topography, vegetation, and species of interest (Noss, 1983 and 1995; Beier and Loe, 1992), it is possible to make generalizations for width requirements for different plant and animal species. Henry *et al.* (1999) reported that corridors should not be less than 100 m wide, as this will not create any 'core' habitat for interior or sensitive species. This idea was reinforced by Croonquist and Brooks (1993), who reported that no sensitive species were recorded in riparian corridors less than 25 m wide. Larger widths are required to accommodate interior forest species and larger mammals. Barnes (2000) and Henry *et al.* (1999) both suggested that corridors of at least 100 m are ideal for faunal movement. Once a width of 100 m has been reached, the interior forest characteristics become appropriate for movement (Barnes, 2000). In studying riparian corridors, Croonquist and Brooks (1993) reported that a total width of 50 m is the minimal requirement for dispersal and breeding opportunities. Furthermore, a width of at least 125 m is needed to adequately support entire bird communities. Beier and Noss (1998) have also reported significant benefits of riparian corridors greater than 100 m in width.

Another linkage dimension considered is the distance that the animal must travel to get to a linkage. This would apply to roadway crossings like overpass, underpass, and culvert crossings, and would be a larger concern for less mobile animals including small mammals and amphibians. McDonald and St. Clair (2004) reported that small mammals used linkages more frequently if they reside within 60 m of a linkage. Without linkages in close proximity, these small mammals tended to simply cross the road without the aid of a linkage.

The most important factor in considering habitat composition is connectivity. It is important to ensure that corridor habitat is compatible with the habitats of the fragments to be connected. Dover (2000) explains that two patches may be physically linked by a corridor, but for optimal results it is important that the fragments are also ecologically linked. Corridors, as described by Briffet (2001), should be wide, long, well connected, and with a variety of good-quality habitats. A wide variety of quality habitats will ensure a higher species richness that has the ability to utilize the corridor. Another important attribute, as described by Clevenger *et al.* (2001), is that corridor vegetation be self-sustaining, requiring no (or very little) human influence after implementation.

Some generalizations can be made based on basic habitat preferences of different species groups. McDonald and St. Clair (2004) have observed that in using road corridors, small mammals show preference to corridors and linkages with a high percentage of vegetative cover. This is directly associated to the potential increased predation rate associated with open areas. Complex vegetative cover within corridors has also been found to increase use by ground/cavity nesting and ground/tree nesting bird species (Fernandez-Juricic, 2000).

Very few studies have examined the role that corridors play in the migration of plant species. Tikka *et al.* (2001) reported that a large part of plant distribution can be attributed to animals and animal movements, thus implying that corridors used routinely by animals will therefore allow migration by many plant species. Also observed by Tikka *et al.* (2001) was that fencerows, which were initially thought to contribute as corridors for plant movement, were not adequate for the movement of woodland plants. Grassland plants have been shown to avoid use of corridors when the matrix habitat is unsuitable (Tikka *et al.,* 2001). This is likely related to the edge preference of many grassland plants. An unsuitable matrix will decrease suitable edge habitats available for movement.

Within the study area, Sixteen Mile Creek provides a broad wooded linkage to lands north of Highway 407 and south of Dundas Street. This is a key ecological corridor that should be focused on for the identification and/or creation of forested linkages. It is noted that north of Highway 407, Sixteen Mile Creek valley runs in an east-west direction that provides a good opportunity for east-west connectivity outside of the study area.

Discontinuities in linkages are noted in background research to occur when breaks of over 20 m are found (MNR, 2000), and in some cases discontinuities over 50 m are seen as creating sufficient gaps to preclude significant movement of certain more sensitive wildlife species (Hounsell, 1985). Some authors, such as Noss (1987) and Hickman (1990) report that even narrow clearings such as roads, utility corridors, and nature trails can create breaks large enough to produce edge effects. However, connectivity between habitat patches can occur simply as a result of proximity (without a direct physical connection). In these cases plant and wildlife species that can tolerate gaps or use saltatory movements (*e.g.,* flying over gaps) are able to benefit from this type of connection. In effect, habitat units that are close to each other can be used as "stepping stones" (Dramstad *et al.,* 1996).

Linkages for some species currently exist throughout the study area by way of the agricultural fields.

As noted above, the study area is predominantly active agriculture, therefore for the evaluation of existing linkages, the character of the surrounding habitat was assumed to be consistent. Also based on the background literature the following the types of discontinuities in potential linkages were identified:

- Continuous corridors: gaps <20 m;
- Discontinuous corridors: gaps between 20 and 100 m; and
- Fragmented corridors: gaps >100 m.

Based on a combination of habitat character, width and discontinuities, the following types of linkages were possible seen in **Table 5.9.3**.

Table 5.9.3
Type of Linkages in the study area

TYPE	DESCRIPTION	PRESENCE IN STUDY AREA
Open field, pasture, hayfields and other agricultural lands	Corridor habitat dominated by herbaceous vegetation Width is variable and in some cases can be great Discontinuities can be great in some cases	Wider corridor areas consisting of meadow habitats are fairly uncommon to rare in the study area, associated with the landfill as well as south of Hwy 407 east of Sixteen Mile Creek Narrow meadow areas are more common especially associated with drainage ways throughout the study area Agriculture dominated areas are widespread throughout the study area
Thicket or savannah dominated corridors	As above, but dominated by shrubs or immature treed stands	Thicket or savannah dominated linkages are not abundant in the study area, some are found associated with Joshua's Creek valley system
Hedgerows	Generally narrow, consisting of single or double rows of trees, also with mixed shrubs in some cases	Numerous hedgerows are found throughout the study area, in many cases they do not have end habitats, and include considerable gaps
Narrow forested corridors	Forested areas, generally less than 100 m in width, but wider than hedgerows Continuous or discontinuous	Rare to absent in the study area, some smaller pockets have been included into habitat units
Forested pockets or blocks	Forested areas, generally greater than 100 m in width, but with gaps >100 m	These features represent the isolated woodlands found within the study area
Forest interior corridor	Forested areas, generally >100 m in width and continuous	None found within the study area with the exception of the Sixteen Mile Creek valley

The approach used in **Table 5.9.3** readily allows for the examination of types of linkages found within the study area. The approach also can be used to identify enhancement opportunities, such as the ability to change a corridor feature from one category to another (*i.e.*, moving down the table) and feasibility, as some factors can be influenced (*e.g.,* composition), while others may not be (*e.g.,* discontinuities).

The existing corridors within the study area fall into general categories:

- Agricultural fields - (Hay and pasture are better than cropped fields as they remain vegetated for longer periods during the year and provide better habitat for more species), some open field habitats are also found;
- Hedgerows - Generally single rows of trees, sometimes double rows, often shrub-dominated or mixed;
- Riparian habitats - Associated with watercourses that are primarily meadow and/or marsh habitats. In these areas, a multiple of ecological and hydrological functions must be considered;
- Stepping stones created by proximity of habitat types with little connecting habitat; and
- Connectivity created by contiguous woodland habitats.

The current non-wooded gaps between forested blocks indicate that the feasibility of creating forested connections would require setting aside existing meadow or other open areas for natural succession. The existing discontinuities created by roadways are also an impediment to creation of a continuous forested connection through the study area.

5.9.2 Terrestrial Relationship with Stream Reaches

As part of the evaluation and classification of stream reaches, terrestrial conditions were considered. This included the determination of the role of the terrestrial characteristics in stream function. For example, if a linear wetland exists along the stream, it will impact on aquatic habitat, maintenance of base flows and nutrient supply. Similarly, a well vegetated stream corridor assists in protecting water quality, providing nutrients to aquatic resources and detaining flows during flood events.

Terrestrial conditions along the streams are summarized in **Appendix X** and are used in **Section 6.0** of this report in the overall stream classification.

5.9.3 Potential Terrestrial Impacts

Generally any discussion of potential impact to natural features can be divided into the following:

- Direct impacts - Associated with disruption or displacement caused by the actual proposed "footprint" of the undertaking; and
- Indirect impacts - Associated with changes in site conditions such as drainage.

Typical indirect impacts can relate to:

- Site drainage and water balance within wetlands and watercourses;
- Sediment and erosion; and
- Impacts to wildlife movement corridors.

The scientific literature contains abundant research on forest interior habitats and associated impacts of forest fragmentation as well as edge effects. For the purposes of this report, the key findings of this research have been distilled and salient points are provided. A number of helpful general references and literature reviews are available, (*e.g.,* the 2000 document prepared by the MNR entitled: *Significant Wildlife Habitat Technical Guide*. This document was prepared in support of the Provincial Policy Statement and provides guidelines for the identification and evaluation of significant wildlife habitats including forest interior and corridor habitats, amongst others).

The key findings of this huge volume of research are as follows.

Individual habitat patches (especially forested stands) are affected by their surroundings. At the edge of forested stands wind and sunlight result in drier conditions compared to the sheltered interior of the forest. As well, the edges are more accessible to predators and invasive plant species.

The extent that edge effects extend into the forest stand vary depending on a number of factors including the character of the existing forest edge, extent of buffering as well as the nature of the edge effect in question. Forest interior functions have been variously stated to be found at varying distances from the forest edge. A number of documents have recommended that forest interior habitats can be found 100, 200, or 300 m from the edge. The amount of actual interior habitat is also an important factor.

Fragmentation of habitats (especially forest stands) can result from creation of gaps that not only increase the amount of edge, but also result in smaller potential isolated remnant habitats.

In some instances, it has been found that gaps as large as 100m are readily traversed by species (*e.g.,* birds) while gaps as small as 20m may affect habitat continuity. The nature of the discontinuity is also a factor, ranging from the relatively benign affects of intervening natural habitats to more impacts associated with human-dominated uses.

In some cases forested habitats surround open pockets of habitat (*e.g.,* marshes and clearings). The forest edges bordering these open habitats are often intact and create a stable edge. As this is an interior natural “edge”, the extent of influence on forest interior habitats is anticipated to be less than edge effects associated with a cultural edge.

Beyond the habitat impacts which result from land use changes around natural habitats, the use of the lands around the outside of forested habitats, including development and roadways, can have an impact on neighbouring habitats due to noise, light and movement impacts. Introduction of exotic species as well as feral domestic pets can also impact neighbouring natural areas. The introduction of human-dominated land uses within a forested habitat can not only have footprint impacts (resulting in loss of habitat), as well as indirect impacts arising from noise, light, movement (as well as erosion and pollution depending on the use).

Research has found that despite controls to the extent of the footprint of facilities within woodlands (*i.e.,* controlling vegetation and soil disruption), that indirect impacts arise from the actual use of the facility by humans (and their pets). This involves the generation of potential noise and light impacts. Some wildlife can become habituated to these types of impacts after exposure, however when these are associated with movements or are sudden and loud, habituation is less likely to occur. A number of species of conservation concern are sensitive to these types of impacts and will not tolerate them. Other impacts such as dust and fumes may occur depending on the use. Setbacks and/or buffers are required to protect the function of remnant natural habitats.

Induced impacts are associated with impacts after the development is constructed such as subsequent demand on the resources created by increased habitation/use of the area and vicinity. Induced impacts are described as those that are not directly related to the construction or operation of the facilities in question, but rather arise as a result of the use of natural areas as a result of the development. The simplest example is increased use of a natural area by residents. Once development is completed, subsequent use of the retained natural areas by residents is sometimes difficult to control.

Education of residents with respect to the values and implications of the neighbouring natural areas is one tool that can be used. A system of authorized trails can be used to focus use onto properly constructed, laid out and maintained trails. A system of signage educating residents and other users of the lands to the natural values of the area may also be used.

Cumulative impacts are associated with the spatial and temporal implications of a specific proposal in conjunction with other undertakings in the area.

In order to evaluate the potential for cumulative impacts, it is necessary to look beyond the boundaries of the specific site to the lands that currently drain to the site as well as lands that are downstream. The Subwatershed Study provides a good basis for the analysis of potential cumulative impacts. Cumulative impacts as they relate to development may arise as a result of the following:

- Spatial Crowding - Occurs when more than one proposal will occur in close proximity to others, such that there is potential for relatively minor impacts from each undertaking to add up (or combine) since they overlap;
- Temporal crowding - This can occur when phases of a development or different developments overlap in time;
- Spatial Lags - occur in cases where potential impacts are not found for some distance from the proposed undertaking.
- Temporal Lags - Cumulative impacts that arise from temporal lags are those that occur after time has elapsed between the source of the impact and the possible effect. An example of this is when compounds released change to some more problematic compound after some time of exposure to the environment.
- Shared Impact Linkages - These are similar to spatial and temporal crowding, but focus on cases where more than one development, that may not actually overlap in time or space, affects the same component of the ecosystem. An example of this is when one land use change affects the breeding grounds of a species, while a second development affects the over-wintering habitat of the same species. Potential impacts to metapopulations of species can be considered a possible source of cumulative impacts.

5.10 AQUATIC RESOURCES

5.10.1 Approach

During subwatershed planning it is useful to categorize aquatic habitats such that the relative importance of the habitat and the relative sensitivity to development can be determined. This helps to guide the management decisions surrounding a particular habitat. A number of systems are currently in use in Ontario for summarizing and categorizing aquatic habitats. In addition to the standard systems such as the Provincial Policy Statement (MNR 1999) and the DFO Agricultural Drain Classification system (DFO, 1999), LGL (2000) developed a system for categorizing aquatic habitats unique to the OPA 198 lands. A summary of the relevant components of these three systems is included in **Table 5.10.1**.

For the analysis of aquatic habitat reaches for this study, the aquatic habitat components identified as being of significance in the Provincial Policy Statement (PPS) (**Section 2.4, Fish Habitat**) and supporting documentation from Table A2 of the PPS were deemed to be the most comprehensive and so were adopted and supplemented by knowledge of the study team. The specific components used to categorize aquatic habitats are described in **Table 5.10.2**. For each habitat component a decision was made as to whether the particular component was critical, important or marginal in terms of contribution to the stream reach in question. This decision was made on the basis of the rationale provided in **Table 5.10.2**.

Results of this analysis are provided in **Appendix X**. Analysis of the various components of the categorization system allowed a categorization of habitats, by stream reach, resulting in an overall rating of critical, important or marginal for each reach (see **Appendix X**). An additional category of “no habitat” was also included to identify those reaches which contribute flow to downstream reaches but show no evidence of any in situ aquatic habitat. If one of the habitat criteria was satisfied for any given component then the habitat received that typing. For example, if groundwater discharge was present, then the "critical" designation for the groundwater component resulted in an overall classification of critical even if no other component was given the critical designation. For any given stream reach, if the criteria were the same for both important and marginal habitat categories (*i.e.*, no groundwater discharge present), then the categorization defaulted to marginal.

The presence of redside dace was a determining factor in identifying two reaches of Fourteen Mile Creek (14W-12 and 14W-1A) as critical habitat. Redside dace were sampled in these reaches as part of the 2002 electrofishing exercise carried out for this study in both of these reaches. In addition, numerous recent records exist of redside dace in these same stretches of creek, within the first two kilometers downstream of Dundas Street (MNR 2003e). In East Morrison Creek, no fish were sampled within Reach MOC-4 (Dundas Street area) and it did not receive the critical habitat designation. However, a recent record does exist within 400 m downstream of this reach and the reach exhibits good herbaceous riparian vegetation cover which has been identified as a preferred habitat type for redside dace (Parish, 2004).

