OAKVILLE

North Oakville Creeks Subwatershed Study

CHARACTERIZATION REPORT

August 2006

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August 25, 2006

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1.0 INTRODUCTION

1.1 Introduction

To prepare and plan for future urban development in the North Oakville Development Area (north of Dundas Street), the Town of Oakville is preparing a secondary plan for the study area. This area is bounded by Dundas Street to the south, Highway 407 to the north, Ninth Line to the east and Tremaine Road to the west (see **Figure 1.2.1**). This report presents the North Oakville Creeks Subwatershed Study (Subwatershed Study) which was in support of the Secondary Plan, and provides a management strategy to assist in setting policy direction for future development in the watershed. Within the study area, there are a number of catchment areas that are part of the larger individual subwatersheds that drain to the south, outletting to Sixteen Mile Creek or directly to Lake Ontario, that are part of this study. These catchment areas include Joshua's Creek, Morrison Creek, Munn's Creek, Shannon Creek, Osenego Creek, Fourteen Mile Creek, Taplow Creek, Glenn Oak Creek, and Sixteen Mile Creek (including tributaries to Sixteen Mile Creek. The management strategy presents the approach to manage resource use that will protect, rehabilitate, and enhance the environment within the North Oakville Creeks Subwatershed (both upstream and downstream of Dundas Street), and meets the goals and objectives set for the Subwatershed Study.

The purpose of the Subwatershed Study is:

> *"To develop a subwatershed plan that allows sustainable development while ensuring maximum benefits to the natural and human environments on a watershed basis. The subwatershed areas in this study include Joshua's Creek, Morrison Creek, Munn's Creek, Shannon Creek, Osenego Creek, Fourteen Mile Creek, Taplow Creek, Glenn Oak Creek, and Sixteen Mile Creek (including tributaries to Sixteen Mile Creek)."*

A series of goals and objectives have been developed as part of the Subwatershed Study process, which need to be met to achieve the overall study purpose. The goals and objectives relate to the management of the natural resources within the subwatershed, including aquatic resources, terrestrial conditions, fluvial geomorphology, flood and erosion protection, hydrologic and hydrogeologic conditions. The goals and objectives consider the ecosystem within the catchments, and linkages to lands outside the catchments.

The goals and objectives identified for developing a strategy for the North Oakville Creeks Subwatershed recognize the importance of developing a strong framework upon which a management strategy is based. This framework is comprised of an in depth understanding of subwatershed conditions and the ecological, hydrologic and hydrogeologic processes that support and/or influence those conditions. The fundamental characteristics of a subwatershed are a result of all of the resource conditions and processes that occur. Part of these processes is obviously linked to the activities taking place. These include not only ecologically based wildlife activities (aquatic and terrestrial) but also human activities (urban and agricultural). The analysis of a watershed to provide the understanding needed for an effective management approach, and therefore must include an assessment of:

- Watershed characteristics (environmental and land use);
- Natural processes including;
  - Hydrology, hydraulics, and hydrogeology;
  - Fluvial geomorphology;
  - Terrestrial environment (vegetation and wildlife);
  - Aquatic environment (fisheries);
  - Water quality;
  - Riparian systems; and
- Human activities.

In order to develop a management strategy that sets the future direction of the catchements in a fashion that is workable and useful, it must reflect the needs of both the subwatershed ecosystem and the community. Sometimes these needs conflict and, as a result, an approach based upon a sound understanding of the subwatershed is necessary to ensure that the strategy developed is balanced and sustainable.

Initially, the Subwatershed Study focused on lands east of Sixteen Mile Creek. The subwatershed characterization (**Section 4.0**) initially covered only lands east of Sixteen Mile Creek. As the characterization was completed, work was also initiated on the west side of Sixteen Mile Creek within the study area. For that reason, the Characterization sections of this report are divided into two parts.

4E.0 – Characterization – East of Sixteen Mile Creek **(**see **Figure 1.2.1)**
4W.0 – Characterization – West of Sixteen Mile Creek **(**see **Figure 1.2.1)**

The remaining sections of the report, Analysis (**Section 5.0**), Management Strategy (**Section 6.0**) and Implementation (**Section 7.0**), address both the east and west portions of the study area simultaneously.

The study team included Totten Sims Hubicki Associates, Natural Resource Solutions Inc., Parish Geomorphic, Morrison Environmental, and Weatherbe and Associates, with assistance from the Town of Oakville, Halton Region Conservation Authority, Region of Halton, and the Technical Advisory Committee (TAC). A complete listing of the Steering Committee, TAC and study team is provided in **Section 3.2**. The study team acknowledges the Ministry of Natural Resources (MNR) has also been an active participant in the Subwatershed Study.

1.2 North Oakville Creeks Subwatershed

The North Oakville Creeks Subwatershed study area is bounded by Oakville Town limits to the north and east, Dundas Street to the south and Tremaine Road to the west (see **Figure 1.2.1**). The subwatershed area includes Joshua's Creek, Morrison Creek, Munn's Creek, Shannon Creek, Osenego Creek, Fourteen Mile Creek, Glen Oak Creek, Taplow Creek and Sixteen Mile Creek (including tributaries to Sixteen Mile Creek). The headwaters for each of these creeks are located within the areas of analysis, with the exception of Sixteen Mile Creek.

Currently land use is a mixture of agriculture, recreation (golf course and riding stable) and rural residential. The Fourth Line Landfill and the Moore Reservoir are also located within the study area. There are a number of terrestrial features from an environmental perspective including wetland areas, woodlots and the Trafalgar Moraine. Research has shown that terrestrial features play a role in setting the environmental conditions which exist in any watershed. For example, wetland areas store water during rainfall events, and augment base flows in receiving streams during dry periods. The wetlands

and woodlands can provide wildlife habitat and an excellent area for nature viewing, environmental education and aesthetic features to the community.

1.3 Approach to This Study

This Subwatershed Study provides a management strategy (within the context of land use changes) for the protection, enhancement and rehabilitation of natural environment features and their function. As outlined in **Figure 1.3.1**, there are four major phases in a subwatershed plan.

Phase I – Involves establishing the form, function and linkages of the water and related environmental resources. This is done by examining environmental features and functions (*e.g.,* soils, climate, groundwater, surface waters, river systems, habitats, and wildlife) and how they interrelate.

Phase II – Further characterization of subwatershed and data collection (based on the focus provided by Phase I). Detailed analysis of processes that influence watershed characteristics. Impact analysis of land use changes and analysis of effectiveness of management scenarios.

Phase III – Development of a management strategy and implementation plan.

Phase IV – Implementation and monitoring plan and evaluation/modification of the management strategy.

The sections of this report follow the four phases outlined above, and are covered in the following sections: **Section 4.0 – Characterization** focuses on Phase I; **Section 5.0 – Analysis** covers Phase II; **Section 6.0 – Management Strategy** discusses Phase III; and **Section 7.0 – Implementation Plan** details Phase IV.

1.3.1 Study Goal and Objectives

The project requirements are outlined in the Study Terms of Reference included in **Appendix A.** This includes a listing of the goals and objectives to be met in carrying out the Subwatershed Study. A summary of the study goals and objectives is outlines as follows.

Study Goal

- To develop a management plan for North Oakville Creeks Subwatershed which considers the natural resource features and provides for future uses in the subwatershed that recognize these features and will protect and enhance environmental conditions.

Study Objectives

- To develop a management plan for North Oakville Creeks Subwatershed such that the watershed goals and objectives can be met in view of the combined impacts of all land use and land use changes existing or expected in this watershed. Such impacts include urban development, regional/municipal service infrastructure, rural residential development, recreation (*e.g.,* golf courses), and agriculture.
- To streamline land use planning and approvals by determining the boundaries of areas that are regulated or set aside from development based on Provincial and Municipal Policies and Legislation including:
  - Provincially Significant Wetlands (PSW);

  - Environmentally Sensitive Areas (ESAs); and
  - Floodplains.
- To integrate the Subwatershed Planning process with other related processes:
  - Secondary Plans;
  - Comprehensive Environmental Impact Studies under the Provincial Policy Statements;
  - Class Environmental Assessments for Water Management and Municipal Works; and
  - Community Plans.
- To develop an integrated watershed plan that will provide guidance to local and regional governments in planning future land use, infrastructure, and resource development while at the same time protecting and enhancing the environment. The goals of such a plan will be refined through the Subwatershed Process and will include measures:
  a) To protect, restore and enhance groundwater quantity and quality especially regarding the Town of Oakville water supply;
  b) To conserve, protect and restore the natural land, water, forest, and wildlife resources of the North Oakville Creeks Subwatershed;
  c) To restore, protect and enhance water quality and associated aquatic resources and water supplies;
  d) To minimize the threat to life and the destruction of property and natural resources from flooding and erosion, and preserve natural floodplain hydrologic functions;
  e) To ensure public participation in the planning, development, implementation, and monitoring of the watershed management plan;
  f) To provide information on natural heritage features and areas which assist municipalities in addressing the Provincial Policy Statements, while respecting the rights of individual landowners; and
  g) To identify stewardship opportunities for the watershed.

Study Steps

The study approach is illustrated in **Figure 1.3.2**, and outlined as follows:

- Review background information and develop a summary including:
  - Topographic mapping, air photos, and resource maps;
  - Relevant study reports;
  - Servicing information;
  - Discussion with agencies;
  - Available field information (*e.g.,* environmental, streamflow, and groundwater);
- Prepare a list of reference material;
- Carry out site reconnaissance and collect field data;
- Carry out analysis to characterize subwatershed;
- Prepare a characterization report;
- Work with steering committee, TAC and hold Open House meetings to solicit input;
- Prepare an issues summary and vision;
- Carry out additional field work and detailed analysis of subwatershed conditions;
- Prepare an analysis report;
- Develop a preliminary management strategy;
- Analyze potential impacts of urban land use conditions;
- Identify management needs;
- Develop a management strategy; and
- Prepare and implementation plan.

1.4 Report Structure

The sections and information provided in this report are as follows.

Section 1.0 Outline of purpose of study and approach
Section 2.0 Discussion on subwatershed planning in general and legislative framework
Section 3.0 Outline of the public participation process followed and summary of discussions
Section 4.0 Characterization of North Oakville Creeks Subwatershed
Section 5.0 Watershed Analysis
Section 6.0 Management Strategy
Section 7.0 Implementation Plan

1.5 Sources of Information

1.5.1 Introduction

During the initial phase of this Subwatershed Study, background information was collected and reviewed. This provided a portion of the information for characterization of the catchments. Through this review, the type and amount of additional information to permit the characterization of the catchments was determined and steps carried out to collect it as part of this Subwatershed Study.

1.5.2 Natural Environment Information

The background information collected and reviewed included reports, other information such as existing field data, as well as information collected through discussions with various agencies and other groups (*e.g.,* university research groups).

The reports that were collected and reviewed are listed in **Appendix B**. Generally, the information collected and reviewed included:

- Topographic mapping;
- Aerial photography;
- Natural heritage and environmental mapping (terrestrial and aquatic);
- Geologic and hydrogeologic characterization maps and reports;
- Well records and other borehole data;
- Background reports related to:
  - Watershed and subwatershed studies;
  - Environmental Characterization;
  - Hydrogeology and geology;
  - Fluvial geomorphology;
  - Land use planning documents;
  - Servicing reports;
  - Landfill reports;
- Climatic data;
- Past hydrologic models developed;
- Relevant flow data; and
- Information related to external ecological linkages.

Discussions were held with all involved external agencies and groups to collect relevant data. This included: Conservation Halton; Region of Halton; MNR; Department of Fisheries and Oceans (DFO), and the University of Guelph, Department of Zoology.

Independent field data was collected by the study team to enable the characterization and analysis of the catchments, including development of a management strategy.

1.5.3 Land Use

Information on planned land use is readily available from planning documents which are applicable to the Town of Oakville. Available planning documents, including the Region of Halton and Town of Oakville Official Plans (OPs), and the Official Plan Amendment No. 198 (OPA 198), with related schedules (including servicing), were reviewed. The Town's draft North Oakville East Secondary Plan and the conceptual land use plan for North Oakville West were also reviewed. The available information on planned land use has been used in this phase of the study as it relates to environmental background data. It will also be used in the impact analysis to be carried out in the next phases.

2.0 SUBWATERSHED PLANNING

2.1 Subwatershed Management Strategy

Subwatershed management is intended to augment the land use planning process, as well as provide for sound management of environmental conditions and natural resources. Subwatershed plans are based on natural drainage boundaries instead of political boundaries.

Watershed management is an evolving science. The evolution of the science is a response to the recognized need to manage our resources and guides future land use decisions. New management philosophies and tools are being developed to provide the most effective approach. The common thread through this evolution is that a broad perspective is needed to ensure that the plan meets environmental and societal needs. It is important that watershed management recognizes environmental, social and economic conditions to ensure that all three elements are included and provide a "balanced" approach.

Public participation is a critical component of subwatershed planning. Although a comprehensive, blended (economic, social, and environmental) approach is necessary, community needs and values should be taken into account in developing a management strategy. This will assist in facilitating acceptance of the strategy and provide a sustainable plan.

A recent evolution of watershed management is the recognition of the need to provide an adaptive environmental management (AEM) approach. Management strategies should encompass refinement of management tools and approaches, and changes in societal characteristics and needs. A management strategy must provide a direction to follow, but just as importantly it must have flexibility built in so that modifications and "fine tuning" can be carried out.

A monitoring plan is one of the critical elements of a management strategy with specific targets set to be monitored. This is then used to measure the effectiveness of the management strategy in meeting the goals (and targets set). If the targets are not being met, modifications can be made to ensure that the management strategy goals can be followed.

Given the comprehensive and complex nature of the watershed, an ecosystem approach is required in developing a management strategy. The watershed ecosystem is made up of the wildlife, vegetation, people and physical landscape that occupies the watershed, and by the processes that link these components. Degradation of the quality of any of these components will affect the entire ecosystem. For example, if water is polluted and streamflows are depleted, it will have a negative impact on fish. If woodlots and wetlands are removed, there will be a loss of wildlife habitat.

The hydrologic cycle diagram (**Figure 2.1.1**) shows the major components of a watershed ecosystem, the linkages between components and the major functions or processes that control the shape and quality of the watershed resources.

The major connecting link in a watershed ecosystem is the flow of water. This flow pattern is called the water budget. How and where the water flows determines the quality of the water, the shape and stability of streambanks, the health and diversity of the vegetation, and the availability of fish and wildlife habitat. In a relatively natural watershed, the flow of water is controlled by topography, soil type, and vegetation. As human use of a watershed increases, all of these characteristics can change altering the water budget. The changed water budget then results in changes in the quality of ground and surface water, the size and shape of stream channels and the stability of streambanks, vegetation cover and fish and wildlife habitat. These unintentional changes caused by the change in water budget often reduce the ability of the human

population to use and enjoy the resources of the watershed.

The ecosystem approach requires description of ecosystems, description of stresses on the ecosystems and identification of indicators of the health of the ecosystem and the impact of the stresses. An integrated set of policies and management practices must be developed which considers people as an integral part of ecosystems. This is in contrast to the more common approach of relating environmental resources to an independent human population and set of policies. Inherent in the ecosystem approach is the concept of carrying capacity. The application of the concept of carrying capacity requires an attempt to understand the limits of an ecosystem's ability to support various life forms and land use activities. Human activities are then managed in a way that does not exceed these natural limits. When the carrying capacity is respected, the ecosystem remains healthy. When the natural limits are exceeded, the health of the ecosystem declines. The ecosystem approach used in this watershed study used the concepts of carrying capacity and ecosystem health in evaluating land use scenarios and watershed management options.

The major requirement, as well as the major benefit, of the ecosystem approach is that the people planning for human modification of the ecosystem have a basic conceptual understanding of the way in which the ecosystem functions and can anticipate, with some degree of confidence, the impact of human activities on ecological functions.

2.2 Subwatershed and Municipal Planning

Planning for the protection and conservation of natural resources and the management of land pattern Planning for the protection and conservation of natural resources and the management of land pattern change within the Oakville North Creeks Subwatershed is the responsibility of landowners, Provincial Agencies, Conservation Halton, Halton Region and the Town of Oakville. Authority for such land use planning is provided by the Planning Act (R.S.O. 1990) of Ontario.

The primary method of planning at the municipal level is the OP. This is a legal document that is used by council and land owners as a decision making guide. The OP sets out objectives and policies that establish the basis for land pattern change and for protecting and conserving natural resources. To implement the OP's policies and objectives, municipalities pass zoning by-laws which establish certain land use rights, and restrictions, on individual properties. Area municipalities approve the creation of new lots and their supporting services through plans of subdivision and consents to sever.

Conservation Halton functions under the Conservation Authorities Act. One of the main purposes is to conserve and protect water-oriented natural resources throughout Halton Region. The implementation of subwatershed studies as complete plans falls to area municipalities through their OP process and land owners.

2.2.1 Current State of Planning

The following summary of the status of planning in the Oakville North Creeks Subwatershed provides a context for understanding how subwatershed planning objectives can be implemented by various government institutions.

- The Government of Ontario has put into place a Provincial Policy Statement that provides direction in achieving sound environmental objectives in the subwatershed. Additional legislation exists that applies to the development and implementation of subwatershed plans, including: Environmental Protection Act, Environmental Assessment Act, Planning Act, and Conservation Authorities Act.

- Within the subwatershed, growth and development is primarily controlled and directed by the Region of Halton and the Town of Oakville OPs and the Town's Zoning By-law. Among other matters, these policies and regulations, together with the Provincial Policy Statement, are designed to provide reasonable protection for significant natural areas such as floodplains, Environmentally Sensitive Areas and Provincially Significant Wetlands against changes in the use of land either in or adjacent to them.

- The Town's existing OP was recently amended by OPA 198. This amendment incorporates the lands north of Dundas Street into Oakville's urban area as identified in Regional OPA 8. OPA 198 establishes conditions for the development of the lands north of Dundas Street, including the protection and enhancement of natural features. The amendment also provides direction with respect to matters such as general development objectives, planning period, planned population, and employment levels and phasing.

2.2.2 Legislative Framework

There is a broad framework of legislation that regulates land use and other activities within a watershed and along streams. The current framework for watershed planning is illustrated in **Figure 2.2.1** and legislation related to issues is outlined in **Table 2.2.1**.

Table 2.2.1
Ontario Policies and Regulations Related To Watershed Planning

Problem/Issue	Legislation/Policy Document	Administered By
• Flood Protection Stormwater Conveyance Design	• Municipal Act	MMAH
	• Planning Act	MMAH
	• Building Code Act	MMAH
	• Conservation Authorities Act and Related Regulations	MNR, CA
	• Lakes and Rivers Improvement Act	MNR
	• Navigable Waters Protection Act	TC
	• Floodplain Criteria (1982)	MNR
	• Beds of Navigable Waters Act	MNR
	• Drainage Act	OMAFRA
	• Public Lands Act	MNR
	• MTO Drainage Manual	MTO
• Sediment Control During Construction	• Municipal Act	MMAH
	• Conservation Authorities Act	MNR, CA
	• Endangered Species Act	MNR
	• Environmental Protection Act	MOE
	• Lakes and Rivers Improvement Act	MNR
	• Ontario Water Resources Act	MOE
	• Environmental Contaminants Act	EC
	• Fisheries Act	DFO
• Fisheries Protection	• Endangered Species Act	MNR
	• Fisheries Act	DFO
• Bacteria Control	• Environmental Protection Act	MOE
	• Ontario Water Resources Act	MOE
	• Environmental Protection Act	EC
• Water Quality (Aesthetics)	• Pesticides Act	MOE
	• Environmental Protection Act	MOE

Table 2.2.1
Ontario Policies and Regulations Related To Watershed Planning

Problem/Issue	Legislation/Policy Document	Administered By
	• Ontario Water Resources Act	MOE
	• Environmental Contaminants Act	EC
• Watershed Planning	• Conservation Authorities Act	MNR, CA
	• Crown Timber Act	MNR
	• Drainage Act	OMAFRA
	• Endangered Species Act	MNR
	• Environmental Assessment Act	MNR
	• Environmental Protection Act	MOE
	• Forestry Act	MNR
	• Game and Fish Act	MNR
	• Historical Parks Act	MCCR
	• Lakes and Rivers Improvement Act	MNR
	• Municipal Act	MMA
	• Ontario Planning and Development Act	MMA
	• Ontario Water Resources Act	MOE
	• Aggregate Resources Act	MNR
	• Planning Act	MMA
	• Trees Act	MNR
	• Woodlands Improvement Act	MNR
	• Canada Waters Act	EC
	• Canada Wildlife Act	DFO
	• Navigable Waters Protection Act	TC
	• Provincial Policy Statement	MMAH

Agencies:

MMAH	-	Ministry of Municipal Affairs and Housing
MNR	-	Ministry of Natural Resources
CA	-	Conservation Authority
TC	-	Transport Canada
OMAFRA	-	Ontario Ministry of Agriculture and Food
EC	-	Environment Canada
DFO	-	Department of Fisheries and Oceans
MOE	-	Ministry of the Environment
MTO	-	Ministry of Transportation

Note: Both the 1997 and the 2005 PPS were reviewed in the preparation of this study. Guidance was also taken from the environmental policies of Regional Official Plan amendment 25 and the associated background reports. The Natural Heritage Reference Manual was also reviewed.

3.0 COMMUNITY PARTICIPATION

3.1 Introduction

Community participation is a key requirement in developing a subwatershed management strategy. Since the management strategy will guide the future environmental and aesthetic conditions in the subwatershed, it is important that the community has input in the decision making process and that the strategy reflects the goals of the overall community (society needs).

The Subwatershed Study included public participation for the purpose of identifying the key issues, developing a vision and objectives, discussing analysis findings for characterization and development of a management and Greenspace strategy.

3.2 Community Participation Process

Community participation was provided for through the study process, and was included as part of the process, through a number of methods. The overriding process used to facilitate input by key stakeholders included the Technical Advisory Committee (TAC) for the duration of the study.

A TAC was established to provide technical support and guide the development of a management strategy for the North Oakville Creeks Subwatershed. The committee includes representatives of the community, staff members from the agencies that are most active in the management of catchments, advisory committee members, development group representatives and key members of the study consultants, plus the MNR on occasion. A summary of the discussion held at the TAC meetings provided in the following sections with additional notes in **Appendix C.**

Other activities and methods used to provide for participation included:

- **Public Meetings** – Held at specific points throughout the study as illustrated in **Figure 1.3.2**;
- **Steering Advisory Committee** (SAC) – Formed by the Town to meet on a regular basis and provide input to the overall secondary planning process. Periodic discussions were held with this committee to provide updates on the Subwatershed Study, the process, and receive input;
- **Council Meeting**s – Periodic presentations were made to Town Council to provide updates, and receive input, to the Subwatershed Study; and
- **Design Charette** – A design charette was held to provide input to both the secondary plan and subwatershed plan development.

3.3 Subwatershed Plan Items Raised During Public Participation

A number of items and comments to be considered in carrying out the Subwatershed Study and in developing a management strategy were raised during the community participation process.

These items were considered in the development of the subwatershed plan, and most were already included in the study goals and objectives. The items of consideration are summarized as follows.

- It was recognized that the portions of the catchments within the secondary planning area were headwater systems. Concerns regarding what approach was needed to effectively manage the ground and surface water as source areas were raised.