The majority of the study reaches within the study area were classified as either important or marginal habitat as seen in **Figure 5.10.1**. These reaches provide a range of habitat conditions and currently support fish species in a number of locations. A small number of reaches were categorized as critical habitats. These include:

- The lower portion of the western-most tributary of Fourteen Mile Creek
- The lower portion of the central (main) branch of Fourteen Mile Creek
- Two well-vegetated reaches in Joshua's Creek

5.10.2 Identification of Aquatic Constraints

The presence of redside dace in Fourteen Mile Creek and Morrison Creek is an important aquatic constraint within the study area. In 1987, COSEWIC (Committee on the Status of Endangered Wildlife in Canada) updated the national status of the redside dace from vulnerable to a species of special concern (*Parker et al.*, 1988). More recently, COSEWIC is considering upgrading the species status to threatened due to increased concern over the species status. In Ontario, redside dace was designated as a threatened species in 2000 due to loss of habitat and deteriorating water quality. The Redside Dace Recovery Strategy (Dextrase *et al.*, 2005) identifies at least nine potential threats to redside dace populations left remaining in Ontario. The two most predominant threats are urban development and agricultural activities. Siltation and removal of bank cover in urban and rural headwater areas are important limiting factors directly related to the decline of redside dace populations (Dextrase *et al.,* 2005). Since these activities can be associated with the development proposed for the study area, care must be taken to ensure an adequate level of protection for this species is enshrined in the recommendations of this Subwatershed Study.

Locations in the study area where groundwater was observed discharging to surface water were few and only found along specific reaches of Joshua's Creek. It is interpreted that the discharges identified in and near reaches JC-5 and JC-36 may contribute to both perennial flow and seasonal/event based flow. Thus, preservation of the wooded area around these reaches will also protect the groundwater discharge area. Regardless of whether the discharge is seasonal or perennial, the habitats that this groundwater discharge supports must remain functional to the same extent they are now.

Preservation of the flow characteristics of the various streams must also be considered. This is particularly important for Fourteen Mile and Morrison's Creek where redside dace are still known to thrive. Improper stormwater management and hardening of previously unpaved surfaces can lead to peak flows over and above the natural flow regime. Impacts typically associated with alterations to the hydrograph include increased movement of bed load and associated scour and erosion. This affects redside dace habitat by shifting substrates (i.e. spawning gravels) and filling in refuge areas such as pools. Increases in turbidity brought about by ineffective construction controls or SWM can also have detrimental effects on all species of fish. Redside dace are especially vulnerable to sedimentation (Dextrase *et al.,* 2005).

Removal of riparian vegetation can negatively affect streams by removing root mats which bind soils on the banks, leading to erosion. Removal of vegetation can also decrease riparian shading resulting in subsequent increases in stream temperature which can be detrimental to aquatic life. Development scenarios for these lands must include provisions for retention of riparian habitats.

5.10.3 Potential Aquatic Impacts

Specific potential impacts to aquatic habitats are discussed below.

Direct Loss of Aquatic Habitats

The direct loss of fish habitat is governed by the Federal Fisheries Act. Compensation for impacts to existing reaches in many cases can be achieved, since enhancement opportunities exist, especially for the important and marginal reaches. DFO advocates a hierarchical approach to dealing with direct habitat loss where avoidance of the impact is most preferred followed in order by mitigation of the impact and compensation for lost habitat.

Indirect Impacts to Aquatic Habitats

The following potential indirect impacts may occur:

- Sedimentation and runoff, especially during construction phases;
- Loss of riparian habitats (although many reaches in the study area have little riparian vegetation);
- Reduced infiltration (as discussed in **Section 5.5.2**) can reduce baseflow in some reaches;
- Reduced water quality (especially linked to stormwater management, see **Sections 5.5.2** and **5.7**); and
- Changes in flow characteristics (as discussed in **Section 5.8**) can modify habitat characteristics for aquatic organisms.

5.11 OPPORTUNITIES, CONSTRAINTS, MANAGEMENT NEEDS

5.11.1 Introduction

Future urban land use in the North Oakville Creeks Subwatershed presents challenges and opportunities for maintaining and enhancing ecological functions. Appropriate management measures must be applied to mitigate the following potential impacts:

- Flood and erosion potential;
- Reduced groundwater infiltration to the aquifer system;
- Reduced baseflow to the creek system;
- Stress to fishery resources ;
- Impacts to wildlife habitat; and
- Impacts to woodlands and wetlands (changes in species and health of vegetation due to changes in groundwater, and edge impacts).

5.11.2 Riparian Corridor Classification

General

Riparian corridor systems (along streams) are a key element of a management strategy to preserve (and provide for enhancement of) form and function within a subwatershed. Riparian lands are typically the most fertile and productive part of the landscape in both primary production and ecosystem characteristics. These corridors often have better quality soils and typically retain moisture over a longer period.

There is a complex interaction between riparian land and the stream that it is adjacent to. Riparian land will “buffer” the streams against sediment and nutrient wasting of adjacent lands, it will be a source of food to aquatic organisms through insects and other matter that falls from trees and shrubs. Similarly, aquatic organisms are food to wildlife that lives in the riparian vegetation. The shading effects of vegetation will reduce temperatures or prevent temperatures from rising in the stream, protecting aquatic life.

The role of a riparian system can be summarized as:

- Trapping sediments, nutrients and other contaminants that are in streamflow during high flow stages;
- Reducing the rates of erosion and providing bank stability;
- Controlling nuisance aquatic plants (*i.e.,* algae) by reducing nutrient levels,
- Providing stream shading which is very important for temperature moderation
- Helping to ensure healthy stream ecosystems;
- Providing a source of food and habitat for stream animals;
- Providing an important location for conservation and movement of wildlife (*i.e.,* corridors, linkages);
- Providing recreation and delivering an aesthetically pleasing landscape.

It is therefore important to identify the riparian corridor systems that exist and assess their function from an overall subwatershed perspective. As a result, identifying the riparian corridors that need to be preserved and enhanced are a key element of the management strategy, and just as important as the terrestrial features that have been identified (discussed in **Section 5.9**).

Identification and Classification of Riparian Corridors

In identifying and classifying the riparian corridor system both the overall form that exists (characteristics) and function of the corridor must be considered. To include the underlying philosophy of subwatershed planning, to protect and enhance environmental conditions, the overall potential of a corridor that may currently be degraded must be considered. For example, a stream that has been altered, but provides a potential linkage function between two terrestrial units, or can provide a role in protecting downstream receiving system must be considered for its potential role in meeting the management objectives.

As indicated in the introductory section, the role of riparian corridors are as complex as they are important. Their characteristics and functions however can be evaluated through the analysis carried in this phase of the Subwatershed Study. The form and function of the riparian corridors (and streams) have been evaluated on a reach basis in the following sections.

Section 5.5 – Hydrogeology and Water Balance

- To consider the stream correction to the groundwater system in supporting baseflow discharge and its role in supporting aquatic life (see **Appendix X**).

Section 5.6 – Hydrology, Hydraulics, Water Quality

- The role of the stream corridors from a hydraulic perspective in providing flow augmentation, and the potential to improve water quality (see **Appendix X**).

Section 5.8 – Stream Morphology

- The condition of the stream from a geomorphologic standpoint and associated erosion process as well as the overall quality as a stream corridor (including aquatic habitat structure) (see **Appendix X**).

Section 5.9 – Terrestrial Resources

- The terrestrial resource conditions as they affect stream corridor functions are summarized in **Appendix X**.

Section 5.10 – Aquatic Resources

- The condition and role of a corridor to support a healthy aquatic system (habitat) (see **Appendix X**).

All of these factors are being used in developing an overall ranking of the streams by constraint and are outlined in **Section 6.0 Management Strategy**.

5.11.3 Terrestrial and Wetland Natural Heritage System

Current approaches to the conservation and management of terrestrial and wetland resources focus on the need to consider the diversity of features as well as the connections between them. This approach considers a system approach that extends beyond identification of isolated features or habitats. The conservation of terrestrial and wetland resources must consider:

- Management of the feature itself;
- Identification of a suitable buffer; and
- Management recommendations for lands beyond the buffer that may influence the feature (*e.g.,* servicing, SWM, and grading).

Section 5.9 includes an assessment of the habitat units within the catchments against a series of criteria typically used to identify significance at the feature-level. This section also included discussions of other features, such as open habitats and linkages that are not always assessed.

Section 6.0 of this report provides a discussion of feature-level management, buffers and land use considerations from the perspective of conserving the terrestrial and wetland resources consistent with the project Terms of Reference.

5.11.4 Stormwater Management

Increased impervious area through future development and urbanization impacts may affect water resources in several different ways. The increase in impervious area often results in increased downstream flooding due to increased runoff volumes and peak flows, increased erosion and geomorphic changes, and degradation of aquatic habitat due to poor water quality. Therefore, quantity and quality of stormwater runoff should be taken into consideration.

Quantity

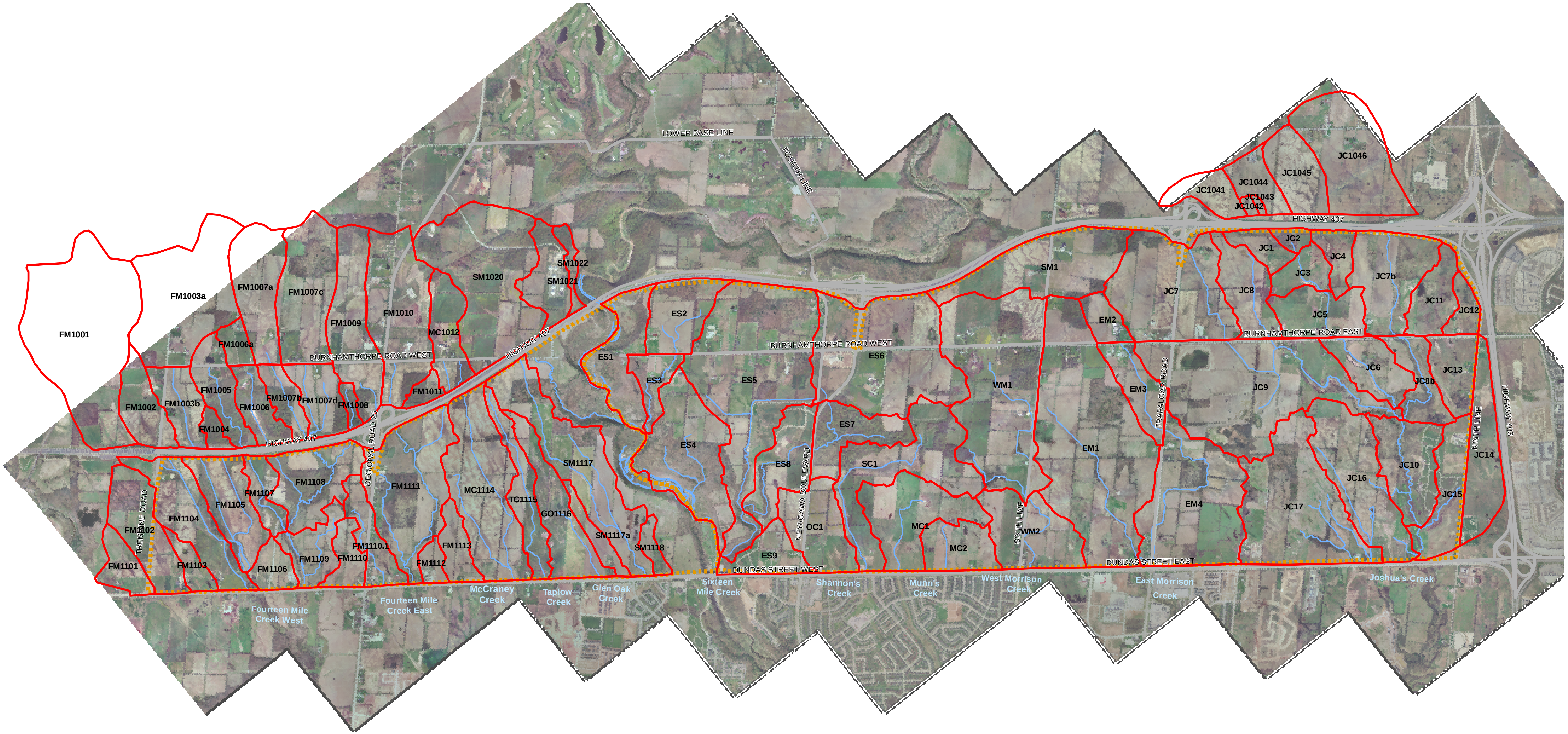
The analysis section has indicated that runoff values (volume and peak runoff) will increase with development, significantly unless managed. The increase in peak flows will, in turn, increase water levels and associated flood potential in receiving watercourses. To mitigate these impacts, stormwater management facilities will need to be addressed in the management strategy for controlling post development runoff volumes and peak flows to match predevelopment conditions.

Fluvial geomorphological assessments that were performed on the stream systems within the area provide erosion thresholds that will need to be incorporated into the stormwater management facility design. These constraints will dictate the hydraulic performance of the SWM facility in order to provide the appropriate level of protection.

Quality

The aquatic sensitivity of the receiving watercourse will dictate the level of protection that the SWM facility must provide. As discussed in **Section 5.7.1** the Stormwater Management Practices and Design Manual (MOE, 2003) provides guidelines for designing a facility to meet a level of performance based on the sensitivity of the receiving watercourse. The quality of stormwater runoff can lead to excessive nutrient loadings to the receiving watercourses which ultimately drain to Lake Ontario. **Section 5.7.6** notes that phosphorous loadings will increase by 141% due to future development unless managed. Excessive nutrient loading can create eutrophic conditions that are detrimental to aquatic habitat and aesthetics due to the growth of algae blooms.

The recommended SWM approach will be addressed in the **Section 6.0 - Management Strategy**.



NORTH OAKVILLE CREEKS SUBWATERSHED STUDY

TSH engineers architects planners

PARISH geomorphic

Natural Resource Solutions Inc. Aquatic, Terrestrial and Wetland Biologists

Donald G. Weatherbe Associates

Morrison Environmental Limited Groundwater Consultants

EWRG Environmental Water Resources Group Ltd.