- Many of the items of concern were raised as questions:

  - What roles or functions do current resource features play (wetlands and streams), and what is their relative importance (*i.e.,* priority) in the overall ecosystem of the subwatershed?
  - How can development proceed in a sustainable manner?
  - What is the state of water balance in the subwatershed?
  - What is the connectivity between surface water, groundwater and wells within the subwatershed and adjoining watersheds now and in the future?
  - What management is necessary to protect, rehabilitated and enhance environmental conditions?
  - What is the potential for non-point source contaminant loadings (*i.e.*, nutrient or pesticide)?
  - What are the recharge areas and infiltration rates as well as groundwater use potential?
  - What are the potential impacts of land use on the subwatershed and streams?
  - What should the targets be to protect and enhance the subwatershed?
  - What should the Best Management Plan and Stormwater Management (SWM) guidelines be?
  - Are there any additional ESA\Environmental Protection Area (EPA) that require designation?
  - What are the potential trails and connections and associated compatibility with natural heritage linkages?
  - What is the current state of fishery and protection/enhancement needs?
  - What are the rehabilitation opportunities?
  - What should the community role be in developing a plan?

- The Sixteen Mile Creek valley dominates the central part of the secondary planning area. This area has been well-studied in the past and has been designated as both an ESA and a regionally significant Area of Natural and Scientific Interest (ANSI). These plus other constraint lands have been outlined in the Strategic Land Use Study. This study however does not address linkages to stream corridors and the analysis of stream systems does not include fluvial geomorphology in the assessment. An expanded assessment of stream processes and linkages to terrestrial features is needed in the Subwatershed Study.

- The Sixteen Mile Creek Valley and associated woodlands were identified in the North Oakville Natural Heritage Inventory and Analysis (NONHIA) (LGL *et al*., 2000) as Environmental Protection 1 lands. In the NONHIA report, as well as subsequent studies by Ecoplans (2001) as well as Hemson *et al.* (2000), these lands were identified as areas that should not be developed. A number of the woodlands in the central portions of the study area have also been identified as significant natural features. The Morrison Creek channel was identified as requiring protection for redside dace.

- A number of the smaller woodlands have been categorized as Environmental Protection 2 features in NONHIA. A number of these features have been described as Category 4 features which are "ecological/linkage restoration opportunity or other natural feature to be acquired or integrated (where possible)". Like the Environmental Protection 1 features, these areas are recommended for retention.

- Many of the tributaries in the study area have been described as systems that have been highly altered and disturbed due to historical agricultural land use practices in their catchments. Limited riparian cover, stream bed down cutting, bank erosion and sediment deposition zones were evident in many of the systems. In some cases the watercourses are described as poorly defined swales

and ditches that do not support fish habitat due to a combination of factors including limited intermittent flows, poor or no channel definition, and substrate/cover limitations.

- Variable width creek blocks have been recommended in past studies. Additional field surveys will be required to document specific characteristics of these reaches in order to further understand whether the reaches can be modified and what size of buffers would be required. This analysis must focus on the investigation of all streams as part of their function as headwater streams. Their function from a recharge/discharge function, linkage to terrestrial feature, source and fluvial geomorphologic function must be considered, as well as potential for enhancement to provide full protection to the subwatershed.

- It is important to recognize that the Oakville North area is primarily in the headwater of these stream systems (except for the Sixteen Mile Creek main branch). It will be critical to properly account for the function of these headwater streams from a hydrologic, aquatic, fluvial geomorphologic, terrestrial linkage, and hydrogeologic standpoint in developing a management approach.

- Problems currently exist in the downstream sections of the watercourses in the form of flooding, erosion, and water quality/aquatic impacts. Recent investigations of Fourteen Mile Creek and Munn's Creek demonstrate the importance of evaluating the entire watersheds (upstream and downstream of Dundas Street) in this study to fully understand potential impacts and SWM needs.

- Pertinent issues in this study are maintenance of water budgets, channel function, and identification and preservation of a channel network within appropriate corridors. A focused emphasis of the study will need to be characterization of each distinct stream corridor.

- From a stream morphology perspective, existing conditions must be inventoried and analyzed under future development scenarios, to identify an effective approach for protection. Specifically, the integration of channel morphology with fish habitat quality, and flow regime maintenance is the philosophical synthesis of these objectives.

- The Trafalgar Moraine is a topographic feature located along the north end of the North Oakville lands. It forms a local surface water divide, separating East Sixteen Mile Creek from the smaller creeks that have their headwaters in the area south of the moraine crest.

- From a groundwater perspective, there are three main issues to be addressed:
  - Under existing conditions, what groundwater resources are present in the study area and how does the groundwater system contribute to the ecology of the area, including the contribution to flow in local streams?
  - What role/function does the Trafalgar Moraine have with respect to groundwater flow, interaction with the surface water system, and water quality?
  - What are the opportunities and constraints that will affect groundwater resources in the study area?

- Although assumptions have been made about the interactions between the surface water systems and the groundwater regime in the study area, the specific relationships at the subwatershed level are not well documented. Therefore, important components of the flow regime, such as the groundwater contribution to streamflow, have not been well quantified. Further site specific work is needed to refine our understanding of local groundwater conditions and to identify the constraints and opportunities for the future development in the area.

- The remnant vegetation within the North Oakville Creeks Subwatershed displays a typical pattern for southern Ontario. Remnant stands of upland and lowland forest are found associated with the larger valley systems (especially Sixteen Mile Creek and Joshua's Creek), while little vegetation is left along many of the smaller creek systems. This results in predominantly north-south oriented bands of remnant vegetation. Remnant upland forest blocks are also found arrayed along the backs of lots in a patchwork of rectangular stands left from forestry or maple syrup production. This pattern of vegetation is found throughout the historically agricultural dominated portions of Ontario, and has significant implications on local Natural Heritage System identification, delineation and restoration potential.

- Remnant wetlands are found associated with some watercourses as well as in depressions with relatively impermeable soils.

- The headwaters of many of the creeks are found within the study area (*i.e.,* north of Dundas Street/Regional Road 5). In many of the background documents, it was recognized that year-to-year fluctuations had a great influence on the description of the systems (especially whether the creek reaches were intermittent or perennial). In many of the smaller stream reaches, insufficient site-specific information is available to make definitive statements about existing or potential habitats.

- A number of rare species have been reported from the study area, many of which are associated with the larger habitat blocks along the Sixteen Mile Creek corridor. However, a number of possible or probable records of significant species were also reported from some of the more isolated habitats patches, such as those associated with Morrison Creek.

- Redside dace has been historically reported from a number of the reaches downstream of the study area (*e.g.*, Morrison Creek), but have not been found during recent studies.

- The implications of recent land use change (especially the construction of the Highway 407 corridor) on issues such as local wildlife movements and drainage need to be understood.

- The relationship between ground and surface water resources and vegetation communities and aquatic habitats, including the potential for habitat enhancement or restoration, needs to be further investigated.

- The Subwatershed Study is to provide the necessary resource information to 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 process. Current servicing information (sanitary, water, and roads) is to be considered as well as corresponding issues.

4E.0 NORTH OAKVILLE CREEKS SUBWATERSHED (East of Sixteen Mile Creek)

4E.1 Introduction

The study area, east of Sixteen Mile Creek, is bounded by the Town limits to the east, Highway 407 to the north, by Dundas Street to the South and by Sixteen Mile Creek to the west (see **Figure 4E.1.1**). This Subwatershed Study focuses on the catchment areas of the subwatersheds within the study area. However consideration is also given to the areas of the subwatersheds outside of the study area to provide for a comprehensive understanding of subwatershed conditions and processes. The subwatersheds included east of Sixteen Mile Creek are tributaries to Sixteen Mile Creek, Osenago Creek, Shannon's Creek, Manns Creek, West Morrison Creek, East Morrison Creek, and Joshua's Creek.

A detailed discussion of the existing land uses, environmental features, and processes affecting those features is outlined in the following sections. This "characterization" is based on background data, field information collected, and initial analysis of that data and information.

4E.2 Land Use

The existing land use throughout the study area is predominantly agricultural, but includes scattered wooded areas. Some rural residential development also exists along the major roads in the study area, and there are limited commercial/industrial uses, including some commercial recreation uses (*e.g.,* golf courses and riding stables). The Fourth Line Landfill (now closed) and the Moore Reservoir are also contained within the study area boundaries.

OPA 198 designates the lands north of Dundas Street as an urban area. OPA 198 has been approved by the Ontario Municipal Board and adopted by Council, but does not have final approval. The Town has adopted a position in response to appeals by certain landowners of their application to amend the official plan for North Oakville, east of 16 Mile Creek (Draft North Oakville East Secondary Plan). The Town has also prepared a conceptual land use plan for the lands in North Oakville West (the North Oakville West Conceptual Land Use Plan). Both the Draft North Oakville East Secondary Plan and the North Oakville East Conceptual Land Use Plan were used in this Subwatersheds Study. These Plans are found at **Figure 4E.2.1**.

4E.3 Physiography and Geology

4E3.1 Physiography

The study area is entirely within the South Slope Physiographic Region of southern Ontario (Chapman and Putnam, 1984). The South Slope includes the strip of land between the Lake Iroquois shoreline to the south and the Peel Plain to the north.

The glaciers that covered Ontario more than 10,000-years ago left a variety of deposits and landforms across the province, including Halton Region. One of the more common soil types left by the glaciers was till, an unsorted, heterogeneous mix of gravel, sand, silt, and clay. Till was deposited in a variety of landforms generally related to moraines. Therefore, the term moraine is used to describe the hills, planar features, and other landforms composed of till.

A description of the moraine west of Sixteen Mile Creek is provided in the characterization chapter for North Oakville West (**Section 4E.0**), along with a discussion on fluting. Within the North Oakville study area east of Sixteen Mile Creek, there are no areas mapped as being fluted **(**see **Figure 4E.3.1)**.

Along the west side of the study area, the main branch of Sixteen Mile Creek cuts through the Trafalgar moraine in a deeply incised valley. The creek has not only cut through the moraine, but also incised itself well into the underlying bedrock.

Between the main branch of Sixteen Mile Creek and Sixth Line Road, the form of the Trafalgar Moraine changes. In this area, it is bounded on the north by East Sixteen Mile Creek, which flows in a westerly direction along the north toe of the moraine. On the south side of the moraine, there is a notable change in slope north of Burnhamthorpe Road. The ground surface rises to a crest roughly along the alignment of Highway 407. The moraine is particularly notable when driving north on Sixth Line Road. The crest of the moraine is the top of the hill that occurs north of Burnhamthorpe Road, just south of Highway 407.

Between Sixteen Mile Creek and Trafalgar Road, there appears to be more depressions and small ponds than along other sections of the moraine in the study area. The presence of the standing water suggests that the underlying soils (Halton Till) have a very low permeability, not allowing the water to infiltrate. In some cases drainage from these areas may, in part, contribute to the flow in the intermittent streams both north and south of the moraine.

East of Sixth Line, the moraine begins to broaden out along the crest and the terrain becomes more gently undulating than in areas to the west. East of Trafalgar Road, the moraine becomes a broad low undulation in the local landscape.

From Dundas Street the ground surface rises to the north as a low relief, gently undulating till plain. North of Burnhamthorpe Road there is a notable change in slope, with the ground surface rising more quickly to a crest roughly along the alignment of Highway 407. Ground surface rises northward from an approximate elevation of 160m (at the east and west edges of the study area near Ninth Line and Neyagawa Boulevard, respectively) and 170m (near Trafalgar Road) at Dundas Street, to 183m near Burnhamthorpe Road. North of Burnhamthorpe Road, the ground surface rises to an elevation of approximately 190m. This height of land represents the crest of the area referred to as the Trafalgar Moraine **(Figure 4E.3.1).**

Overall, the till plain is moderately well drained. Along the Trafalgar Moraine, the ground surface shows typical moraine topography, with a ridge crest and some pitting of the ground surface. The pitting creates a subdued hillock and depression type topography that can be seen in several areas along the moraine, both within the study area and beyond. The relief associated with the hillock and depression topography is very low, usually less than 2m. In addition, the historic and current agricultural use of the land has altered the shape and form of many depressions. In areas where the land remains forested the original topographic form is best preserved. The best examples of pitting on the Trafalgar Moraine are in the area west of Sixteen Mile Creek north of Highway 407, beyond the study area.

Drainage from the crest, along the south slope of the moraine, and in the till plain to the south has a dendritic pattern. Along the crest of the moraine in the study area, as in other sections of the Trafalgar Moraine, some of the depressions contain water for at least part of the year. Drainage from these depressions contributes, at least in part, to the flow in the intermittent streams that rise along the south side of the moraine. The contribution of groundwater to base flow in local streams is discussed in **Section 4E.5**.

4E.3.2 Geology

4E.3.2.1 Bedrock Geology

The bedrock in this part of Halton Region is predominantly the soft, red, Upper Ordovician-aged shale of the Queenston Formation (Karrow, 1987; Ostry, 1979; MNR, 1975). To the south and east, the Ordovician-aged Georgian Bay Formation has been mapped. The Georgian Bay formation is a grey to green coloured shale with interbedded siltstone and limestone layers. **Figure 4E.3.2** shows the bedrock geology.

Within the study area, the bedrock is the red Queenston shale. The bedrock is uniform in character with little variation from one locale to another. Overall, the bedrock surface is flat to gently undulating with a southeastward slope. There has been small bedrock high mapped near the eastern end of the study area.

There are no mapped bedrock outcrops in the study area, other than in the Sixteen Mile Creek valley. However, during field reconnaissance surveys of the area, some bedrock outcrops were noted in one small area of the Joshua's Creek valley between Dundas Street and Burnhamthorpe Road. At this location, the creek appears to have cut through a localized bedrock high.

4E.3.2.2 Quaternary Geology

Overlying the bedrock is a veneer of till, known as the Halton Till, which was deposited during the last major advance of the Laurentide Glaciers, the glacial ice mass that covered most of central and eastern Canada and extended well into the northeastern USA. The Halton Till was deposited during the time when the Erie-Ontario lobe of the Laurentide glacier was re-advancing into the eastern end of the Lake Erie Basin (Chapman and Putnam, 1984).

As the glacier reached its maximum point of advance, the ice stagnated for periods of time at several positions, oscillating between advancing and melting back, over a relatively short distance. As the ice moved, it released more debris at the ice margin, pushing it up into a ridge. In Halton, the result was the development of the area referred to as the Trafalgar Moraine.

The Halton Till is characteristically a silt to clayey-silt till that typically has very low permeability (on the order of 10^{-7}cm/sec). Within the till, occasional sandy layers or lenses are sometimes encountered. These lenses tend to be very limited in both aerial extent and thickness. The Halton Till ranges from less than 5m thick in the area south of Burnhamthorpe Road to more than 19m thick along the crest of the Trafalgar Moraine, north of Burnhamthorpe Road. Often the upper few meters of the clayey-silt till are fractured and weathered.

Within the larger stream valleys, such as the Joshua's Creek valley and in the Sixteen Mile Creek valleys, deposits of recent alluvium are found. These are predominantly sands and silts placed by various stages of these creeks during recent (<10,000yrs) time, including the present. During the drive point or mini piezometer installations, alluvium was encountered at several locations. These locations tended to be towards the southern end of the subwatershed area in the larger stream valleys such as Joshua's Creek valley and the Morrison Creek valley near Dundas Street. Near the top end of the watershed, there were indications of a varying thicknesses of alluvium noted in the small swale along the south flank of the Trafalgar Moraine and at locations on Joshua's Creek (see **Figure 4E.3.1)**.

Going from west to east along Burnhamthorpe Road, the ground surface rises to a high just east of Sixth Line, then slopes down in an easterly direction. This height of land represents the drainage divide between the two main watersheds in this part of the study area, Joshua's Creek watershed and Sixteen Mile Creek watershed. **Figures 4E.3.3** and **4E.3.4** show the west to east profile along Burnhamthorpe Road roughly from Sixteen Mile Creek to Ninth Line. **Figure E-1** in **Appendix E** shows the cross-section location. The profile also shows that, using the available water well data, the water table is a subdued reflection of the ground surface topography.

Along this cross-section the geology is consistent. The Queenston Shale is overlain by a layer of till. Only occasional sand or gravel layers are encountered and most of these are found in the area east of Trafalgar Road.

Looking in a north-south direction along Neyagawa Boulevard **(Figure 4E.3.5)**, the bedrock surface rises slightly to the north. In the vicinity of the Burnhamthorpe Road area, the till thickens in the vicinity of the Trafalgar Moraine. The geological profile along Sixth Line **(Figure 4E.3.6)** is similar. Again, only occasional sand layers have been logged in local wells. One such lens was encountered in MW-1 at the Moore Reservoir located near the crest of the Trafalgar Moraine **(Figure 4E.3.1)**.

Further to the east, along Ninth Line, the ground surface shows a gentle rise in elevation to the north, but not the change in slope or thickening of the till that is typical of the area along the moraine **(Figure 4E.3.7)**. In this area, the shale bedrock is covered with a till mantle but the change in topographic relief and the thicker till typical of the Trafalgar Moraine are found north of the study area, north of Highway 407.

As part of this Subwatershed Study, a series of four test holes and monitoring wells were completed at two locations along the Moraine. **Figures MEL-1** through **MEL-26** in **Appendix E** present the borehole logs and well construction details for the monitoring wells and minipiezometers and **Figure E-1** shows the well locations.

The drilling results confirm that the Trafalgar Moraine is composed of the silty to clayey-silt Halton Till. Grain size testing shows that there is very little variation in till composition either with depth or location. The till has 9 to 15% gravel, 11 to 16% sand, 42 to 50% silt, and 22 to 36% clay sizes. Grain size testing suggests that these results are consistent with the findings of others, but that there may be a slightly higher amount of small stones or gravel (typical of a till material) at depth in the unit.

At depth in MW-1, a coarser grained layer was encountered just above the bedrock. The unit was composed of about 12% gravel, 38% sand, 43% silt, and 7% clay. **Figures MEL-34** to **MEL-37** (**Appendix E**) present the grain size testing results. Based on grain size testing, the hydraulic conductivity for the Halton till at these locations is estimated to range from 9×18^{-8} to 3×10^{-7}cm/sec. For the silty sand unit the estimated hydraulic conductivity is 2.5×10^{-5}cm/sec. These results are consistent with published values for the till.

4E.4 Groundwater Flow System Characterization

Sufficient existing information is available to develop an understanding of groundwater flow systems in the study area. This includes available water well records, the regional groundwater model, existing Subwatershed Study work, and the results from existing hydrogeological studies and monitoring. This information was augmented with the data collected as part of this subwatershed study. As additional monitoring results become available, the assessment of existing conditions is in the analysis part of this study.

There are essentially two functions for groundwater. One function is the use of groundwater as a water supply source. Depending on the need, groundwater can be used for activities such as human consumption, irrigation, or other agricultural and commercial uses. The second is the ecological function, primarily the contribution of groundwater to streamflow and to sustaining wetland features.

4E.4.1 Regional Groundwater Flow

Regionally, the hydrostratigraphic model consists of a surficial till unit (Halton Till) that acts as an aquitard overlying the Queenston Shale bedrock. Although not a good aquifer, the shale is the unit in which the vast majority of private water supply wells are completed. There are no municipal water supplies being taken from the shale bedrock. Within the Halton Till, particularly in areas where the overburden thickens, occasional coarser soil layers can be found. These layers or lenses are discontinuous and tend not to be thick. In some cases however, wells built in these layers/lenses yield sufficient water for domestic purposes, but not enough to sustain a municipal groundwater supply.

Regionally, groundwater flow in the shallow bedrock is predominantly south-east from the topographic high (Trafalgar Moraine) north of Burnhamthorpe Road toward Lake Ontario. Along the west side of the study area in the Sixteen Mile Creek watershed, there is a component of groundwater flow directed toward the Sixteen Mile Creek valley.

Based on work by Ostry (1979), Funk (1979) and others, the water table in the till/shallow bedrock appears to be a subdued expression of the ground surface. The limited number of water wells completed in the till unit preclude the development of a detailed groundwater flow map for the till unit. Locally, groundwater flow is influenced, to some degree, by the creeks, swales and other watercourses in the study area. Close to these watercourses, groundwater flow in the overburden tends to be toward these surface water features.

4E.4.2 Groundwater Flow in the Study Area

In the study area, local groundwater flow is consistent with the regional model. At the north end of the study area in the vicinity of the Trafalgar Moraine, shallow groundwater flow in the bedrock north of the moraine is toward Sixteen Mile Creek to the north. Since the water table in the study area is a subdued expression of ground surface topography, the northward flow in this area is expected.

On the south side of the moraine, groundwater flow is generally southward. Although there are slightly higher water levels in wells on the moraine, it appears that these water levels are a result of local topography. **Figures 4E.3.3** through **4E.3.7** show the original water levels measured by drillers when each well was constructed. The overall pattern observed is the consistent southward slope of the water table. In addition the groundwater divide between the Sixteen Mile Creek watershed and the watersheds to the east can be observed on Figures **4E.3.3** and **4E.3.4**, the west to east profiles along Burnhamthorpe Road.

Infiltration of precipitation and recharge to the local groundwater flow system occurs throughout the study area, although the amount of water reaching the bedrock is small. Groundwater discharge primarily occurs only near the bottom of the topographic depressions forming watercourse valleys. As part of the Subwatershed Study, mini-piezometers were installed at 11 locations throughout the study area. The instruments were placed in pairs (22 in total at 11 locations) usually within the stream valley and water levels were monitored monthly after installation.

The results indicate that in the valley immediately adjacent to the main branch of Joshua's Creek there were upward (discharge) hydraulic gradients during much of the monitoring period. Similar results were seen for the main branch of Morrison Creek. Based on monitoring done to date, there is some indication that these gradients may vary at least seasonally or even more frequently (*i.e.*, on a precipitation event basis).

Throughout the remainder of the study area, the hydraulic gradients in the shallow valleys associated with local watercourses also appear to vary based on either seasonal or precipitation event basis.

4E.4.3 Groundwater Use

Groundwater in the study area is not used as a municipal water supply source, but as a water supply source for local residences and farms. Based on the house-to-house survey conducted, well yields from the bedrock, the predominant aquifer in the area, are low. In many cases, the well yields are not reliable (too low during the summer) and groundwater quality is poor. Many local residents drink bottled water, only using the well water for non-consumptive purposes.

The absence of an overburden aquifer and the poor quality and quantity of groundwater from the bedrock suggest that the potential to develop a significant groundwater supply in the study area is very low.

4E.4.4 Groundwater Quality

Groundwater quality in the study area has historically been considered poor, with elevated concentrations of naturally occurring sulphate and chloride. As part of the Subwatershed Study, representative groundwater quality samples were collected from the monitoring wells installed and selected private wells.

The results indicate that groundwater from the bedrock has elevated calcium, sodium, magnesium, strontium, chloride, sulphate, hardness, and total dissolved solids (TDS) levels. These are typical of water from the Queenston Shale. In addition, two wells had elevated nitrate levels, an indication of impacts from either agricultural operations or nearby septic systems. Two other wells had measurable ammonia levels. In all, groundwater quality from the bedrock is considered poor and may not meet the Ontario Drinking Water Standards. The groundwater quality testing results are presented in **Appendix E**.

4E.5 Groundwater Balance

The groundwater balance for the area has been developed considering local surface water courses, the geology of the area, the topography of the area and the conceptual hydrogeological model. The groundwater balance is based on conditions through the study area, but can be applied to specific locations in the study area.