OAKVILLE

August 2006

N

0 500 1,000

Meters

Legend

Study Area

Road

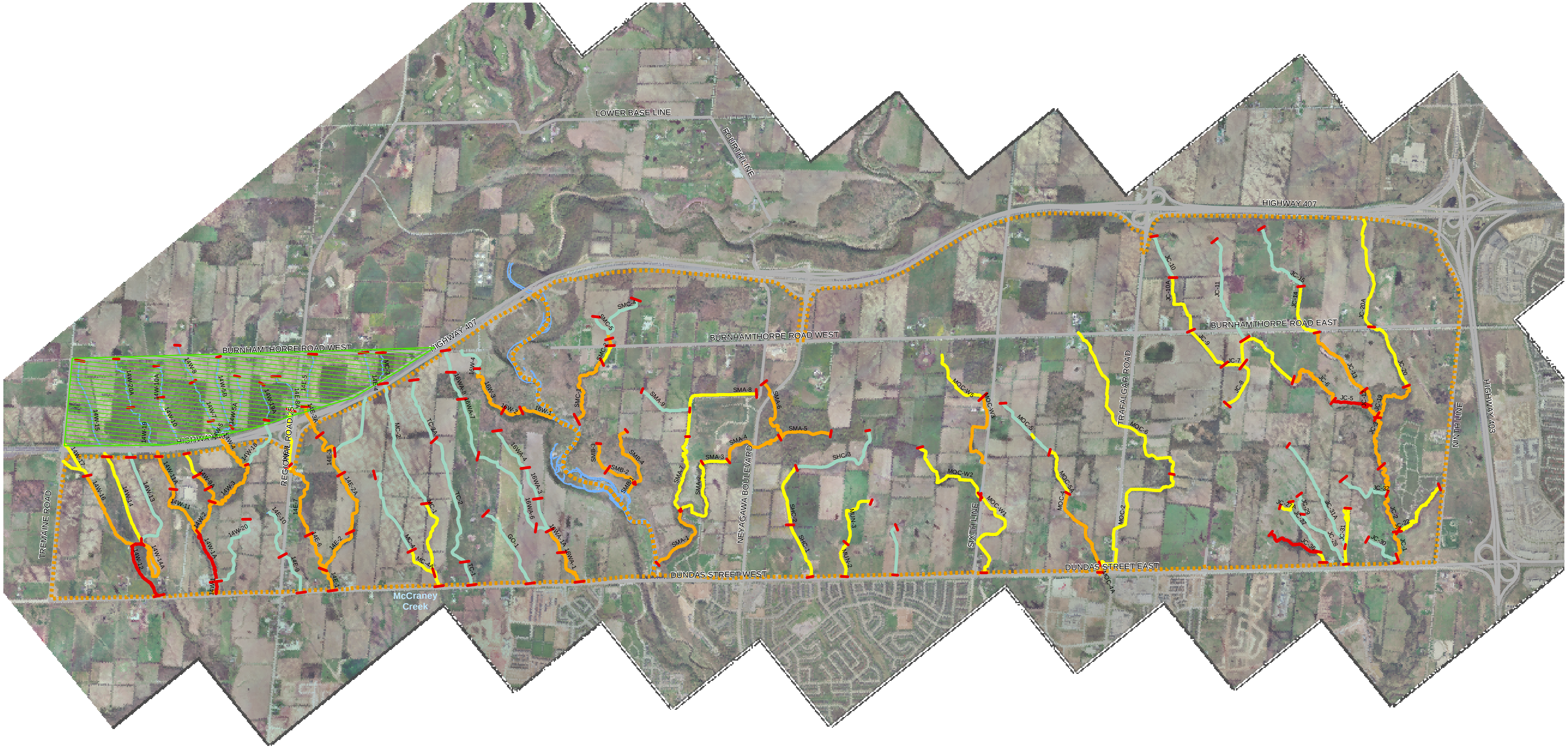
Watercourse

Subcatchments

OC1 Subcatchment Identification

Subcatchment Boundaries

Figure 5.1.1



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N

0 500
Meters

Legend

- Study Area
- Road
- Watercourse

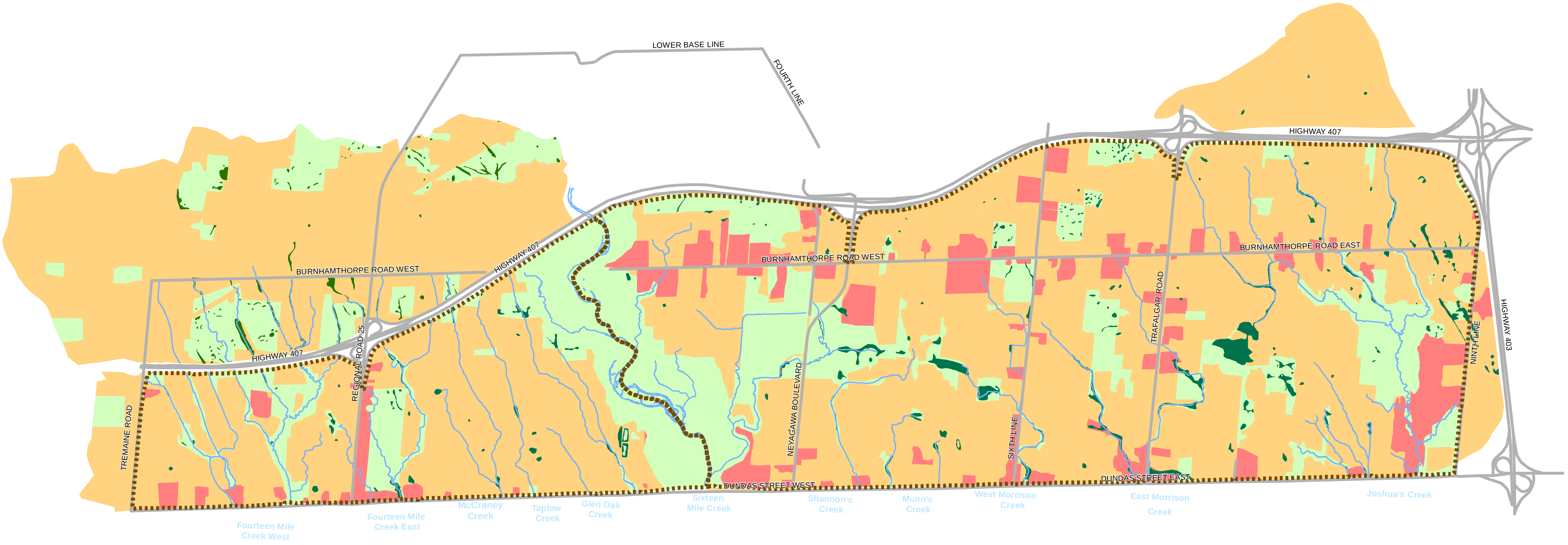
Aquatic Habitat Classification

- Critical Habitat
- Important Habitat
- Marginal Habitat
- No habitat
- Reach

▨ No Habitat Studies Completed

Aquatic Habitat Classification

Figure 5.10.1



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N

0 500 1,000

Meters

Legend

▨ Study Area

— Road

— Watercourse

Land Use

🟧 Agricultural

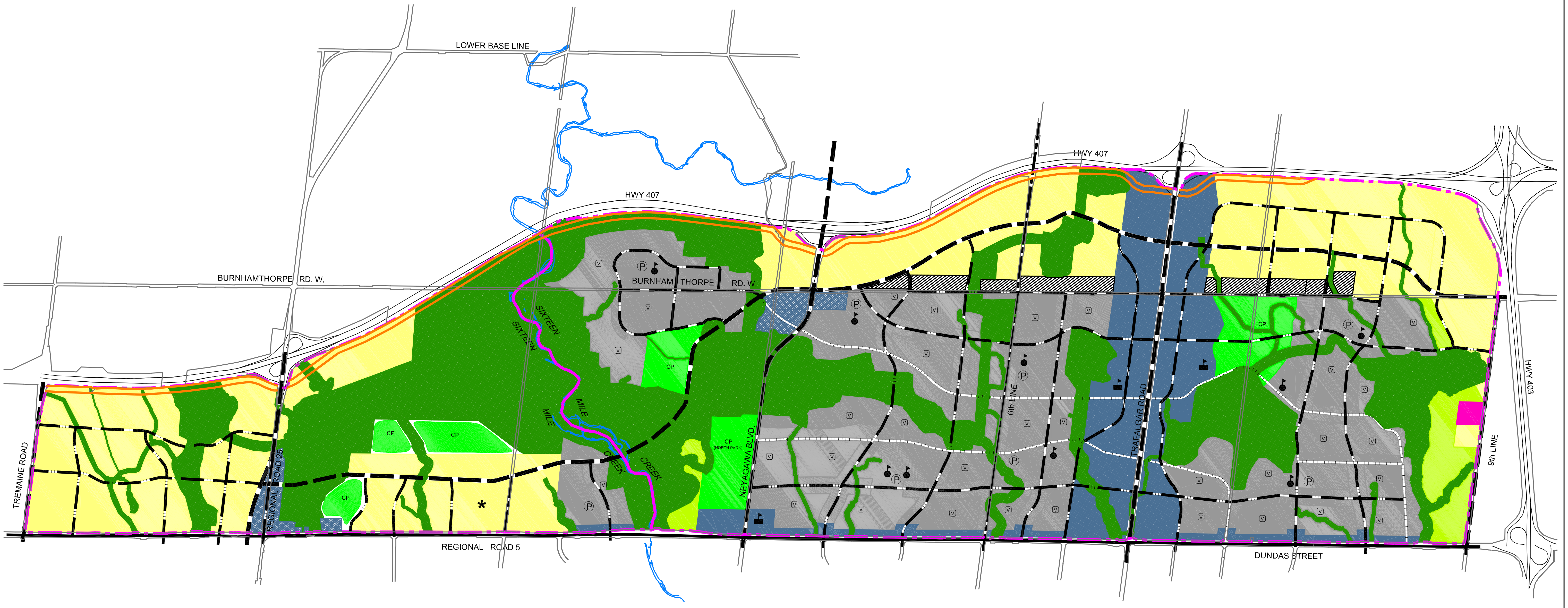
🟥 Residential / Commercial

🟩 Wetland

🟩 Remnant Upland Habitat

Existing Land Use

Figure 5.2.1



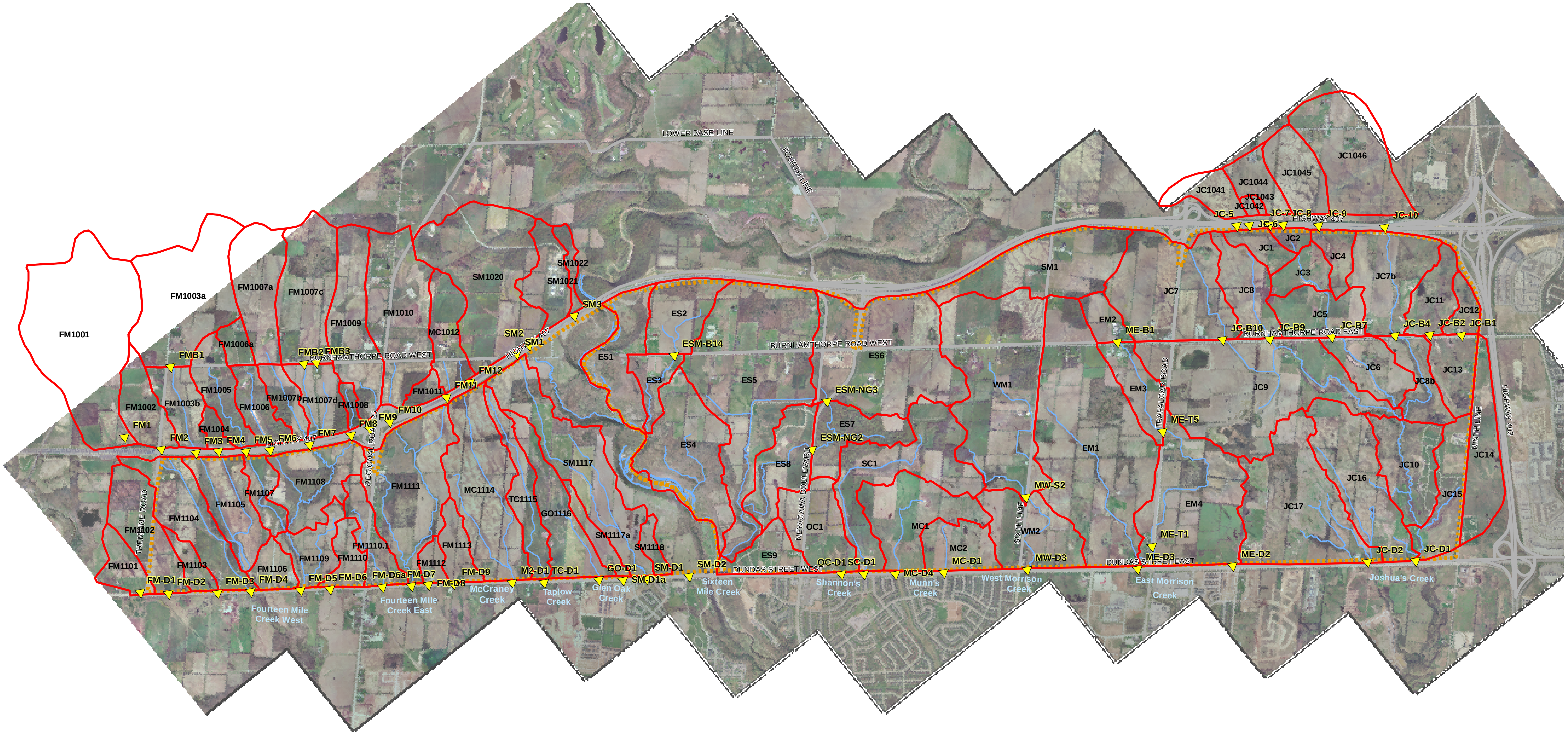
LEGEND

- ▬ ▪ ▬ STUDY AREA
- ═ PROVINCIAL FREEWAY
- ▬ BOULEVARD/TRANSIT CORRIDOR
- ▬ ▬ MAJOR ARTERIAL/TRANSIT CORRIDOR
- ▬ ▪ ▬ MINOR ARTERIAL/TRANSIT CORRIDOR
- ▬ · ▬ AVENUE/TRANSIT CORRIDOR
- ┆┆┆ CONNECTOR/TRANSIT CORRIDOR
- ═ TRANSITWAY
- Ⓥ VILLAGE SQUARE
- ▨ DUNDAS URBAN CORE AREA
- ▨ NEYAGAWA URBAN CORE AREA
- ▨ REGIONAL ROAD 25 URBAN CORE AREA
- ▨ TRAFALGAR URBAN CORE AREA
- ▨ TRANSITIONAL AREA
- 🟨 EMPLOYMENT DISTRICT
- 🟩 NATURAL HERITAGE SYSTEM AREA
- * HEALTH ORIENTED MIXED USE NODE
- 🟩 COMMUNITY PARK AREA
- 🟩 CEMETERY AREA
- 🟥 INSTITUTIONAL AREA
- ● ELEMENTARY SCHOOL SITE
- ■ SECONDARY SCHOOL SITE
- Ⓟ NEIGHBOURHOOD PARK AREA
- ▨ NEIGHBOURHOOD AREA