When precipitation occurs in the study area, some of the water evaporates, some is returned to the atmosphere through transpiration, some runs off as surface water flow, and some infiltrates into the ground. Of the total water entering the ground, a portion percolates downward to the water table. This component is considered the recharge to the groundwater system. The remaining portion moves through the fractures in the thin overburden toward local surface watercourses. This infiltration, called interflow, provides some of the baseflow to the various watercourses at different times of the year.

Streamflows in the North Oakville Creeks vary throughout the year. During the summer base flow period for 2002, all the streams east of Sixteen Mile Creek had no flow. Also, there were no seepage areas or groundwater discharge points observed during the completion of the field studies. This indicates that groundwater, either through interflow in the thin overburden or as groundwater discharge from the underlying shale, was not contributing to streamflow. Based on these observations, groundwater discharge to surface water is not sufficient to sustain base flow in the streams and the streams are generally considered intermittent in the study area. 2002 was an extremely dry, if not record dry summer.

As previously mentioned, the ground surface across the top of the Trafalgar Moraine between Neyagawa Blvd. and Trafalgar Road shows evidence of pitting. During wet periods of the year such as the spring and late autumn, as well as after sustained periods of precipitation, these depressions may retain water. The retained water is then either slowly released to the surface water system as runoff from the depression or as interflow. The retention of water in the depressions appears to result in an extended period when the retained water may be released to local water courses. However, the amount of recharge to the bedrock flow system in this area is not significantly different from areas in other parts of the Halton Till plain, since the permeability of the till beneath the depressions is likely the same as in other areas.

Preliminary estimates of the total infiltration range from about 50 to 110mm/year. Considering the permeability of the local soils, the amount of recharge reaching the bedrock is estimated to range from as little as 5 to 50mm/year. The range is a function of the range of soil permeability that results from the drying and wetting periods during the year. The remainder of the infiltrating water will move slowly laterally toward nearby surface watercourses.

4E.6 Surface Water – Hydrology

4E.6.1 Introduction

The eastern portion of the study area is bound by Dundas Street West in the south and Highway 407 in the north, Ninth Line to the east, and Sixteen Mile Creek to the west. The study area is drained by Sixteen Mile Creek, Shannon's Creek, Munn's Creek, West Morrison Creek, East Morrison Creek, and Joshua's Creek.

4E.6.2 Climate

A portable weather station was erected at the Moore Reservoir, located to the east of Sixteen Mile Creek. The monitor recorded the following meterological data at 30-minute intervals since March 2003:

- Temperature/Humidity Index;
- Outside Temperature;
- Windchill;
- Pressure;
- Temperature (High/Low);
- Outside Humidity;
- Dewpoint;
- Wind speed/Direction; and
- Precipitation.

Monthly precipitation and mean daily temperatures (from 1971 – 2000) for the Oakville Southeast WPCP gauge are shown in **Table 4E.6.1**. The gauge is located near Winston Churchill Boulevard and Lakeshore

Road East. The data is representative of precipitation and temperature data expected to occur within the study area. **Table 4E.6.1** shows mean annual precipitation that can vary as much as 30% from one year to the next.

Table 4E.6.1
Climate Data, Oakville Southeast WPCP, 1971-2000

	J	F	M	A	M	J	J	A	S	O	N	D	Ann.
Mean Daily Temperatures													
Daily Maximum, ^{o}C	-1	0	5	11	18	23	26	25	21	14	8	2	13
Daily Minimum, ^{o}C	-9	-9	-4	1	7	12	15	15	10	5	0	-6	3
Mean Daily Precipitation													
Rainfall, mm	31	28	47	65	70	71	73	78	79	69	69	47	726
Snowfall, cm	28	17	15	3	0	0	0	0	0	0	3	18	83
Total, mm	59	44	62	68	70	71	73	78	79	69	72	65	809

The adjacent Burlington Royal Botanical Garden precipitation gauge has an average annual precipitation of approximately 860mm with 730mm of rainfall and 120mm of snowfall. The Royal Botanical Garden gauge has a longer period of record than the Oakville gauge.

4E.6.3 Land Use

As discussed in **Section 4E.2**, the land use is mostly agricultural with some woodlots and wetlands. Some residential units are located along the roadways such as Dundas Street West, Burnhamthorpe Road West, Trafalgar Road, and Neyagawa Boulevard. Highway 407 bisects the study area in a west-east direction. .

4E.6.4 Topography

Within the study area, runoff drains in a northwest to southeast direction. The maximum study area elevation is approximately 190m. The elevation near Dundas Street West is approximately 145m above mean sea level (AMSL).

4E.6.5 Physiography

Although the physiography of the study area has already been discussed in **Section 4E.3**, this section will consider the effect of physiography with respect to hydrology. The physiography of the study area shown in **Figure 4E.3.2** shows a till moraine, the Trafalgar Moraine, north of the study area. **Figure 4E.3.2** also shows that the entire area is within till plain called Halton Till.

4E.6.6 Soils

Figure 4E.6.1 displays the study area soils. Soils developed in Halton Till include Oneida, Chinguacousy, and Jeddo. Chinguacousy clay loam soils are imperfectly drained and occupy the gentle landscape slopes. Chinguacousy soils have developed in clay and silty clay glacial till deposits. Oneida soils occupy the steeper soils and are well drained. Jeddo clay loam soils are found in slight depressions and are poorly drained. **Table 4E.6.2** shows the United States Soil Conservation Service (US S.C.S) hydrologic soil groups found in the study area.

Table 4E.6.2 US S.C.S. Hydrologic Soil Groups in Study Area	
Soil Type	**Hydrologic Soil Group**
Chinguacousy, clay loam	C
Oneida, clay loam	D
Jeddo, clay loam	C
Trafalger, clay	A

Although the soils have been classified into four groups from "A" through "D". Hydrologic Soil Group A generates low runoff volumes while hydrologic Soil Group D generates high runoff volumes.

4E.6.7 Flow Monitoring

Information has been collected on flow conditions for Joshua's Creek and Morrison's Creek. A flow monitoring probe for Morrison's Creek was installed on April 12, 2002 immediately upstream of Dundas Street. Another flow monitoring probe was installed at Joshua's Creek immediately upstream of Dundas Street on May 15, 2002. Continuous water level monitoring data was periodically downloaded and is provided in **Appendix F.** The water level information was converted to flows through the use of discharge relationship based upon field measurement

In addition to continuous flow monitoring, cross-sections and creek velocity were measured at Joshua's Creek, Morrison Creek, Morrison West Creek, Shannon's Creek, Munn's Creek, and three Joshua's Creek Tributaries along Burnhamthorpe Road. During the August 27, 2002 site visit, it was noted that there were no flows in any of the above creeks and the majority of the creeks were dry. Flows for the various creeks are provided in **Table 4E.6.3** and the locations are shown on **Figure 4E.6.1.** Flow monitoring results indicated that both Morrison Creek and Joshua's Creek were dry throughout June, July, and August. This can be translated to the other creeks as Morrison Creek and Joshua's Creeks were the last to become dry based on observations during various field visits.

Table 4E.6.3 Creek Flows						
Location	**Flow (m^3/s)**					
	April 12	**April 16**	**May 3**	**May 15**	**June 3**	**August 27**
Joshua's Creek (JC-1)		0.14	0.60	0.29	0.01	0
Morrison Creek (MOC)	0.08		0.23	0.23	0	0
Morrison West Cr (MOCW)		0.05	0.07	0.07	0.01	0
Munn's Creek (MC)		0.02	0.02	0.02	0	0
Joshua's Trib #1 (JC-T1)			0	0.05	0	0
Joshua's Trib #2 (JC-T2)			0.37	0.13	0	0
Joshua's Trib #3 (JC-T3)			0	0	0	0

4E.6.8 Design Flows

In preparation for undertaking an updated hydrologic analysis of the subwatershed, previous reports completed by others were reviewed to identify the design flow rates calculated as part of past work completed within the study area. Flows at Dundas Street previously established by means of hydrologic modelling are summarized in **Tables 4E.6.4 and 4E.6.5**, for each of the watercourses dealt with in this study. As a result of the very dry conditions experienced in 2002, the recorded flows tend to be much lower than the flows established for even the lesser design return periods.

Table 4E.6.4 Summary of Existing Flows At Dundas Street									
Watercourse	**Return Period Flow (M^3/S)**								
	1-yr	**2-yr**	**5-yr**	**10-yr**	**20-yr**	**25-yr**	**50-yr**	**100-yr**	**Regional**
Sixteen Mile Creek	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Osenego Creek (May 1995)	0.357	0.487	0.815	1.084	N/A	1.372	N/A	1.991	N/A
Shannon Creek (May 1995)	0.741	1.012	1.701	2.264	N/A	2.872	N/A	4.186	N/A
Munn's Creek	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
West Morrison Creek – 24 Hour SCS	N/A	2.49	3.35	N/A	N/A	6.96	N/A	8.85	N/A
West Morrison Creek – 4 Hour Chicago	N/A	1.57	2.65	N/A	N/A	4.74	N/A	7.65	N/A
East Morrison Creek	N/A	7.5	11.6	14.3	N/A	17.8	20.4	22.9	37.7
Joshua's Creek (July 1989)	N/A	13.7	17.6	N/A	24.3	N/A	30.1	34.2	81.1

N/A – Not available

Table 4E.6.5 Summary of Proposed Conditions Flows at Dundas Street									
Watercourse	**Return Period Flow (m^3/s)**								
	1-yr	**2-yr**	**5-yr**	**10-yr**	**20-yr**	**25-yr**	**50-yr**	**100-yr**	**Regional**
Sixteen Mile Creek	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Osenego Creek (Unchanged)	0.357	0.487	0.815	1.084	N/A	1.372	N/A	1.991	N/A
Shannon Creek (Unchanged)	0.741	1.012	1.701	2.264	N/A	2.872	N/A	4.186	N/A
Munn's Creek	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
West Morrison Creek (Uncontrolled) – 24 Hour SCS	N/A	6.19	7.93	N/A	N/A	16.09	N/A	20.55	N/A
West Morrison Creek (with SWM) – 4 Hour Chicago	N/A	5.06	8.33	N/A	N/A	14.35	N/A	21.84	N/A
West Morrison Creek (with SWM) – 24 Hour SCS	N/A	2.09	2.73	N/A	N/A	6.6	N/A	8.28	N/A
West Morrison Creek (Controlled) 4-hour Chicago	N/A	1.56	2.43	N/A	N/A	4.35	N/A	7.52	N/A
East Morrison Creek	N/A	7.4	11.4	14.1	N/A	17.5	20.1	22.6	37.2
Joshua's Creek (Ultimate Development)	N/A	19.8	26	N/A	38.5	N/A	49.2	56.8	91.9

N/A – Not Available Future Foreseeable Land Use

4E.6.9 Hydrologic Issues to Be Addressed

As with most subwatershed studies, the key issues to be addressed, as applicable to each watercourse include:

- Peak runoff quantity control;
- Maintenance of base flow rates/water balance;
- Volume of surface runoff;
- Groundwater recharge/discharge;
- Erosion protection; and
- Runoff water quality control.

Measures in past studies recommended to address each of these issues (if applicable) as a result of past studies are briefly summarized in the following section of this report.

4E.6.10 Recommended Management Alternatives and/or Strategies from Previous Studies

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

This study involved a total of nine catchments tributary to Sixteen Mile Creek, for which a number of management criteria/recommendations were established, including:

- Control of peak post development runoff rates to predevelopment levels;
- Quality treatment of all storm runoff prior to discharge to the creek;
- Control of post development runoff to maintain predevelopment flow duration (*i.e.,* runoff hydrograph) characteristics as much as possible, to minimize erosion potential; and
- Maintain existing groundwater recharge rates on an area basis (*i.e.,* maintain existing infiltration rates to maintain base flow characteristics).

Specific recommendations put forth as a result of this study included:

- Minimize imperviousness by clustering of development, utilizing underground parking, minimizing pavement widths, using grassed ditches instead of curb and gutter, and any other innovative architecture or site layouts that can be identified on a site specific basis. Techniques which encourage infiltration should be emphasized, such as roof downspout disconnection, soakaway pits, grassed filter strips, grassed ditches, swales, depressions, collection of runoff in temporary pooling areas within parks and other open spaces;
- Provide on-site storage equivalent to 5mm over the impervious area through roof and parking lot detention, cisterns;
- Maintain water balances, increase groundwater recharge, and reduce peak runoff rates by encouraging runoff dispersal rather than collection and concentration of runoff;
- Minimize the use of storm sewers and maximize overland drainage and dispersal wherever feasible;

- Extend overland drainage for the greatest distance possible via grassed ditches and swales; and
- Minimize deepening of watercourses to accommodate storm sewer outlets.

It was further concluded that in general, Sixteen Mile Creek will be capable of accommodating the anticipated level of urban development within Milton and North Oakville as defined in the Halton Urban Structure Plan. This would be attainable by maintaining or enhancing the current water quality by implementing appropriate SWM measures. This study also determined that the anticipated levels of future development would not require updating of the current regulatory flood lines.

Water quality control as based on the MOE/MNR Storm Water Management Plan (SWMP) Design Manual (1994) should be adequate, provided the following are taken into account:

- Erosion control should be based on flow duration exceedence characteristics (see Gore & Storrie study);
- Sustenance of base flows should be emphasized based on maintenance of groundwater recharge; and
- Ponds should be designed to minimize their impact on water temperature.

Furthermore, aquifer protection should involve identification of potential contaminant sources, determination of appropriate land uses and monitoring of quality and quantity of groundwater within the watershed. Areas susceptible to groundwater contamination were delineated as part of the Gore & Storrie study.

Recommendations specifically related to agricultural lands included:

- Planting of trees along streams as windbreaks to reduce wind erosion, and to provide riparian habitat and filter buffers along streams;
- Reconstruction of ponds or pond outfalls or construction of pond bypass channels;
- Fencing to limit cattle access to streams and wetlands; and
- Protection/retention of existing wetlands on agricultural property.

A comprehensive monitoring program was recommended including monitoring of the following:

- Streamflow;
- Water quality including dissolved oxygen, temperature, bacteria, nutrients, pesticides, metals, and suspended solids under dry and wet weather conditions;
- Erosion inventory;
- Groundwater base flow and temperature;
- Infiltration rates in various soil types;
- Water levels in existing wells; and
- Water quality from existing wells.

Osenego Creek / Shannon Creek (Stormwater Implementation Study Osenego/Shannon Creeks, Cosburn Patterson Wardman Limited et al., May 1995)

This study dealt with SWM requirements associated with development of a northern, central, and southern catchment located between Dundas Street and Upper Middle Road in Oakville. These catchments are tributary to Osenego Creek (northern catchment) and Shannon Creek (central and southern catchments). While these lands are downstream of the limits of the study area being dealt with in the current study, information presented in this Cosburn Patterson Wardman report may be indicative of issues requiring attention in the context of our current study.

External areas north of Dundas Street, while tributary to the subject lands south of Dundas Street, were not included in the design of SWM facilities addressed in this Cosburn Patterson Wardman study. It was assumed that should these areas upstream of Dundas Street be developed, separate SWM facilities would have to be constructed to provide the required controls and protection.

Design of the proposed SWM facilities required to service these lands was based primarily on the objective of preventing an increase in erosion potential in the receiving watercourses due to increased runoff rates. Based on previous work completed by Paul Wisner & Associates Inc. in April 1992, it was concluded that control of peak post development flows to pre-development rates is not required. Therefore, the release rates from the proposed ponds are based on non-erosive release rates determined as part of this 1995 study.

Within the portion of the watercourses downstream of Dundas Street it was determined that "unmanaged stormwater release from the developing study area lands" would result in increased erosion downstream of the development. Therefore, SWM facilities (*i.e.,* ponds) have been designed to control post development runoff rates to non-erosive levels required to avoid construction of protective or armouring works along the affected creeks.

Osenego and Shannon Creeks do not themselves provide breeding, feeding or nursery habitat for fish, based on work previously completed by Paul Wisner & Associates Inc. (1992) and Geomatics International Inc. (1994). However, Sixteen Mile Creek (of which Osenego and Shannon Creek are tributaries) has been designated a Type 4 warm water aquatic environment capable of supporting a viable warm water and migratory salmonid fishery. Therefore, the implementation of best management practices is required in areas tributary to Sixteen Mile Creek to protect this resource.

Munn's Creek (Master Drainage Plan, Morrison and Wedgewood Creeks, The Proctor & Redfern Group and Andrew Brodie Associates Inc., August 1979)

The consultant was retained by the Town of Oakville to prepare a Master Drainage Plan for the Morrison and Wedgewood Creeks watershed. The purpose of the study was to define the current (at the time) flooding, erosion and environmental constraints in order to form a sound basis for the design of drainage facilities for new developments south of Dundas Street. The study was governed by the requirements of Conservation Halton and Town of Oakville as set out in the Town's "Drainage Policies and Criteria Manual".

The general findings of this report are discussed in further detail in the West Morrison Creek segment of this section, since the Master Drainage Plan included both Munn's Creek and West Morrison Creek. In addition to the findings discussed below in the West Morrison Creek section, it was determined that two culverts under Dundas Street for the west and east branches of Munn's Creek (identified in the 1979 report as "Golf Course Creek", Culverts 14 and 15) were undersized. Culvert 14 has a capacity of less than the 10 year flow, while Culvert 15 has a capacity less than the 100 year storm.

West Morrison Creek (Master Drainage Plan, Morrison and Wedgewood Creeks, The Proctor & Redfern Group and Andrew Brodie Associates Inc., August 1979)

As discussed above, the consultant was retained to prepare a Master Drainage Plan that included West Morrison Creek, as well as Munn's Creek.

At the time of the 1979 study, it was determined that Oakville policy would ensure that no increase in flow rates would be transmitted downstream from the currently undeveloped drainage area(s) north of Dundas

Street tributary to West Morrison Creek, should these areas ever become urbanized. It was also to be ensured that existing works present downstream of Dundas Street not be detrimentally affected by future upstream development.

Drainage constraints addressed in the 1979 Proctor & Redfern Group study included flooding constraints, erosion constraints, and environmental constraints. No flooding constraints were identified in this report for the west branch of Morrison Creek. A culvert capacity of 24.1cms was established for the culvert under Dundas Street, which is sufficient to accommodate the Regional storm flow for conditions which existed at that time. The 1979 study focused primarily on areas downstream of Dundas Street, and revealed no erosion concerns along West Morrison Creek. However, no information was provided for portions of the creek upstream of Dundas Street.

Flow in Morrison Creek was categorized as being relatively clean and free of suspended solids. While no specific water quality criteria were applied to Morrison Creek in the 1979 study, it was identified as a tributary to Sixteen Mile Creek for which water quality criteria would apply. Therefore, as a tributary to Sixteen Mile Creek, the same criteria would apply to West Morrison Creek. While the Proctor & Redfern Group report does not specify the 1979 criteria, it can be assumed that today it is appropriate to follow the MOEE/ SWMP Design Manual (2003) guidelines. Thus, since Sixteen Mile Creek, within the study area, has been identified as a warm water aquatic environment capable of supporting a viable warm water and migratory salmonid fishery (see *Osenego Creek / Shannon Creek Stormwater Implementation Study Osenego/Shannon Creeks, Cosburn Patterson Wardman Limited et al., May 1995),* best management practices should be applied to protect the water quality in West Morrison Creek.

East Morrison Creek (East Morrison Creek Subwatershed Study, Cosburn Patterson Wardman Limited et al., April 1995)

This study dealt primarily with watershed management issues affecting that portion of East Morrison Creek downstream of Dundas Street. However, external drainage from lands upstream of Dundas Street was taken into account under Official Plan land use (lands north of Dundas Street designated as agricultural) and future foreseeable development conditions, as well, representing full potential development north of Dundas Street.

The 1995 Cosburn Patterson Wardman analysis indicated that downstream of Dundas Street, future foreseeable development levels would result in only a very minor increase in streamflow. However, a noticeable increase in flow was noted upstream of Dundas Street. Based on Conservation Halton's policy of controlling post development flows to existing levels, quantity control SWM measures would be required upstream of Dundas Street for rainfall events up to the 100 year storm. Measures need to be implemented to ensure that downstream subwatershed management strategies remain effective for the entire watershed.

This study indicated that the headwaters of East Morrison Creek form shallow swales with only intermittent streamflow generated primarily by surface runoff, including interflow. As the creek becomes more incised in the local landscape south of the Trafalgar Road/Dundas Street intersection it is expected that there may be a greater groundwater contribution to perennial stream flow.

The MNR has designated East Morrison Creek as a potential cold water stream (Type 2 stream) based on a 1984 record of redside dace being present in the watercourse. This designation requires at least a normal level of protection for the stream and all areas tributary to it. However, past and present agricultural land use and surrounding urbanization may limit the coldwater habitat potential of the watercourse. Despite this degradation and the effective isolation of the stream from Sixteen Mile Creek by the concrete lined Morrison-Wedgewood Diversion Channel, the apparent groundwater recharge indicated by cool stream

temperatures relative to ambient air temperatures during August site surveys, makes the stream a potential localized coldwater habitat (but not a migratory one). Thus, it is worth protecting and where possible, enhancing.

Fundamental objectives of the watershed management strategy included:

1. Minimize threat to life, property and natural resources from flooding
2. Restore, protect and enhance water quality and associated aquatic resources
3. Restore, protect and enhance the recreational and visual amenities of rural and urban stream corridors.

Based on the results of the analysis of existing conditions, the primary goal of the East Morrison Creek Subwatershed Study was determined to be Objective #2, above, with particular emphasis placed on protection against accelerated bank erosion. The following four erosion protection alternatives were considered:

1. Extended detention erosion control ponds at existing and future storm sewer outlets
2. In-stream erosion protection for entire watercourse
3. Extended detention erosion control ponds at all future storm sewer outlets
4. Extended detention erosion control ponds at all future storm sewer outlets and continue to deal with erosion problems within existing development areas on an as needed basis

Alternative 4, above, was selected as the recommended alternative. This decision was based on the limited Level 1 environmental area not being sufficient to justify the disturbance associated with Alternatives 1 and 2, and the fact that Alternative 3 would not address existing erosion problems.

Water quality controls are often preferred by MNR and Conservation Halton to be based on infiltration techniques. However, the soil conditions in the East Morrison Creek watershed are generally not suitable for this approach. Therefore, it is necessary to provide the required level of control through the use of extended detention ponds. Pond design should be based on the MOEE/MNR, June 1994 guidelines, preferably in the form of wet ponds, as per MNR's preference.

Joshua's Creek (Master Drainage Study Joshua's Creek Upstream of Upper Middle Road, Marshall Macklin Monaghan Limited, July 1989)

The watershed management strategy developed as a result of this study included the following conclusions and recommended management alternatives:

1. Peak runoff under future development levels north of Dundas Street was to be controlled to pre-development levels by the provision of detention ponds. Provision of both a single, large pond and provision of two smaller ponds upstream of Dundas Street were considered. It was determined that the interaction between these ponds and the pond proposed for construction at Upper Middle Road would actually result in a decrease in peak flows at Upper Middle Road.
2. Erosion and flooding have been concluded to not be a concern along Joshua's Creek despite a few cases of isolated minor erosion within the low flow channel of the watercourse.
3. Confirmation was obtained from the Cambridge District Office of MNR that Joshua's Creek did not represent a fisheries habitat due to its low base flow. As a result, water quality was not a concern of the MNR, and therefore only quantity control measures were deemed necessary within this watershed.