North Oakville Creeks Subwatershed Study

Future Land Use

Figure 5.2.2



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N

0 500 1,000

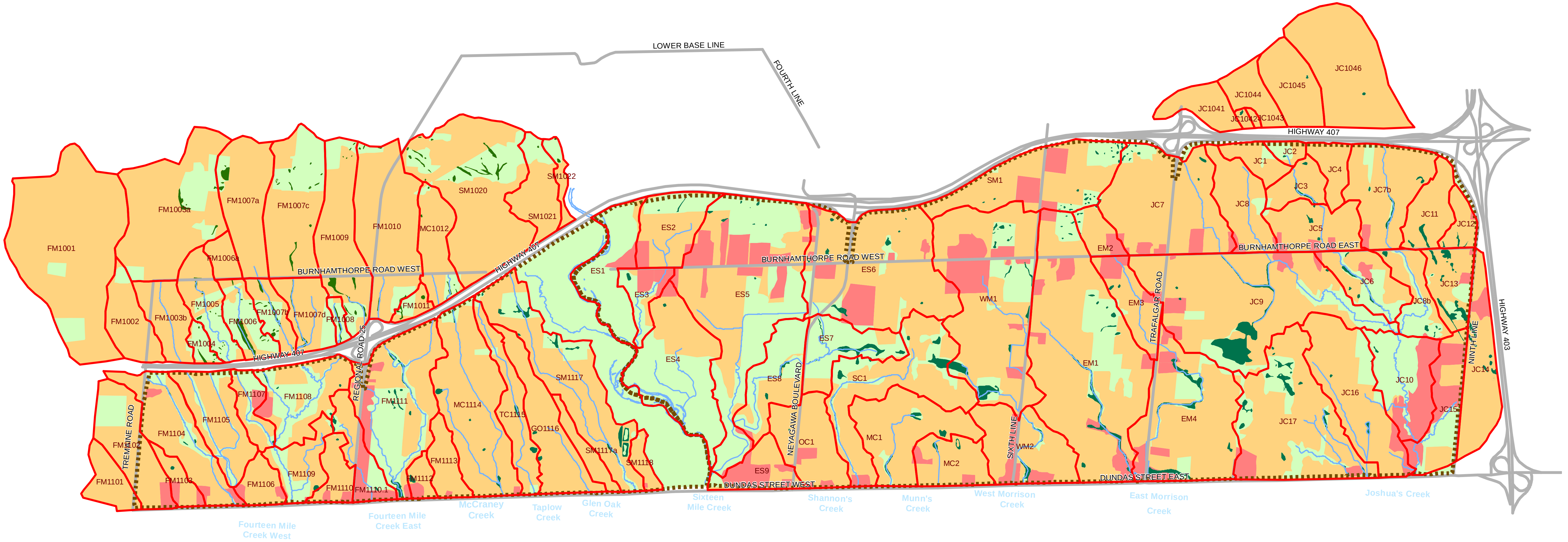
Meters

Legend

- ▨ Study Area
- — Road
- — Watercourse
- ☐ Subcatchments
- △ Culvert

Culvert Locations

Figure 5.4.1



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Legend

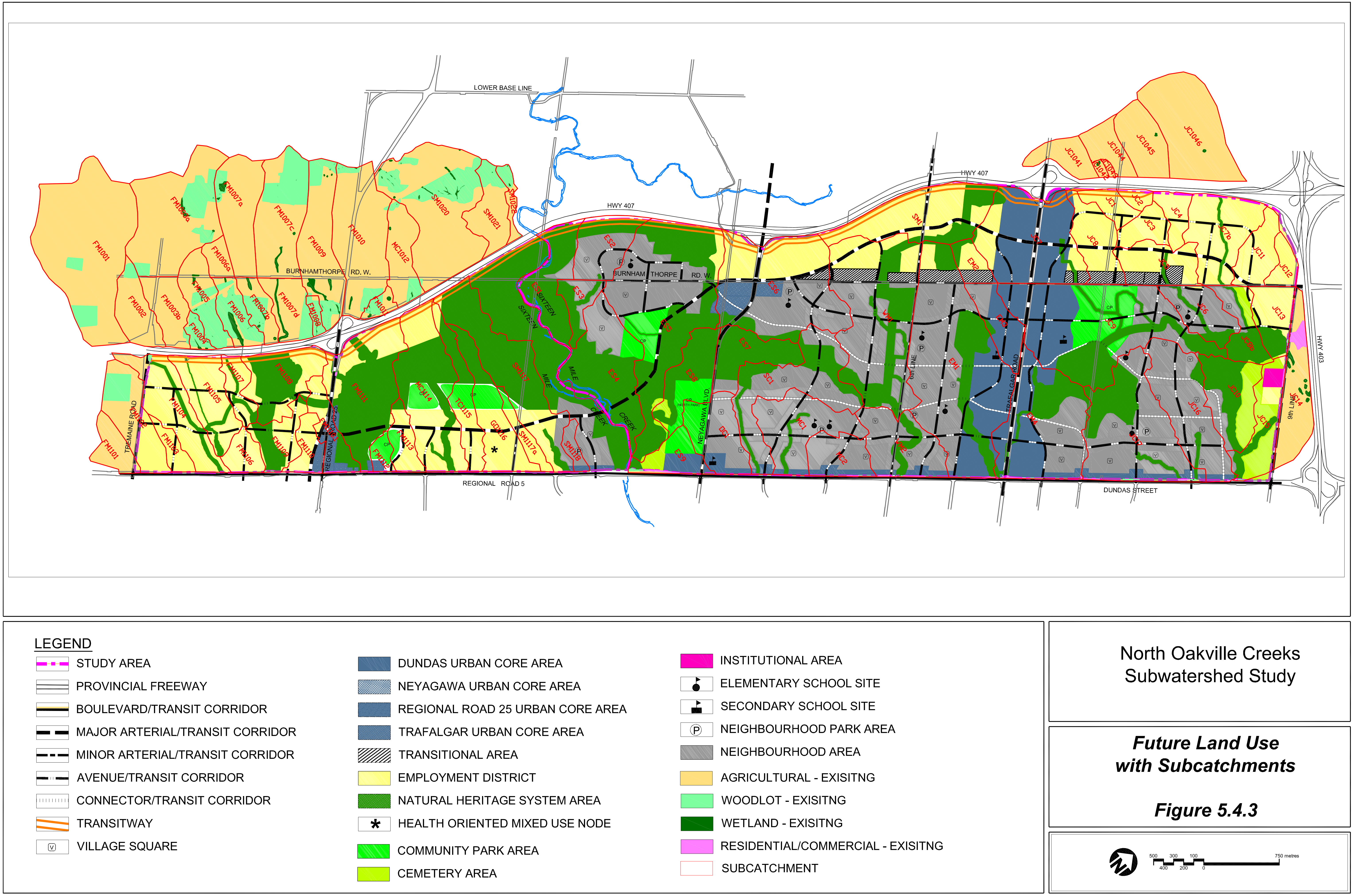
- ▨ Study Area
- — Road
- — Watercourse
- ☐ Subcatchments

Land Use

- 🟧 Agricultural
- 🟥 Residential / Commercial
- 🟩 Wetland
- 🟩 Remnant Upland Habitat

Existing Land Use with Subcatchments

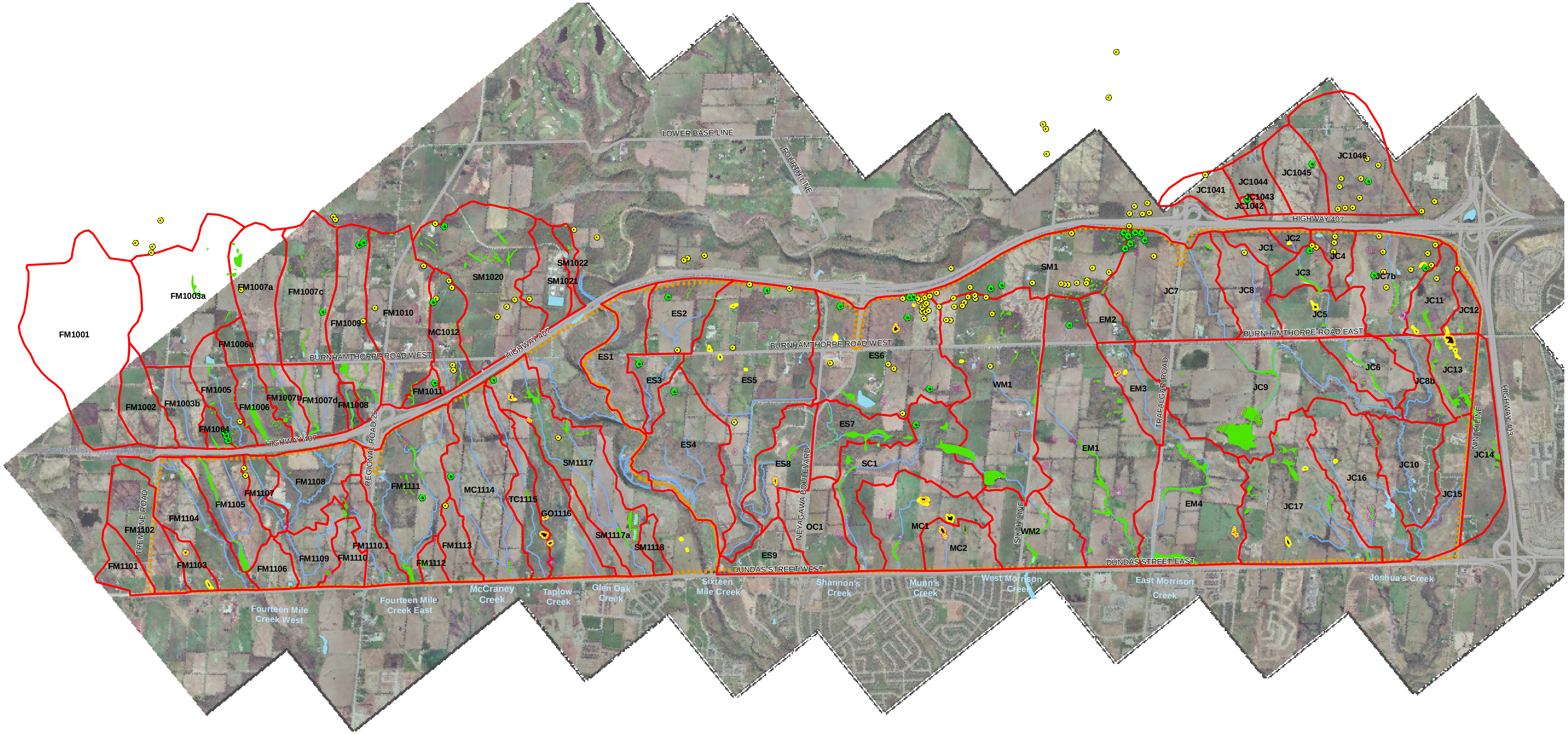
Figure 5.4.2



North Oakville Creeks
Subwatershed Study

Future Land Use
with Subcatchments

Figure 5.4.3



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N

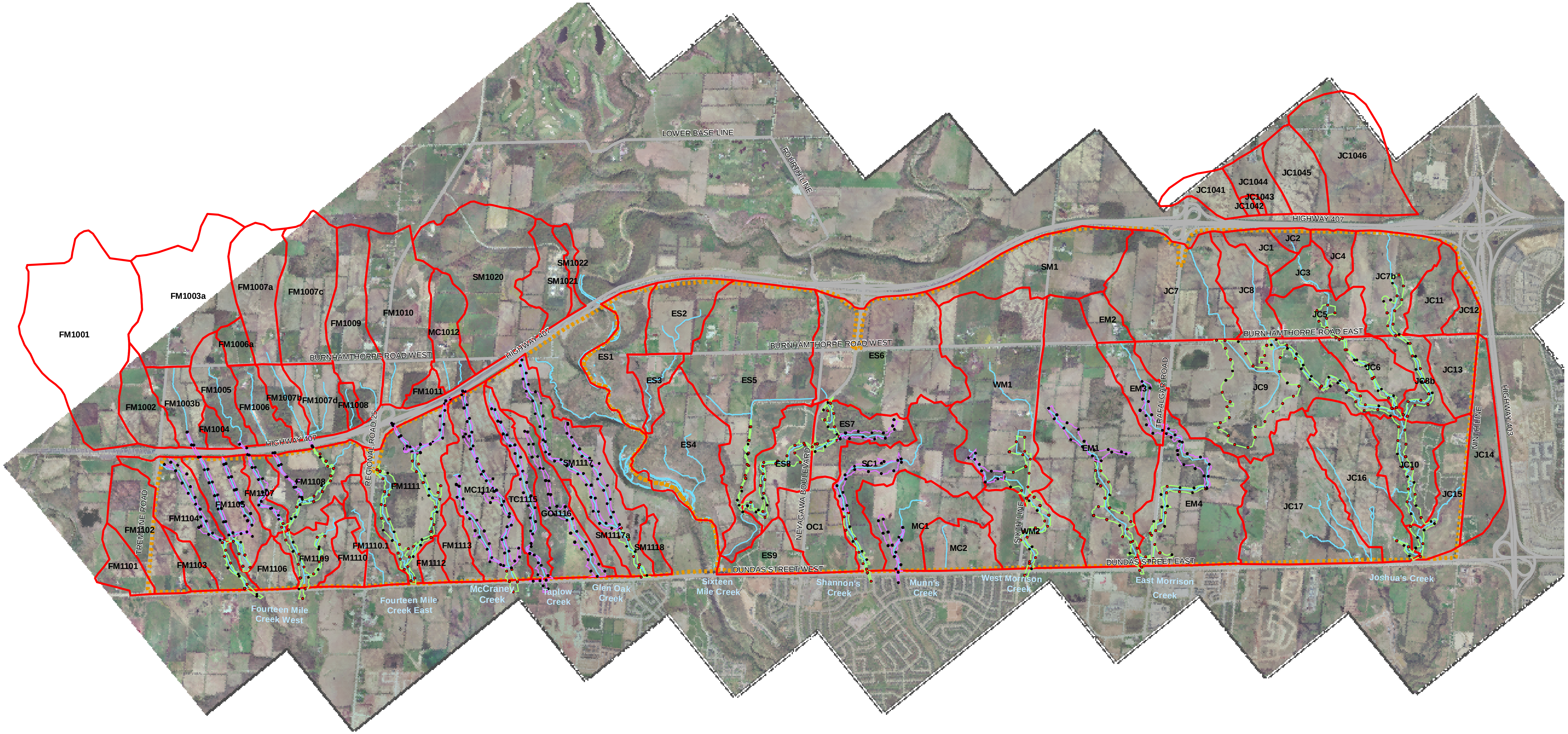
0
Meters

Legend

- ▨ Study Area
- — Road
- — Watercourse
- ☐ Subcatchments
- 🟩 Wetlands
- ▭ Artificial Ponds
- ■ Wetlands contributing to Hydrologic Function
- ▭ Depressional Storage Areas
- ⊙ Pits
- ⬟ Pits Overlapping Wetlands