4E.6.5 Hydrologic Analysis Approach for the Analysis Phase

As part of the characterization phase, a review of the background reports, particularly for hydrologic and hydraulic analysis, was carried out. The investigation included a review of the scope of analysis and modelling, the resulting summary of conditions, design flows developed and any identified requirements from SWM. The findings provided preliminary information on hydrologic conditions, watershed conditions and the basis for developing a modelling approach in the analysis phase of this study.

A variety of analytical techniques and models are, or have been, available for undertaking the required hydrological analyses for a Subwatershed Study. At least three different models have been used in past studies for the seven subwatersheds being dealt with in this study. Furthermore, the general approach to modelling can be either single rainfall event driven or based on continuous, multi-event simulations over a long period of time. Both of these approaches have been utilized in various studies within this study area, completed by others. Other considerations when setting up an appropriate hydrologic model include the level of detail when drainage areas and sources of rainfall data used to represent weather conditions.

A review of the available background reports has revealed inconsistencies in the approaches taken to hydrologic modelling associated with the various watercourses. **Table 4E.6.6** summarizes these approaches in terms of model used, technique employed (continuous versus event modelling), level of detail, and rainfall data used.

Table 4E.6.6
Past Hydrologic Modelling

Watercourse	**Hydrologic Modelling Approach**				
	Previous Model	**Technique**	**Level Of Detail**	**Streamflow Calibration Data**	**Rainfall Data Source**
Sixteen Mile Creek	Qualhymo	Continuous	9 Subwatersheds 33 Catchment Areas	Yes	AES Records Station Unspecified)
Osenego Creek	Interhymo	Event	3 Catchments (Pre) 8 Catchments (Post)	No	Bloor Street Station
Shannon Creek	Interhymo	Event	11 Catchments (Pre) 13 Catchments (Post)	No	Bloor Street Station
Munns Creek	Otthymo	Event	N/A	N/A	N/A
West Morrison Creek	Otthymo	Event	11 Catchments		
East Morrison Creek	Gausser	Event			
Joshua's Creek	Qualhymo	Event	11 Catchments		

In developing a modelling approach for the next phase of this study, the background reports and associated modelling were reviewed, as well as the need to address the issues in this Subwatershed Study. This review was carried out with the Town of Oakville and Conservation Halton staff to review the watershed study needs, as well as future needs by both agencies in the implementation phases. The overall needs of the modelling include:

- Provide a consistent approach across the watersheds (one model);
- Ability to address watershed analysis needs:
  - model hydrologic response of watersheds for events;
  - provide both event and continuous approach;
  - provide for water balance analysis;
  - provide information to geomorphologic analysis; and
- Provide for the long-term analysis of the watersheds, as well as the review process during implementation.

The modelling approach that has been adopted will include two models to cover all of the needs a water balance model and event model that can also be applied in continuous mode.

Water Balance Model

A water balance model will be developed to obtain daily flow summaries for each subwatershed to analyze existing conditions, investigate potential impacts of land use and evaluate mitigative measures (*i.e.,* SWM). The analysis will focus on runoff volumes, base flows and overall water balance. The model will have the following characteristics:

- The existing 30-year precipitation database will be used;
- Hourly rainfall data will be used;
- The output will include daily average flows, evaporation, infiltration and base flow;
- Flow data being collected in the study area will be used for model verification;
- Data from past monitoring carried out on downstream reaches will be used as part of model verification;
- The model can be used for impact analysis and evaluation of mitigative SWM measures; and
- Results will be produced for each subwatershed.

Event Model

As discussed with the Town of Oakville and Conservation Halton, the current models for the North Oakville Creeks Subwatershed will be converted to GAWSER (Guelph All-Weather Storm Event Runoff Computer Simulation Model). They will be used for peak flow analysis to analyze response characteristics to storm events, the potential impact of land use changes, and effectiveness of SWM measures. The following characteristics will exist:

- The models will be developed for each subwatershed;
- A full range of design events will be applied (bank full, 2, 5, 10, 25, 50, and 100-year, and Regional) for a flow regime analysis; and
- One selected subwatershed will be applied in continuous mode to provide erosion verification with the water balance analysis.

4E.7 Hydraulics

Of all the creeks located in the study area, through past studies, floodlines have only been completed for Joshua's Creek. Only one building, which is located below Burnhamthorpe Road, lies within the floodlines and therefore, may be subject to flooding. Streamflow velocity measurements were taken at various locations during field visits (see **Table 4E.7.1**). A hydraulics review was completed as part of the analysis phase of this project.

Table 4E.7.1
Streamflow Velocity Measurements

Location	Velocity (m/s)						
	April 12	**April 16**	**May 3**	**May 15**	**June 3**	**June 21**	**August 27**
Joshua's Creek		0.37	1.9	1	0.2	0	0
Morrison Creek	0.25		0.55	0.5	0	0	0
Morrison West Creek		0.13	0.67	1	0.2	0	0
Munn's Creek		0.25	0.25	0.25	0	0	0
Joshua's Tributary #1			0	0.17	0	0	0
Joshua's Tributary #2			0.25	0.1	0	0	0
Joshua's Tributary #3				0	0	0	0

4E.8 Physical Stream Conditions - Morphology

Geology and hydrology exert the principal natural controls on the form and function of most drainage basins. Local geology influences the drainage pattern, the spatial distribution of water and sediment inputs (*i.e.*, quantity and type). The drainage basin hydrology controls the amount and rate of water entering the channel network. These natural controls are modified by human activity. Channels are modified directly (*e.g.*, channel straightening, realignment and constriction) and indirectly through land use changes which influence the hydrologic cycle and sediment inputs (*e.g.*, land clearance, increased urbanization and impermeable surface). These three controls are discussed in detail in **Sections 4.2** through **4.6**, furnishing the background information for the geomorphic analysis provided in this section.

In this section the morphology and condition of the streams and creeks within the study area are outlined through characterization of the headwater drainage networks and individual reaches, a historic analysis of the channel network and associated land use, and quantification of channel stability and overall health.

4E.8.1 Headwater Drainage Network: Form and Function

The overall form of the headwater drainage network indicates the function of the system. Where vegetated swales, depressions without a well-defined channel, dominate the headwater it can be expected that discharge is rarely high enough to erode sediment; vegetation tends to retard the flow, and the root matrix enhances the sediment's resistance to erosion. Conversely, headwater areas dominated by unvegetated swales make a much more significant contribution to downstream sediment supplies, usually after large precipitation events. In either case, these systems are sensitive to land use changes that remove vegetation or increase the volume or intensity of discharge. These changes increase the driving force and retard the resisting forces; beyond a certain threshold erosion occurs and rills, gullies and finally defined channels will develop.

Defined headwater channels tend to be erosive, supplying sediment to downstream channels. They also tend to have storm-driven, flashy discharge regimes. Although each headwater channel provides only a small amount of sediment and water to the overall basin, as they are numerous, changes in their throughput of sediment and water produces cumulative effects through the watershed.

Within the study area there are parts of the watersheds for Joshua's Creek, Morrison Creek (East and West), Munn's Creek, Shannon's Creek and Sixteen Mile Creek (**Figure 4E.8.1**). In the case of Munn's Creek, Shannon's Creek and Morrison Creek much of the network within the study area were small defined channels that degraded into swales further upstream.

4E.8.2 Reach Morphology

Channel form is a product of the flow (magnitude) and the channel materials (sediment type, supply and bed/bank strength). If one of these is altered the channel adjusts its form to retain or find a new 'dynamic' equilibrium. The characteristics of the flow or channel materials can and do change along a creek or stream. In order to provide channel measures from homogeneous sections of a creek or stream, channels are separated into reaches – generally several hundred meters to several kilometres in length. In the delineation of reaches the following measures are considered: sinuosity, gradient, hydrology, local geology, degree of valley confinement, and vegetative control using methods outlined in Parish Geomorphic Ltd. (2001). **Figure 4E.8.1** outlines the reaches within the study area and **Table 4E.8.1** provides lengths, gradients and sinuosity measurements for each reach.

Table 4E.8.1.
Length, Gradient and Sinuosity for Each Reach

Reach	Length (m)	Gradient (%)	Sinuosity
Joshua's Creek			
JC-1	380.38	0.69	1.22
JC-2	822.1	0.65	1.32
JC-3	536.9	0.71	1.25
JC-4	186.4	0.82	1.39
JC-5	358.2	0.87	1.19
JC-6	703.5	0.68	1.15
JC-7	1022	0.42	1.03
JC-8	458	0.07	1.01
JC-9	434	0.39	1.01
JC-10	409	0.90	1.02
JC-10A	607	0.21	1.01
JC-11	679.1	0.51	1.03
JC-12	254.6	1.77	1.29
JC-13	817.9	0.76	1.10
JC-14	455.8	0.53	1.00
JC-15	570.7	0.87	1.01
JC-19	670.4	0.96	1.34
JC-20	661	0.77	1.03
JC-20A	1042	0.35	1.02
JC-22	859.8	0.17	1.35

Table 4E.8.1. Length, Gradient and Sinuosity for Each Reach			
Reach	**Length (m)**	**Gradient (%)**	**Sinuosity**
JC-27	472	1.56	1.02
JC-27A	123.21	1.37	1.03
JC-28	672	1.35	1.03
JC-28A	266	1.68	1.04
JC-29	1034	1.15	1.10
JC-30	360.1	2.3	1.01
JC-31	181	1.79	1.01
JC-31A	1050	1.12	1.04
JC-32	702.9	0.68	1.03
JC-36	503	1.60	1.12
Morrison Creek (East and West)			
MOC-2	1119.6	0.8	1.01
MOC-4	847.5	0.55	1.03
MOC-5	598	0.48	1.02
MOC-5A	451	0.63	1.04
MOC-6	1788	0.64	1.07
MOC-W1	1053.5	0.47	1.03
MOC-W2	932	0.29	1.08
MOC-W3	848	0.29	1.02
MOC-W5	587	0.51	1.03
Sixteen Mile Creek			
SMA-1	823.0	2.7	1.22
SMA-2	1049.4	2.01	1.30
SMA-3	231.9	2.31	1.04
SMA-4	700.6	0.19	1.09
SMA-5	248.4	0.81	1.09
SMA-6	478.0	0.52	1.19
SMA-7	901.8	2.44	1.31
SMA-8	966.3	0.96	1.00
SMA-9	535.2	0.51	1.04
SMB-1	132.9	5.5	1.28
SMB-2	227.4	8.2	1.01
SMB-3	346.9	1.63	1.18
SMB-4	345.7	8.08	1.11
SMC-1	567.7	4.1	1.34

Table 4E.8.1. Length, Gradient and Sinuosity for Each Reach			
Reach	**Length (m)**	**Gradient (%)**	**Sinuosity**
SMC-2	465.4	3.47	1.06
SMC-3	128.6	1.48	1.10
SMC-4	529.1	1.63	1.07
SMC-5	340.1	1.35	1.02
Shannon's Creek			
SHC-1	424.1	0.80	1.00
SHC-2	689.8	0.59	1.01
SHC-3	915	0.95	1.02
Munn's Creek			
MUN-1	862.8	0.66	1.01
MUN-2	253.2	0.99	1.02
MUN-3	413.4	1.09	1.04

4E.8.3 Historic Analysis

Historical land use and channel changes were evaluated over a 45 year time period for the entire study area. An examination of historical aerial photographs allow natural tendencies of the river through time to be determined as well as changes in land use and the subsequent response of the channel to be identified. Included in the historical analyses were aerial photographs taken in: 1954 (scale 1:15,800), 1983 (scale 1:20,500), and 1999 (digital aerial photographs). Due to the scale of the aerial photographs, the size of some of the channels and the ephemeral nature of swales, and channel patterns could not always be observed.