Depression Storage Related Features

Figure 5.5.2



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N

0

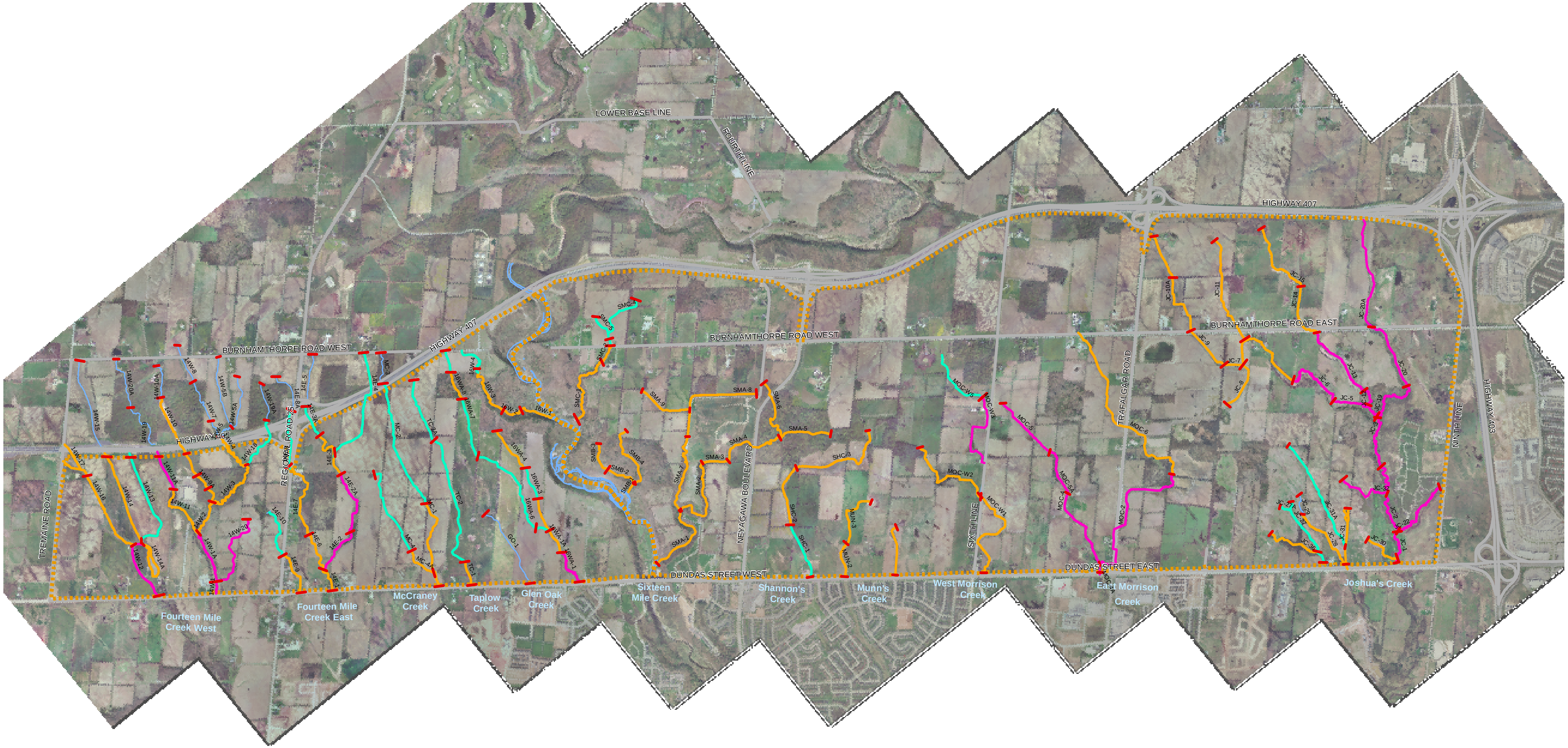
Meters

Legend

- ▨ Study Area
- ─ Road
- ─ Watercourse
- 🟥 Subcatchments
- •─• Floodline (Drainage Area greater 125 ha)
- •─• Floodline (Drainage Area less than 125 ha)

Floodline Mapping

Figure 5.6.1



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0 500
Meters

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Legend

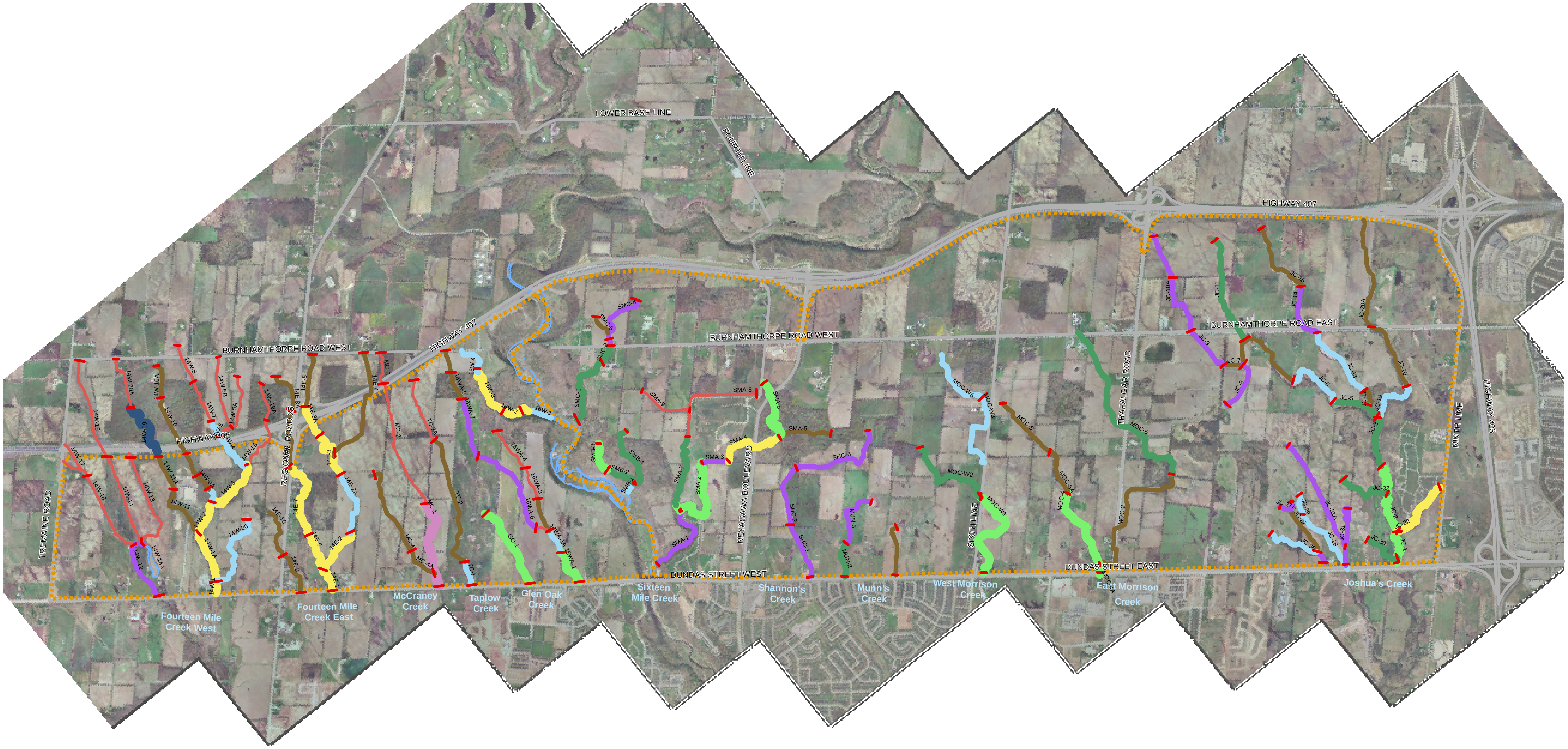
Study Area
Road
Watercourse
Reach Break

Hydrologic Function

High
Medium
Low

Hydrologic Function Classification

Figure 5.6.2



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N

0
Meters

Legend

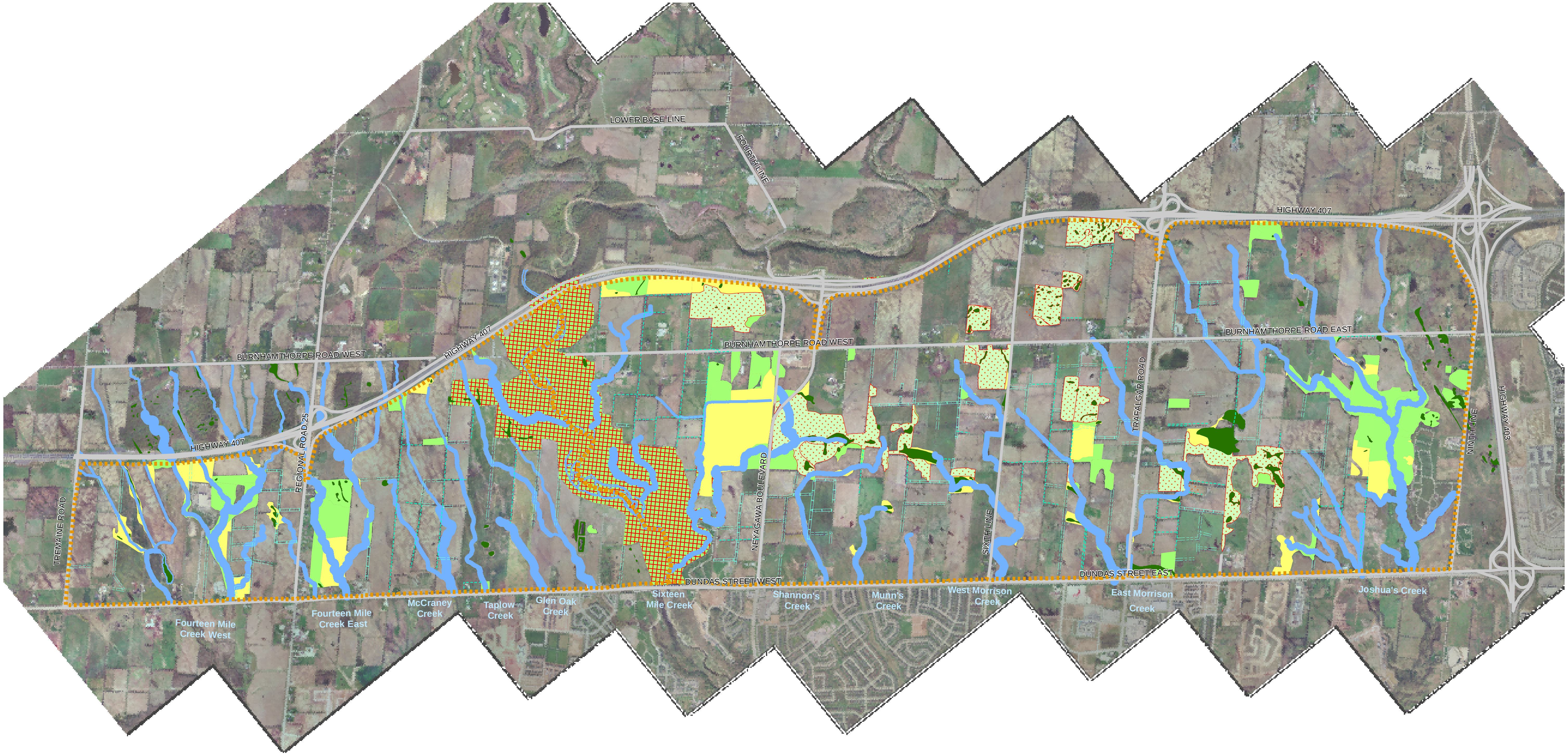
- Study Area
- Road
- Watercourse
- Reach Break

Meander Belt Width (m)

🟥	25
🟫	40
🟪	45
🟦	50
🟩	55
🟨	70
🟩	75
🟦	80
🟪	85

Corridor Widths

Figure 5.8.2



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0
Meters

Legend

- ━ Road
- — Watercourse
- ▨ Secondary Plan Boundary
- 🟩 Wetland
- 🟩 Woodlot
- 🟨 Non-Wooded Terrestrial Features
- ▨ Current ANSI - Earth & Life Science
- ▨ Candidate Life Science ANSI
- 🟦 Stream Corridor

Hedgerow

- Mixed Hedgerow
- Shrub Dominated Hedgerow
- Tree Dominated Hedgerow

Selected Features

Figure 5.9.1

Table 5.4.1 - Hydrologic Cycle, Return Peirod Peak Flow Rates									
Location	Culvert No.	Land Use	Reg. m^3/s	100 year m^3/s	50 year m^3/s	25 year m^3/s	10 year m^3/s	5 year m^3/s	2 year m^3/s
14 Mile Creek									
Dundas St. W.	FM-D1	Existing	0.87	0.31	0.27	0.24	0.18	0.15	0.09
		Future		<------------------		NC	------------------>		
Dundas St. W.	FM-D2	Existing	2.07	0.73	0.64	0.55	0.41	0.33	0.18
		Future	2.83	1.25	1.10	0.96	0.75	0.61	0.37
Dundas St. W.	FM-D3	Existing	0.53	0.19	0.17	0.15	0.11	0.09	0.05
		Future	0.73	0.38	0.34	0.31	0.25	0.22	0.16
Highway 407	FM-1	Existing	6.76	2.42	2.12	1.83	1.40	1.13	0.64
		Future		<------------------		NC	------------------>		
Highway 407	FM-2	Existing	1.33	0.47	0.42	0.36	0.27	0.22	0.12
		Future		<------------------		NC	------------------>		
Burnhamthorpe Rd. W.	FM-B1	Existing	4.33	1.52	1.33	1.14	0.86	0.68	0.37
		Future		<------------------		NC	------------------>		
Highway 407	FM-3	Existing	5.59	1.97	1.72	1.48	1.12	0.89	0.49
		Future		<------------------		NC	------------------>		
Highway 407	FM-4	Existing	0.27	0.08	0.07	0.06	0.04	0.03	0.01
		Future		<------------------		NC	------------------>		
Dundas St. W.	FM-D4	Existing	18.85	6.68	5.85	5.04	3.83	3.05	1.70
		Future	20.58	8.04	7.09	6.17	4.81	3.91	2.38
Highway 407	FM-5	Existing	1.25	0.42	0.36	0.30	0.22	0.17	0.07
		Future		<------------------		NC	------------------>		
Highway 407	FM-6	Existing	1.33	0.44	0.38	0.32	0.23	0.17	0.08
		Future		<------------------		NC	------------------>		
Burnhamthorpe Rd. W.	FM-B2	Existing	2.26	0.81	0.71	0.61	0.47	0.37	0.21
		Future		<------------------		NC	------------------>		
Burnhamthorpe Rd. W.	FM-B3	Existing	2.86	0.98	0.85	0.72	0.53	0.41	0.21
		Future		<------------------		NC	------------------>		
Highway 407	FM-7	Existing	6.99	2.43	2.12	1.81	1.36	1.07	0.56
		Future		<------------------		NC	------------------>		
Highway 407	FM-8	Existing	0.19	0.06	0.05	0.04	0.03	0.02	0.00
		Future		<------------------		NC	------------------>		
Dundas St. W.	FM-D5	Existing	14.39	4.93	4.27	3.64	2.71	2.10	1.05
		Future	16.05	6.05	5.28	4.54	3.45	2.73	1.51
Highway 407	FM-9	Existing	2.60	0.91	0.79	0.68	0.52	0.41	0.22
		Future		<------------------		NC	------------------>		

Table 5.4.1 - Hydrologic Cycle, Return Peirod Peak Flow Rates

Location	Culvert No.	Land Use	Reg. m^3/s	100 year m^3/s	50 year m^3/s	25 year m^3/s	10 year m^3/s	5 year m^3/s	2 year m^3/s
Dundas St. W.	FM-D6	Existing	0.77	0.28	0.24	0.21	0.16	0.13	0.08
		Future	1.06	0.55	0.49	0.44	0.36	0.31	0.22
Dundas St. W.	FM-D6a	Existing	1.14	0.41	0.36	0.31	0.23	0.19	0.10
		Future	1.58	0.75	0.67	0.59	0.47	0.39	0.26
Highway 407	FM-10	Existing	3.66	1.30	1.14	0.99	0.75	0.60	0.34
		Future		<------------------		NC	------------------->		
Highway 407	FM-11	Existing	0.30	0.10	0.09	0.07	0.05	0.04	0.02
		Future		<------------------		NC	------------------->		
Dundas St. W.	FM-D7	Existing	10.77	3.77	3.29	2.82	2.13	1.68	0.90
		Future	12.23	4.68	4.10	3.53	2.69	2.13	1.19
Dundas St. W.	FM-D8	Existing	0.37	0.14	0.12	0.10	0.08	0.07	0.04
		Future	0.51	0.24	0.21	0.19	0.15	0.13	0.08
Dundas St. W.	FM-D9	Existing	0.85	0.31	0.27	0.23	0.18	0.15	0.08
		Future	1.17	0.58	0.52	0.47	0.38	0.32	0.23
McCraney Creek									
Highway 407	FM-12	Existing	1.40	0.50	0.44	0.38	0.29	0.23	0.13
		Future		<------------------		NC	------------------->		
Dundas St. W.	MC-D1	Existing	5.64	2.02	1.77	1.53	1.17	0.93	0.53
		Future	7.19	3.15	2.78	2.44	1.93	1.59	1.01
Taplow Creek									
Dundas St. W.	TC-D1	Existing	1.50	0.53	0.47	0.41	0.31	0.25	0.14
		Future	2.05	0.97	0.87	0.76	0.61	0.51	0.34
Glen Oak Creek									
Dundas St. W.	GO-D1	Existing	2.14	0.77	0.68	0.59	0.45	0.36	0.21
		Future	2.93	1.42	1.27	1.13	0.91	0.77	0.52
West 16 Mile Creek Tribs.									
Dundas St. W.	SM-D1	Existing	3.57	1.25	1.09	0.94	0.71	0.56	0.30
		Future	4.88	2.10	1.85	1.61	1.25	1.01	0.59
Dundas St. W.	SM-D1a	Existing	0.57	0.21	0.18	0.16	0.12	0.10	0.06
		Future	0.79	0.40	0.36	0.32	0.26	0.22	0.16
Dundas St. W.	SM-D2	Existing	0.37	0.13	0.12	0.10	0.08	0.06	0.04
		Future	0.50	0.24	0.22	0.19	0.16	0.13	0.09
Highway 407	SM-1	Existing	5.06	1.76	1.53	1.31	0.98	0.77	0.41
		Future		<------------------		NC	------------------->		
Highway 407	SM-2	Existing	1.32	0.46	0.40	0.34	0.26	0.20	0.11

Table 5.4.1 - Hydrologic Cycle, Return Peirod Peak Flow Rates

Location	Culvert No.	Land Use	Reg. m^3/s	100 year m^3/s	50 year m^3/s	25 year m^3/s	10 year m^3/s	5 year m^3/s	2 year m^3/s
		Future		<-----------------		NC	------------------>		
Highway 407	SM-3	Existing	0.34	0.11	0.10	0.08	0.06	0.05	0.02
		Future		<-----------------		NC	------------------>		
East 16 Mile Creek Tribs.									
Neyagawa Blvd.	ESM-NG3	Existing	5.89	2.12	1.86	1.61	1.23	1.00	0.57
		Future	8.10	3.97	3.56	3.16	2.56	2.16	1.48
Neyagawa Blvd.	ESM-NG2	Existing	1.42	0.44	0.37	0.31	0.21	0.14	0.04
		Future	1.42	0.45	0.38	0.32	0.22	0.15	0.05
Sixteen Mile Creek	----	Existing	16.24	5.55	4.80	4.08	3.02	2.32	1.14
		Future	21.27	9.19	8.09	7.02	5.46	4.40	2.64
Burnhamthorpe Rd. W.	ESM-B14	Existing	1.70	0.59	0.51	0.44	0.33	0.26	0.13
		Future	1.98	0.86	0.77	0.68	0.54	0.45	0.29
Osenego Creek									
Dundas St. W.	OC-D1	Existing	2.01	0.73	0.64	0.56	0.43	0.35	0.20
		Future	2.74	1.33	1.19	1.05	0.85	0.72	0.49
Shannon's Creek									
Dundas St. W.	SC-D1	Existing	3.61	1.26	1.09	0.94	0.71	0.55	0.29
		Future	4.94	2.26	2.00	1.75	1.39	1.14	0.72
Munn's Creek									
Dundas St. W.	MC-D1	Existing	1.35	0.49	0.43	0.37	0.29	0.23	0.14
		Future	1.85	0.92	0.83	0.74	0.60	0.52	0.36
Dundas St. W.	MC-D4	Existing	2.66	0.95	0.84	0.72	0.55	0.45	0.26
		Future	3.63	1.77	1.59	1.41	1.14	0.97	0.66
West Morrison Creek									
Sixth Line	MW-S2	Existing	6.33	2.25	1.97	1.70	1.29	1.03	0.57
		Future	8.66	4.04	3.60	3.16	2.53	2.10	1.37
Dundas St. E.	MW-D3	Existing	8.71	3.11	2.72	2.35	1.79	1.43	0.80
		Future	11.94	5.60	4.99	4.40	3.53	2.94	1.93
East Morrison Creek									
Bunhamthorpe Rd. E.	ME-B1	Existing	0.65	0.23	0.20	0.18	0.13	0.11	0.06
		Future	0.89	0.44	0.39	0.35	0.28	0.24	0.16
Trafalgar Road	ME-T5	Existing	1.96	0.71	0.62	0.54	0.41	0.33	0.19
		Future	2.69	1.34	1.20	1.07	0.87	0.74	0.51
Trafalgar Road	ME-T1	Existing	7.19	2.55	2.22	1.92	1.44	1.14	0.64
		Future	9.90	4.75	4.22	3.74	3.03	2.56	1.71
Dundas St. E.	ME-D2	Existing	15.43	5.42	4.71	4.06	3.02	2.39	1.32

Table 5.4.1 - Hydrologic Cycle, Return Peirod Peak Flow Rates

Location	Culvert No.	Land Use	Reg.	100 year	50 year	25 year	10 year	5 year	2 year
			m^3/s	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s
		Future	21.28	10.06	8.92	7.89	6.34	5.33	3.51
Joshua's Creek									
Highway 407	J - 5	Existing	0.94	0.34	0.30	0.26	0.20	0.16	0.09
		Future		<------------------		NC	------------------>		
Highway 407	J - 6	Existing	0.09	0.03	0.03	0.03	0.02	0.02	0.01
		Future		<------------------		NC	------------------>		
Highway 407	J - 7	Existing	0.07	0.02	0.02	0.02	0.01	0.01	0.01
		Future		<------------------		NC	------------------>		
Highway 407	J - 8	Existing	0.91	0.33	0.29	0.25	0.19	0.16	0.09
		Future		<------------------		NC	------------------>		
Highway 407	J - 9	Existing	1.54	0.56	0.49	0.42	0.32	0.26	0.15
		Future		<------------------		NC	------------------>		
Highway 407	J - 11	Existing	3.71	1.34	1.18	1.02	0.78	0.64	0.37
		Future		<------------------		NC	------------------>		
Bunhamthorpe Rd. E.	JC-B1	Existing	0.55	0.20	0.18	0.15	0.12	0.09	0.06
		Future	0.76	0.40	0.36	0.32	0.26	0.23	0.16
Bunhamthorpe Rd. E.	JC-B2	Existing	1.18	0.43	0.37	0.32	0.25	0.20	0.12
		Future	1.63	0.85	0.77	0.69	0.57	0.49	0.35
Bunhamthorpe Rd. E.	JC-B4	Existing	6.72	2.43	2.14	1.86	1.43	1.16	0.67
		Future	7.81	3.38	3.01	2.65	2.13	1.78	1.17
Bunhamthorpe Rd. E.	JC-B7	Existing	8.11	2.93	2.57	2.23	1.71	1.38	0.80
		Future	9.68	4.34	3.87	3.43	2.76	2.32	1.56
Bunhamthorpe Rd. E.	JC-B9	Existing	1.68	0.60	0.53	0.46	0.35	0.28	0.16
		Future	2.32	1.19	1.07	0.95	0.78	0.67	0.47
Bunhamthorpe Rd. E.	JC-B10	Existing	4.46	1.60	1.41	1.22	0.93	0.76	0.43
		Future	6.15	3.10	2.79	2.49	2.03	1.74	1.22
Dundas St. E.	JC-D1	Existing	42.63	15.13	13.24	11.41	8.68	6.92	3.86
		Future	53.45	23.68	21.37	18.85	15.16	12.69	8.38
Dundas St. E.	JC-D2	Existing	5.82	2.05	1.79	1.54	1.17	0.93	0.51
		Future	7.99	3.71	3.30	2.90	2.31	1.92	1.24

Table 5.4.2 - Hydrologic Cycle, Mean Annual Water Balance Values

			Based on Precipitation from 1962 to 1992			
Location	**GAWSER**	**Land Use**	**Precip.**	**Evapotrans.**	**Runoff**	**Infiltration**
	Hyd. No.		**mm**	**mm**	**mm**	**mm**
14 Mile Creek						
Dundas St. W.	1101	Existing	785	528	227	30
		Future	785	528	227	30
Dundas St. W.	1102	Existing	785	532	205	48
		Future	785	438	306	41
Dundas St. W.	1103	Existing	785	511	244	30
		Future	785	218	560	7
Highway 407	1001	Existing	785	533	219	33
		Future	785	533	219	33
Highway 407	1002	Existing	785	533	217	35
		Future	785	533	217	35
Burnhamthorpe Rd. W.	0031	Existing	785	536	203	46
		Future	785	536	203	46
Highway 407	2019	Existing	785	533	208	44
		Future	785	533	208	44
Highway 407	1004	Existing	785	555	100	130
		Future	785	555	100	130
Dundas St. W.	2034	Existing	785	529	215	41
		Future	785	476	272	37
Highway 407	1005	Existing	785	551	154	80
		Future	785	551	154	80
Highway 407	1006	Existing	785	547	155	83
		Future	785	547	155	83
Burnhamthorpe Rd. W.	0071	Existing	785	532	217	36
		Future	785	532	217	36
Burnhamthorpe Rd. W.	0073	Existing	785	548	174	63
		Future	785	548	174	63

Table 5.4.2 - Hydrologic Cycle, Mean Annual Water Balance Values

Location	GAWSER Hyd. No.	Land Use	Precip. mm	Evapotrans. mm	Runoff mm	Infiltration mm
			Based on Precipitation from 1962 to 1992			
Highway 407	2048	Existing	785	540	191	54
		Future	785	540	191	54
Highway 407	1008	Existing	785	568	83	134
		Future	785	568	83	134
Dundas St. W.	2061	Existing	785	539	182	64
		Future	785	499	225	61
Highway 407	1009	Existing	785	537	201	47
		Future	785	537	201	47
Dundas St. W.	1110	Existing	785	515	240	30
		Future	785	221	557	7
Dundas St. W.	2367	Existing	785	504	230	51
		Future	785	330	417	38
Highway 407	1010	Existing	785	536	214	35
		Future	785	536	214	35
Highway 407	1011	Existing	785	544	168	73
		Future	785	544	168	73
Dundas St. W.	2475	Existing	785	532	203	50
		Future	785	503	233	49
Dundas St. W.	1112	Existing	785	502	249	34
		Future	785	372	391	22
Dundas St. W.	1113	Existing	785	525	230	30
		Future	785	281	494	10
McCraney Creek						
Highway 407	1012	Existing	785	533	211	41
		Future	785	533	211	41
Dundas St. W.	2085	Existing	785	526	224	35
		Future	785	422	336	27

Table 5.4.2 - Hydrologic Cycle, Mean Annual Water Balance Values						
			Based on Precipitation from 1962 to 1992			
Location	GAWSER Hyd. No.	Land Use	Precip. mm	Evapotrans. mm	Runoff mm	Infiltration mm
Taplow Creek						
Dundas St. W.	1115	Existing	785	530	220	35
		Future	785	359	404	22
Glen Oak Creek						
Dundas St. W.	1116	Existing	785	528	228	29
		Future	785	329	442	14
West 16 Mile Creek Tribs.						
Dundas St. W.	2392	Existing	785	535	200	50
		Future	785	466	275	44
Dundas St. W.	1117	Existing	785	527	227	31
		Future	785	257	519	9
Dundas St. W.	1118	Existing	785	524	225	36
		Future	785	317	452	16
Highway 407	1020	Existing	785	541	191	53
		Future	785	541	191	53
Highway 407	1021	Existing	785	543	192	50
		Future	785	543	192	50
Highway 407	1022	Existing	785	551	160	74
		Future	785	551	160	74
East 16 Mile Creek Tribs.						
Neyagawa Blvd.	2124	Existing	785	517	232	36
		Future	785	299	466	20
Neyagawa Blvd.	2127	Existing	785	562	106	117
		Future	785	541	130	114
Sixteen Mile Creek	2137	Existing	785	538	176	71
		Future	785	420	303	62
Burnhamthorpe Rd. W.	2914	Existing	785	538	188	59
		Future	785	391	345	49

Table 5.4.2 - Hydrologic Cycle, Mean Annual Water Balance Values

			Based on Precipitation from 1962 to 1992			
Location	**GAWSER Hyd. No.**	**Land Use**	**Precip. mm**	**Evapotrans. mm**	**Runoff mm**	**Infiltration mm**
Osenego Creek						
Dundas St. W.	2143	Existing	785	520	237	28
		Future	785	333	439	13
Shannon's Creek						
Dundas St. W.	2146	Existing	785	537	195	53
		Future	785	381	362	42
Munn's Creek						
Dundas St. W.	2177	Existing	785	514	242	29
		Future	785	280	493	12
Dundas St. W.	2174	Existing	785	529	223	33
		Future	785	314	454	17
West Morrison Creek						
Sixth Line	2149	Existing	785	520	220	45
		Future	785	360	391	34
Dundas St. E.	2154	Existing	785	517	226	42
		Future	785	352	403	30
East Morrison Creek						
Bunhamthorpe Rd. E.	2160	Existing	785	517	225	43
		Future	785	301	460	25
Trafalgar Road	2165	Existing	785	513	238	34
		Future	785	280	489	16
Trafalgar Road	2170	Existing	785	517	229	39
		Future	785	309	453	23
Dundas St. E.	2171	Existing	785	525	217	43
		Future	785	323	433	29
Joshua's Creek						
Highway 407	1041	Existing	785	532	225	28
		Future	785	532	225	28

Table 5.4.2 - Hydrologic Cycle, Mean Annual Water Balance Values

			Based on Precipitation from 1962 to 1992			
Location	GAWSER Hyd. No.	Land Use	Precip. mm	Evapotrans. mm	Runoff mm	Infiltration mm
Highway 407	1042	Existing	785	523	222	40
		Future	785	523	222	40
Highway 407	1043	Existing	785	530	215	40
		Future	785	530	215	40
Highway 407	1044	Existing	785	523	233	29
		Future	785	523	233	29
Highway 407	1045	Existing	785	529	227	29
		Future	785	529	227	29
Highway 407	1046	Existing	785	525	231	29
		Future	785	525	231	29
Bunhamthorpe Rd. E.	2255	Existing	785	520	232	33
		Future	785	214	562	9
Bunhamthorpe Rd. E.	2252	Existing	785	526	228	31
		Future	785	215	562	8
Bunhamthorpe Rd. E.	2238	Existing	785	na	na	na
		Future	785	na	na	na
Bunhamthorpe Rd. E.	2215	Existing	785	521	231	33
		Future	785	376	387	22
Bunhamthorpe Rd. E.	2225	Existing	785	529	223	33
		Future	785	235	539	11
Bunhamthorpe Rd. E.	2222	Existing	785	523	230	32
		Future	785	257	514	14
Dundas St. E.	2275	Existing	785	524	219	42
		Future	785	373	381	31
Dundas St. E.	2278	Existing	785	529	208	48
		Future	785	365	384	36

Table 5.4.3 - Subcatchment Depression Storage

Subcatchment	Sub Cat. Drainage Area ha	N+A Dep. Area ha	N+A Dep. Vol. m^3	N+A Dep. Depth mm	Natural Dep. Depth mm
FM1101	18.9	-	-	-	-
FM1102	46.6	-	-	-	-
FM1103	11.7	0.347	3,470	29.6	3.9
FM1001	149.4	-	-	-	-
FM1002	29.4	-	-	-	-
FM1104	63.3	0.07	650	1.0	0.0
FM1003a	98.3	0.14	1,390	1.4	0.0
FM1003b	27.4	-	-	-	-
FM1004	7.3	0.04	185	2.5	2.5
FM1105	48.6	0.30	2,195	4.5	2.2
FM1005	30.3	0.46	4,590	15.1	0.1
FM1107	21.6	0.18	1,485	6.9	0.1
FM1007a	50.8	0.12	1,240	2.4	0.0
FM1007b	18.1	0.06	600	3.3	0.0
FM1007c	66.4	0.74	7,400	11.1	0.0
FM1007d	27.5	0.03	340	1.2	0.0
FM1008	5.3	-	-	-	-
FM1006	23.0	-	-	-	-
FM1006a	10.5	-	-	-	-
FM1106	15.18	-	-	-	-
FM1108	59.8	0.33	3,280	5.5	0.0
FM1109	26.7	0.16	805	-	-
FM1009	60.1	-	-	-	-
FM1110	16.9	0.23	1,125	6.7	6.6
FM1110.1	26.2	-	-	-	-
FM1010	80.9	0.01	130	0.2	0.0
FM1011	7.2	0.17	1,720	23.8	11.9
FM1111	99.7	0.39	2,515	2.5	1.3
FM1112	8.5	-	-	-	-
FM1113	18.6	-	-	-	-
MC1012	31.5	0.21	1,435	4.6	2.3
MC1114	94.9	0.57	3,240	3.4	2.6
TC1115	33.6	0.37	1,950	5.8	5.1
GO1116	47.2	0.53	2,630	5.6	5.6
SM1117	83.8	1.90	12,025	14.3	8.3
SM1117a	12.5	-	-	-	-
SM1118	8.0	-	-	-	-
SM1020	116.8	0.42	2,670	2.3	1.3
SM1021	29.9	1.36	13,590	45.5	0.0
SM1022	8.1	0.20	1,990	24.6	0.0
ES1	46.7	0.17	965	2.1	1.7
ES2	39.3	0.23	1,665	4.2	0.3

Table 5.4.3 - Subcatchment Depression Storage

Subcatchment	Sub Cat. Drainage Area ha	N+A Dep. Area ha	N+A Dep. Vol. m^3	N+A Dep. Depth mm	Natural Dep. Depth mm
ES3	18.4	-	-	-	-
ES4	80.6	0.08	415	0.5	0.5
ES6	131.4	2.16	18,370	14.0	2.4
ES7	37.9	0.04	350	0.9	0.0
ES8	42.8	0.16	785	1.8	1.8
ES5	171.0	0.94	8,930	5.2	0.3
ES9	24.7	0.09	890	3.6	0.0
OC1	43.9	0.13	875	2.0	1.0
SC1	84.4	0.29	2,125	2.5	1.0
WM1	146.1	0.52	4,135	2.8	0.7
WM2	54.0	0.14	1,370	2.5	0.0
EM1	190.1	1.10	6,195	3.3	2.5
EM2	14.6	0.15	755	5.2	5.2
EM3	29.1	0.09	710	2.4	0.5
EM4	122.9	0.28	1,420	1.2	1.2
MC1	59.6	0.45	2,420	4.1	3.5
MC2	30.0	0.20	1,010	3.4	3.4
JC1041	20.5	0.00	15	0.1	0.1
JC1042	2.2		-	-	-
JC1043	1.4	-	-	-	-
JC1044	19.8	-	-	-	-
JC2	14.1	-	-	-	-
JC1	16.7	-	-	-	-
JC3	17.9	0.12	580	3.2	3.2
JC1045	33.7	-	-	-	-
JC4	16.8	0.44	4,125	24.5	1.0
JC5	37.0	-	-	-	-
JC6	32.7	0.33	2,350	7.2	0.1
JC7	99.0	0.24	1,195	1.2	1.2
JC8	37.0	0.37	3,190	8.6	7.2
JC9	174.1	0.64	3,700	2.1	1.5
JC1046	81.1	0.29	1,465	1.8	1.8
JC7b	68.4	0.91	5,765	8.4	4.8
JC8b	27.9	-	-	-	-
JC10	48.9	1.45	14,195	29.0	0.1
JC11	26.7	0.11	1,005	3.8	0.4
JC12	12.4	0.10	490	3.9	3.9
JC13	28.5	0.10	495	1.7	0.1
JC14	46.9	0.02	240	0.5	0.0
JC15	40.4	-	-	-	-
JC16	74.3	1.64	13,785	18.6	3.5
JC17	134.5	-	-	-	-
	4,120.8				
Legend	N - Natural		A - Artificial		
	Dep. - Depression		Vol - Volume		

TABLE 5.9.1 – SUMMARY OF HABITAT UNIT CHARACTERISTICS –

Habitat Unit	Presence of Designated Area (ANSI, ESA, PSW)	Size Total, beyond 100, 200 and 300m from edge (ha)	Part of Riparian/Drainage System	VTE species (EXP. END, THR, SC, P)	Regionally Rare Species (R)	Locally Rare Species (L, h)	Number of Native Species	Presence of Rare Vegetation Community	Number of Vegetation Types & Relative Area	Presence of 'Mature' Vegetation Type	Character of Surrounding Habitats/Land use etc.
1	No	Total: 29.9 ha >100 m: 0.2 ha	Wetland; stream (reaches 14W-1,2,3,9,11,18,20)	Plants: 2 P Herpetofauna: 1 SC	Plants: 1	Plants: 11 Birds: 4	Plants: 160 Birds: 68 Mammals: 15 Herpetofauna: 11 Butterflies: 3	No	7; dominated by FOD5-3 and CUM1-1	Yes	Agricultural; abuts highway 407 at north end and industry on west
2	No	Total: 44.6 ha >100 m: 17.5 ha >200 m: 2.7 ha	Wetland; stream (reaches 14E-1,2,3,4,6,7)	Birds: 2 P Butterflies: 1 SC		Plants: 7 Birds: 4	Plants: 112 Birds: 64 Mammals: 9 Herpetofauna: 7 Butterflies: 7	FOD2-3, common coontail herbaceous shallow marsh	14; dominated by FOD7-1 and CUM1-1	Yes	Agricultural with residential on west side
3	Yes	Total: 215.6 ha >100 m: 110.3 ha >200 m: 36.7 ha >300m: 2.4 ha	Wetland; stream (reaches SMB-1,2,3,4; SMA-1,2,7; SMC-1; 16W-1,2,3,4; 16WA-4,8)	Plants: 4 EXP, 7 P (1P?) Birds: 1 END, 1 SC, 4 P Butterflies: 1 SC	Plants: 11	Plants: 45 Birds: 11 Mammals:	Plants: 85 Birds: 113 Mammals: 26 Herpetofauna: 14 Butterflies: 4		Dominated by FOD	Yes	Agricultural
4	No	Total: 7.0 ha	Wetland	Butterflies: 1 SC		Plants: 9 Birds: 3	Plants: 70 Birds: 29 Mammals: 7 Herpetofauna: 3 Butterflies: 3	SWT2-9, leafy pondweed herbaceous shallow marsh	4: dominated by FOD2-4 and CUM1-1	Yes	Agricultural; abuts highway 407
5	No *	Total: 19.0 ha >100 m: 3.3 ha	Wetland	Plants: 1 P	Plants: 1	Plants: 17 Birds: 2	Plants: 122 Birds: 38 Mammals: 8 Herpetofauna: 10 Butterflies: 2	Fringed sedge graminoid shallow marsh	3; FOD1-2 dominant	Yes	Agricultural; close to highway 407
6	No	Total: 8.1 ha	Stream (reach SMA-8)	Birds: 1 END		Plants: 1 Birds: 3	Plants: 22 Birds: 44 Mammals: 9 Herpetofauna: 6 Butterflies: 1	No	3; FOD5-2 dominant	Yes	Agricultural, old landfill to south
7	No	Total: 6.1 ha		Butterflies: 1 SC			Plants: 26 Birds: 13 Mammals: 4 Herpetofauna: 1 Butterflies: 1	No	5; FOD5-2 dominant	Yes	Agricultural

TABLE 5.9.1 – SUMMARY OF HABITAT UNIT CHARACTERISTICS

Habitat Unit	Presence of Designated Area (ANSI, ESA, PSW)	Size Total, beyond 100, 200 and 300m from edge (ha)	Part of Riparian/Drainage System	VTE species (EXP. END, THR, SC, P)	Regionally Rare Species (R)	Locally Rare Species (L, h)	Number of Native Species	Presence of Rare Vegetation Community	Number of Vegetation Types & Relative Area	Presence of 'Mature' Vegetation Type	Character of Surrounding Habitats/Land use etc.
8	No *	Total: 71.8 ha >100 m: 16.6 ha >200 m: 2.1 ha	Wetland; stream (reaches SMA-4,5,6; SHC-3; MOC-W2)	Plants: 2 P Birds: 2 P Butterflies: 1 SC	Plants: 3	Plants: 50 Birds: 7	Plants: 248 Birds: 104 Mammals: 16 Herpetofauna: 11 Butterflies: 10	FOD2-2, three-parted beggar-ticks herbaceous shallow marsh, lake sedge graminoid shallow marsh, great duckweed herbaceous shallow marsh, leafy pondweed herbaceous shallow marsh	24; dominated mainly by FOD5-2 and FOD2-4	Yes	Agricultural, old landfill to west
9	No *	Total: 13.9 ha >100 m: 1.0 ha	Wetland	Butterflies: 1 SC	Plants: 1	Plants: 23 Birds: 2	Plants: 169 Birds: 47 Mammals: 11 Herpetofauna: 11 Butterflies: 2	FOD2-2, eastern manna grass graminoid shallow marsh, fringed sedge graminoid shallow marsh, Tuckerman's sedge graminoid shallow marsh, water parsnip herbaceous shallow marsh	12; dominated by FOD2-2	Yes	Primarily agricultural, adjacent to highway 407, some old field meadow to south
10	No *	Total: 5.0 ha >100 m: 0.1 ha	Wetland	Butterflies: 1 SC	Plants: 1	Plants: 10 Birds: 1	Plants: 120 Birds: 31 Mammals: 9 Herpetofauna: 9 Butterflies: 3	Eastern manna grass graminoid shallow marsh, fringed sedge graminoid shallow marsh, great duckweed herbaceous shallow marsh, leafy pondweed herbaceous shallow marsh	7; dominated by FOD4-1 with small wetland pockets	Yes	Agricultural
11	No *	Total: 13.6 ha >100: 1.8 ha	Wetland	Birds: 1 SC, 1 P		Plants: 5 Birds: 4	Plants: 66 Birds: 52 Mammals: 12 Herpetofauna: 5 Butterflies: 1	Eastern manna grass graminoid shallow marsh	5; dominated by FOD5-2	Yes	Agricultural

TABLE 5.9.1 – SUMMARY OF HABITAT UNIT CHARACTERISTICS

Habitat Unit	Presence of Designated Area (ANSI, ESA, PSW)	Size Total, beyond 100, 200 and 300m from edge (ha)	Part of Riparian/Drainage System	VTE species (EXP. END, THR, SC, P)	Regionally Rare Species (R)	Locally Rare Species (L, h)	Number of Native Species	Presence of Rare Vegetation Community	Number of Vegetation Types & Relative Area	Presence of 'Mature' Vegetation Type	Character of Surrounding Habitats/Land use etc.
12	No *	Total: 10.6 ha >100 m: 0.4 ha	Wetland			Plants: 17	Plants: 159 Birds: 32 Mammals: 10 Herpetofauna: 10 Butterflies: 4	Dry-fresh hickory deciduous forest (FOD2-3), bur oak mineral deciduous swamp (SWD1-2), winterberry organic thicket swamp (SWT3-7), blunt spike-rush graminoid shallow marsh, fringed sedge graminoid shallow marsh, Tuckerman's sedge graminoid shallow marsh, hop sedge graminoid shallow marsh, water parsnip herbaceous shallow marsh	12; dominated by FOD2-3	Yes	Agricultural and reservoir on west side
13	No *	Total: 12.0 ha >100 m: 1.6 ha	Wetland	Herpetofauna: 1 SC	Plants: 1	Plants: 18 Birds: 2	Plants: 131 Birds: 46 Mammals: 14 Herpetofauna: 10 Butterflies: 5	Swamp white oak mineral deciduous swamp (SWD1-1), buttonbush mineral thicket swamp (SWT2-4), fringed sedge graminoid shallow marsh	7; dominated by FOD4-1 and FOD2-4	Yes	Agricultural with cultural thicket and meadow to south
14	No	Total: 12.0 ha >100 m: 0.04 ha	No	Birds: 1 SC		Plants: 7 Birds: 2	Plants: 139 Birds: 41 Mammals: 10 Herpetofauna: 3 Butterflies: 3	Buttonbush mineral thicket swamp (SWT2-4)	4; large area of cultural meadow, followed by thicket and FOD5-7	Yes	Agricultural
15	No	Total: 1.5 ha	No	Herpetofauna: 1 SC		Plants: 2 Birds: 1	Plants: 35 Birds: 16 Mammals: 1 Herpetofauna: 0 Butterflies: 0	No	1; dominated by FOD5-6	Yes	Agricultural

TABLE 5.9.1 – SUMMARY OF HABITAT UNIT CHARACTERISTICS

Habitat Unit	Presence of Designated Area (ANSI, ESA, PSW)	Size Total, beyond 100, 200 and 300m from edge (ha)	Part of Riparian/Drainage System	VTE species (EXP. END, THR, SC, P)	Regionally Rare Species (R)	Locally Rare Species (L, h)	Number of Native Species	Presence of Rare Vegetation Community	Number of Vegetation Types & Relative Area	Presence of 'Mature' Vegetation Type	Character of Surrounding Habitats/Land use etc.
16	No *	Total: 46.2 ha >100 m: 5.5 ha	Wetland; stream (reaches MOC2-2, 6)	Birds: 2 P Herpetofauna: 1 SC,P	Plants: 3	Plants: 37 Birds: 6	Plants: 219 Birds: 95 Mammals: 15 Herpetofauna: 12 Butterflies: 4	Dry-fresh oak – hickory deciduous forest (FOD2-2), swamp white oak mineral deciduous swamp (SWD1-1), bur oak mineral deciduous swamp (SWD1-2), buttonbush mineral thicket swamp (SWT2-4), giant bur-reed graminoid shallow marsh, cursed crowfoot herbaceous shallow marsh, lake sedge graminoid shallow marsh	18; dominated by FOD2-4	Yes	Largely agricultural, some old field meadow
17	No	Total: 6.5 ha	No	Butterflies: 1 SC		Plants: 2	Plants: 29 Birds: 6 Mammals: 6 Herpetofauna: 1 Butterflies: 2	No	2; dominated by FOD7-1	Yes	Old field meadow, adjacent to Trafalger Rd., and Dundas St. E.
18	No	Total: 2.3 ha	Wetland			Plants: 1	Plants: 21 Birds: 28 Mammals: 8 Herpetofauna: 4 Butterflies: 0	Dry-fresh oak – hickory deciduous forest (FOD2-2)	1; FOD2-2	Yes	Agricultural
19	No	Total: 4.2 ha	Wetland; stream (reach JC-15)			Plants: 1	Plants: 31 Birds: 29 Mammals: 8 Herpetofauna: 5 Butterflies: 0	No	2; dominated by FOD5-5	Yes	Old field meadow, adjacent to highway 407
20	No	Total: 7.1 ha	Wetland; stream (reaches JC-27, 27A, 36)			Plants: 1	Plants: 34 Birds: 17 Mammals: 1 Herpetofauna: 0 Butterflies: 2	No	2; approximately equal areas	Yes	Agricultural, adjacent to Dundas St. E.

TABLE 5.9.1 – SUMMARY OF HABITAT UNIT CHARACTERISTICS

Habitat Unit	Presence of Designated Area (ANSI, ESA, PSW)	Size Total, beyond 100, 200 and 300m from edge (ha)	Part of Riparian/Drainage System	VTE species (EXP. END, THR, SC, P)	Regionally Rare Species (R)	Locally Rare Species (L, h)	Number of Native Species	Presence of Rare Vegetation Community	Number of Vegetation Types & Relative Area	Presence of 'Mature' Vegetation Type	Character of Surrounding Habitats/Land use etc.
21/22	No	Total: 68.3 ha >100 m: 13.3 ha	Wetland; stream (reaches JC-3, 5, 6, 7, 12, 13, 19, 20)	Birds: 1 P Butterflies: 1 SC	Plants: 1	Plants: 22 Birds: 8	Plants: 180 Birds: 88 Mammals: 21 Herpetofauna: 10 Butterflies: 4	Swamp white oak mineral deciduous swamp (SWD1-1), buttonbush mineral thicket swamp (SWT2-4), fringed sedge graminoid shallow marsh, water parsnip herbaceous shallow marsh	16; dominated by CUT1	Yes	Mainly agricultural, abuts golf course and cemetery. Habitat Unit 22 adjacent to 9th Line.

P = Provincially rare species ranked as S1-S3
* = Associated with candidate Oakville-Milton Wetlands and Uplands Candidate ANSI

Table 5.9.2. Significant Woodland Evaluation Table

ID	Found Within Habitat Unit	Location	ELC Community		Size (ha)	Size of Interior Forest (ha)	Distance from High/Medium Constraint Stream (m)	Comments	Significant Woodland?
1.0	1	Part of Core 1	FOD2-4, FOD-5-3, FOD5-5	Dry-Fresh Oak-Hardwood Deciduous Forest, Dry-Fresh Sugar Maple-Oak Deciduous Forest, Dry-Fresh Sugar Maple-Hickory Deciduous Forest	13.40	0.20	0.00		Yes
1.1	NA	Between Tremaine Rd and Bronte Rd, adjacent to Hwy 407	FOD5-1	Dry-Fresh Sugar Maple Deciduous Forest	1.27	0.00	0.00	Lies almost entirely in path of LRT	Yes
2.0	2	Part of Core 2	FOD2-3, FOD2-4, FOD7-1, FOD7-2	Dry-Fresh Hickory Deciduous Forest, Dry-Fresh Oak-Hardwood Deciduous Forest, Fresh-Moist White Elm Lowland Deciduous Forest, Fresh-Moist Ash Lowland Deciduous Forest	12.33	0.28	0.00		Yes
2.1	NA	Between Bronte Rd and 16 Mile Creek, adjacent to Hwy 407	FOD5-2	Dry-Fresh Sugar Maple-Beech Deciduous Forest	2.08	0.00	530.00	Lies almost entirely in path of LRT	Yes
2.2	NA	Between Bronte Rd and 16 Mile Creek, 500 m south of Hwy 407	FOD2-4	Dry-Fresh Oak-Hardwood Deciduous Forest	0.85	0.00	378.00	Separated from small forest fragment (< 0.5 ha) further west by buckthorn thicket.	No
2.3	NA	Between Bronte Rd and 16 Mile Creek, adjacent to Dundas St	FOD7-1	Fresh-Moist White Elm Lowland Deciduous Forest	1.08	0.00	0.00	Not a woodland (tree count too low)	Not a woodland
4.0	4	Adjacent to Hwy 407, just east of 16 Mile Creek	FOD2-4	Dry-Fresh Oak-Hardwood Deciduous Forest	4.83	0.00	405.00	Part of it lies in direct path of LRT	Yes
5.0	5	Between 16 Mile Creek and Neyagawa Blvd, north of Burnhamthorpe Rd	FOD1-2	Dry-Fresh White Oak Deciduous Forest	18.42	2.40	615	Part of woodland effected by LRT	Yes
6.0	6	Adjacent to north edge of landfill, west of Neyagawa Blvd	FOD5-2	Dry-Fresh Sugar Maple-Beech Deciduous Forest	3.40	0.00	0.00		Yes
7.0	7	South of Burnhamthorpe Rd, west of Neyagawa Blvd	FOD5-2	Dry-Fresh Sugar Maple-Beech Deciduous Forest	3.85	0.00	120.00	Linkage width widens to incorporate entire woodland.	Yes
8.0	8	East of and adjacent to Neyagawa Blvd	FOD2-2, FOD2-4, FOD5-2, SWD2-2, SWD3-1, SWD3-3, SWD4-2	Dry-Fresh Oak-Hickory Deciduous Forest, Dry-Fresh Oak-Hardwood Deciduous Forest, Dry-Fresh Sugar Maple-Beech Deciduous Forest, Green Ash Mineral Deciduous Swamp, Red Maple Mineral Deciduous Swamp, Swamp Maple Mineral Deciduous Swamp, White Elm Mineral Deciduous Swamp	45.42	9.33	0.00		Yes
8.1	8	Between Neyagawa Blvd and Sixth Line	FOD7-1, SWD3-2, SWD4-2	Fresh-Moist White Elm Lowland Deciduous Forest, Silver Maple Mineral Deciduous Swamp, White Elm Mineral Deciduous Swamp	1.98	0.00	15.00	Separated from Woodland 8 by 94 m	Yes
9.0	9	Adjacent to Hwy 407, just west of Trafalgar Rd	FOD2-2, SWD4-1, SWD4-2	Dry-Fresh Oak-Hickory Deciduous Forest, Willow Mineral Deciduous Swamp, White Elm Mineral Deciduous Swamp	9.20	0.00	750.00	Partly affected by LRT	Yes
9.1	9	Adjacent to Hwy 407, just west of Trafalgar Rd	FOD2-4, FOD7-1	Dry-Fresh Oak-Hardwood Deciduous Forest, Fresh-Moist White Elm Lowland Deciduous Forest	1.34	0.00	605.00	Lies almost entirely in path of LRT; separated from Woodland 9 by 27 m.	No
10.0	10	Between Neyagawa Blvd and Sixth Line, north of Burnhamthorpe Rd	FOD4-1	Dry-Fresh Beech Deciduous Forest	4.38	0.00	295.00		Yes
11.0	11	West and adjacent to Sixth Line, south of Burnhamthorpe Rd	FOD5-2, FOD5-8	Dry-Fresh Sugar Maple-Beech Deciduous Forest, Dry-Fresh Sugar Maple-White Ash Deciduous Forest	11.77	0.80	60.00		Yes
12.0	12	Between Sixth Line and Trafalgar Rd, north of Burnhamthorpe Rd	FOD2-3, SWD1-2, SWD2-2, SWD3-1	Dry-Fresh Hickory Deciduous Forest, Bur Oak Mineral Deciduous Swamp, Green Ash Mineral Deciduous Swamp, Red Maple Mineral Deciduous Swamp	9.53	0.43	790.00	Woodlands are connected by 23 m, therefore considered as one contiguous forest.	Yes
13.0	13	Between Sixth Line and Trafalgar Rd, south of Burnhamthorpe Rd	FOD2-4, FOD4-1, SWD1-1	Dry-Fresh Oak-Hardwood Deciduous Forest, Dry-Fresh Beech Deciduous Forest, Swamp White Oak Mineral Deciduous Swamp	12.00	1.62	520.00		Yes
14.0	14	Between Sixth Line and Trafalgar Rd, south of Burnhamthorpe Rd	FOD5-7	Dry-Fresh Sugar Maple-Black Cherry Deciduous Forest	2.83	0.00	135.00		Yes
15.0	15	Between Trafalgar Rd and Ninth Line, south of Burnhamthorpe Rd	FOD5-6	Dry-Fresh Sugar Maple-Basswood Deciduous Forest	0.96	0.00	320.00		No
16.0	16	Between Trafalgar Rd and Ninth Line, south of Burnhamthorpe Rd	FOD2-4, FOD7-1, FOM2-2, SWD1-1, SWD3-2, SWD4-2	Dry-Fresh Oak-Hardwood Deciduous Forest, Fresh-Moist White Elm Lowland Deciduous Forest, Dry-Fresh White Pine-Sugar Maple Mixed Forest, Swamp White Oak Mineral Deciduous Swamp, Silver Maple Mineral Deciduous Swamp, White Elm Mineral Deciduous Swamp	26.22	0.40	0.00	Woodland is somewhat dissected, but narrow corridors are >20 m wide, therefore considered one contiguous forest.	Yes
17.0	17	East of Trafalgar Rd, adjacent to Dundas St	FOD7-1	Fresh-Moist White Elm Lowland Deciduous Forest	1.4	0.00	220	Adjacent to hydrologic feature.	No
18.0	18	Between Trafalgar Rd and Ninth Line, north of Burnhamthorpe Rd	FOD2-3	Dry-Fresh Hickory Deciduous Forest	2.28	0.00	420.00		Yes
19.0	19	Between Trafalgar Rd and Ninth Line, north of Burnhamthorpe Rd	FOD5-5	Dry-Fresh Sugar Maple-Hickory Forest	2.96	0.00	570.00	Partially impacted by LRT	Yes
20.0	20	Between Trafalgar Rd and Ninth Line, just north of Dundas St	FOD3-2	Dry-Fresh White Birch Deciduous Forest	2.46	0.00	0.00		Yes
21.0	21	Between Trafalgar Rd and Ninth Line	FOD6-5, FOD7-1, FOD7-2, FOM2-2, SWD2-2	Fresh-Moist Sugar Maple-Hardwood Deciduous Forest, Fresh-Moist White Elm Lowland Deciduous Forest, Fresh-Moist Ash Lowland Deciduous Forest, Dry-Fresh White Pine-Sugar Maple Mixed Forest, Green Ash Mineral Deciduous Swamp	25.16	0.83	0.00		Yes
22.0	22	Just west west of Ninth Line, south of Burnhamthorpe Rd	FOD6-2, SWD1-1, SWD4-2	Fresh-Moist Sugar Maple-Black Maple Deciduous Forest, Swamp White Oak Mineral Deciduous Swamp, White Elm Mineral Deciduous Swamp	1.39	0.00	170.00	Separated from small forest fragment (< 0.5 ha) further east by MAM2-1.	No
				Total	222.79	16.29			

Table 5.10.1 - COMPARISON OF ALTERNATIVE AQUATIC HABITAT CATEGORIZATION SYSTEMS (CRITERIA USED)													
Categorization System	**Productive Capacity of Habitat**	**In Direct Contribution of Habitat to Fish Productivity**	**Rarity of Habitat**	**Sensitivity to Development**	**Critical Role in Sustaining Fisheries i.e. Spawning or Nursery Habitat**	**Ground Water Discharge**	**Existing Level of Degradation**	**Supports Threatened or Endangered Species**	**Seasonal Habitat Function**	**Cool vs Warm Water Status**	**Top Level Predator vs Baitfish**	**Intermittent vs Permanent Flow**	**Last Modification**
Provincial Policy Statement	X	X	X	X	X	X	X	X	X				
North Oakville Natural Heritage Inventory LGL 2000				X		X	X	X	X				
DFO Agricultural Drain Classification						X		X		X	X	X	X

Table 5.10.2 – Aquatic Habitat Categorization System

	Habitat Component for Classification						
Stream Categorization	**Rarity of Habitat**	**Sensitivity to Development**	**Function of habitat in sustaining fisheries**	**Ground Water Discharge**	**Existing level of Habitat Degradation and Modification**	**Habitat Supports Threatened or Endangered Species or Species of Concern**	**Coldwater Status**
Critical Habitat	Habitat is rare within the study area (i.e. not found elsewhere)	Highly sensitive to activities associated with urban development (e.g. temperature modifications, SWM discharge, flow modifications, sedimentation)	Plays critical role in sustaining the resident fish community. (i.e. Spawning or nursery habitat)	Ground water discharge present	Channel not been modified or degraded (stream in natural state)	Has been confirmed as supporting redside dace*Considered Survival habitat as per recovery strategy	Habitat is known to support coldwater species
Important Habitat	Habitat is common within the study area	Moderately sensitive to activities associated with urban development	Important but not critical in sustaining the resident fish community (i.e. feeding areas, benthic production areas)	No ground water discharge present	Channel has been somewhat modified or degraded but habitat features remain	Habitat is not known to support VTE species	Habitat is not known to support coldwater species
Marginal Habitat	Habitat is very common within the study area	Not sensitive to activities associated with urban development	Does not contribute directly to the sustenance of the resident fish community.	No ground water discharge present	Channel is highly modified or degraded (no buffer, channelized, or plowed through)	Habitat is not known to support VTE species	Habitat is not known to support coldwater species
No Habitat	No Habitat	No sensitivity	No Habitat	No ground water	No Habitat	No Habitat	No Habitat

* - as per definition of Redside Dace Recovery Strategy (See section 14)

Footnote – when two classification criteria are the same (i.e. Important and Marginal with no ground water) the classification will default to the lowest classing (i.e. Marginal)