In general, most of the alterations to the channel network on the agricultural lands in the study area, south of Burnhamthorpe Road and north of Dundas Street, occurred prior to 1954. With the exception of the largest streams in the watersheds of Joshua's Creek and Sixteen Mile Creek, most of the streams and swales were treated as 'drains' and straightened for agricultural purposes prior to the 1954 coverage. Consequently, there was little observable change to the channel planform of the streams and swales on the agricultural lands. This land use generally increases the potential source of finer sediments and reduces the development of stabilizing riparian vegetation if proper management practices are not followed.

Just south of Dundas Street, the land use around Shannon's Creek, Munn's Creek and to a lesser extent West Morrison Creek has been converted from agricultural land to residential since 1983. The creeks themselves have been heavily modified to accommodate the land use change and are now generally "engineered" channels. Along and around the higher order streams of Joshua's Creek north of Dundas Street, between 1954 and 1999, a large segment of the agricultural land was converted to a golf course (White Oaks Golf Club) and a cemetery (Glen Oaks Memorial Garden). The riparian vegetation of much of the channel within the golf course is manicured grass. These land use changes tend to decrease the supply of sediment and do not provide riparian vegetation that would help stabilize the channels.

4E.8.4 Field Investigations

The mapping and aerial photograph analyses provide insight into the controls, modifying influences and general characteristics of the channels. However, they do not provide insight into the condition (*e.g.*, stable, stressed) of the channel. Also, channel processes that were inferred in the mapping and aerial photograph analysis can only be confirmed through field investigation.

During the field investigation, Rapid Geomorphic Assessment (RGA) and Rapid Stream Assessment Technique (RSAT) were conducted on each reach with a defined channel. Stability of each reach was quantified with a RGA, which documents observed indicators of channel erosion and deposition (MOE, 1999). Observations are quantified using an index that identifies channel sensitivity to aggradation, degradation, channel widening and planimetric adjustment. The index produces values that indicate whether the channel is "in regime" (*i.e.*, stable) (<0.20), stressed/transitional (0.21-0.40) or adjusting (*e.g.*, incision, widening and/or aggradation) (>0.41).

A RSAT provides a broader view of the system by also considering the ecological functioning of the stream (Galli, 1996). This included observations of channel stability, scour/deposition, instream habitat, water quality, riparian conditions and biological indicators, such as the abundance of benthic invertebrates. Each indicator was ranked numerically, a lower value indicates poorer stream health and a higher value represents a rich healthy stream. The RSAT score ranks the channel as maintaining a low (<20), moderate (20-35) or high (>35) degree of stream health. Also included in the RSAT were general observations of channel dimensions, such as bankfull width and depth, substrate size, bank height, vegetation cover, channel hardening and other disturbances. Photographs were also taken at this time of all reaches under study (**Appendix CC**).

4E.8.5 Channel Function: Data Analysis and Results

Figure 4E.8.2 and **Table 4E.8.2** summarize the findings of the field investigation of the individual reaches undertaken between April 22 and July 16, 2002. **Figure 4E.8.2** shows that much of the drainage network within the study area is geomorphically stable channels or vegetated swales, including most of the first order streams in the Joshua's Creek and Sixteen Mile Creek watershed and all of the headwater streams of Morrison Creek (East and West), Munn's Creek, and Shannon's Creek. The unstable reaches tended to be the second and third order streams in the Joshua's Creek and Sixteen Mile Creek watersheds.

With the exception of the largest streams in the watersheds of Joshua's Creek and Sixteen Mile Creek, many of the streams and swales were treated as 'drains' and straightened for agricultural purposes prior to the 1954 coverage. Consequently, there was little observable change to the channel planform of the streams and swales on the agricultural lands.

<u>Joshua's Creek</u>

JC-1A, south of Dundas Street, showed signs of aggradation, widening and planimetric adjustment, with the development of locate and medial bars, accretion on point bars, fines deposition on the riffles, basal scour of the banks, low bed relief channel form and the development of chutes, islands and multiple channels. The river was dry, with the exception of standing water in the pools, on the day it was visited (July 16, 2002). Moving upstream, reach JC-3 showed evidence of uncontrolled grazing in the riparian zone, with associated bank slumping, root exposure in the banks and macrophytes in the channel itself. The RGA indicates an overall pattern of aggradation, channel widening and some planform adjustment, which is the expected result of uncontrolled grazing. Reaches JC-22 and JC-19 also show signs of

aggradation and widening, with the development of lobate and medial bars, accretion in the pools and deposition on medial bars and in the overbank zone. JC-19 also shows signs of planform adjustment, including cut-off channels, poor thalweg alignment and the formation of chutes. Reach JC-4 showed evidence of deposition in the channel and erosion into the banks. The channel appears to have been straightened and there was exposed bedrock in the channel. Processes observed in Reach JC-2 were variable and showed signs of both recent aggradation and degradation, which included siltation in pools, development of medial bars, erosion into bedrock, knick point migration and the exposure of bridge footings.

Reach JC-36 is moderately stable and shows signs of aggradation, with the development of lobate and medial bars, accretion in the pools and deposition on medial bars and in the overbank zone.

Of interest was the identification of exposed bedrock, and in some cases till, in the channel bed along reaches JC-1 (only till), JC-3, JC-4, JC-5, JC-12, and JC-28A. These channels are governed by different processes than alluvial channels. Bedrock controlled channels do not tend to aggrade, although temporary infilling is often observed. Channels with exposed bedrock also tend to be more efficient at transporting sediment that is within the channel.

Sixteen Mile Creek

Reach SMB-1 is a high gradient ravine, running through mixed forest and over bedrock, it shows evidence of degradation and widening, in part due to numerous large debris jams.

The other unstable reaches are associated with SMC-1, SMC-2 and their tributaries. Reach SMC-1 and SMC-2 are high gradient streams running through scrub forest and over bedrock, both show signs of degradation and widening, with erosion into bedrock, knick point migration, exposure of man-made structures, large woody debris, basal scour and exposed roots.

These reaches contrast reaches SMC-3, SMC-4 and SMC-5, which are low gradient reaches running through active agricultural land (corn fields). These reaches were straightened with little channel morphology. Channel sediments were silt and clay. Turbid water was observed during the fieldwork, indicating fine sediment transport. The RGA for the reaches indicate that these reaches are aggrading and show some signs of planform adjustment. The aggradation is likely due to the local land use, which leaves little protection from over-land erosion.

Exposed bedrock in the channel bed was identified along reaches SMA-7, SMB-1, SMB-2, SMB-4, SMC-1 and SMC-2. These reaches tended to be steeper than the channels with bedrock exposure observed along Joshua's Creek, in many cases the reaches of Sixteen Mile Creek with steeper slopes were likely products of bedrock control.

Table 4E.8.2 Scores for the RGA and RSAT for Each Reach				
Reach	**RGA**	**Condition**	**RSAT**	**Condition**
Joshua's Creek				
JC-1	0.30	Transitional	25.5	Moderate
JC-2	0.41	Adjusting	30	Moderate
JC-3	0.51	Adjusting	31	Moderate
JC-4	0.41	Adjusting	28.5	Moderate
JC-5	0.23	Transitional	26.5	Moderate
JC-6	0.15	Stable	24.5	Moderate
JC-7	0.11	In Regime	22	Moderate
JC-8	0.07	Stable	15	Low
JC-9	0.07	Stable	15	Low
JC-10	0.08	Stable	16	Low
JC-10A	0.08	Stable	16	Low
JC-11	Swale	N/A	Swale	NA
JC-12	0.41	Adjusting	28.5	Moderate
JC-13	0.22	Transitional	22.5	Moderate
JC-14	0.11	Stable	15	Low
JC-15	Swale	N/A	Swale	NA
JC-19	0.46	Adjusting	28	Moderate
JC-20	0.18	Stable	24.5	Moderate
JC-20A	0.18	In Regime	24.5	Moderate
JC-22	0.41	Adjusting	25.5	Moderate
JC-27	0.41	Adjusting	27	Moderate
JC-27A	0.08	In Regime	17	Low
JC-28	NA	NA	11	Low
JC-28A	0.35	Transitional	25.5	Moderate
JC-29	No Information	No Information	No Information	No Information
JC-30	0.1	Stable	21	Moderate
JC-31	No Information	No Information	13	Low
JC-31A	Swale	NA	Swale	NA
JC-32	0.26	Transitional	13	Low
JC-36	0.41	Adjusting	27	Moderate
Morrison's Creek (East and West)				
MOC-2	0.11	Stable	22	Moderate
MOC-4	0.2	Stable	26	Moderate
MOC-4A	0.32	Transitional	28.5	Moderate
MOC-5	Swale	NA	Swale	NA
MOC-5A	Swale	NA	Swale	NA
MOC-6	No Information	No Information	No Information	No Information

Table 4E.8.2 Scores for the RGA and RSAT for Each Reach				
Reach	**RGA**	**Condition**	**RSAT**	**Condition**
MOC-W1	0.14	Stable	25.5	Moderate
Sixteen Mile Creek				
SMA-1	0.59	Adjusting	26	Moderate
SMA-2	0.28	Transitional	27	Moderate
SMA-3	0.14	Stable	19.5	Low
SMA-4	0.39	Transitional	26	Moderate
SMA-5	0.27	Transitional	26.5	Moderate
SMA-6	0.36	Transitional	24.5	Moderate
SMA-7	0.52	Adjusting	24	Moderate
SMA-8	0.18	Stable	23	Moderate
SMA-9	0.23	Transitional	24	Moderate
SMB-1	0.52	Adjusting	23.5	Moderate
SMB-2	0.44	Adjusting	28	Moderate
SMB-3	0.39	Transitional	26	Moderate
SMB-4	0.34	Transitional	22	Moderate
SMC-1	0.44	Adjusting	16	Low
SMC-2	0.41	Adjusting	21	Moderate
SMC-3	0.33	Transitional	13	Low
SMC-4	0.22	Transitional	10	Low
SMC-5	0.22	Transitional	10	Low
Shannon's Creek				
SHC-1	0.12	Stable	21	Moderate
SHC-2	0.12	Stable	21	Moderate
SHC-3	Swale	NA	Swale	NA
Munn's Creek				
MUN-1	Swale	NA	Swale	NA
MUN-2	Swale	NA	Swale	NA
MUN-3	Swale	NA	Swale	NA

Field Sites

Four reaches were chosen for more extensive characterization (see **Figure 4E.8.1**):

- Reach JC-3 (Joshua's Creek) located on the main channel of Joshua's Creek upstream of Dundas, northwest of the cemetery;
- Reach JC-13 (Joshua's Creek) located downstream of Burnhamthorpe Road between Trafalgar Road and Ninth Line;
- Reach MOC-4 (Morrison's Creek) located North of Dundas Road at Trafalgar Road; and
- Reach SMA-4 (Sixteen Mile Creek) located upstream of Neyagawa Drive across from the landfill.

These reaches were chosen, as they were categorized as sensitive and or provided coverage across the range of potential watersheds and channel forms. In each reach ten cross-sections were described and measured. Bankfull dimensions were measured, modified pebble counts were conducted, channel planform and gradient were surveyed, visual observations were collected and a photographic record was made. These measurements allowed estimates of bankfull conditions (*e.g.*, discharge, velocity, and potential shear stress) along with estimates of potential erosion thresholds. Bankfull conditions, bed material size and erosion threshold measures are provided in **Table 4E.8.3**. Geomorphic summary tables of the detailed field sites can be found in **Appendix CC2.**

Reach JC-3 displayed bedrock exposed at several cross-sections and significant bank erosion. The flows were also likely nutrient rich as there were macrophytes in the channel and vegetation growing on mid-channel deposit. Bed material was generally clay to fine sand although material did range to small boulders. There was significant bank erosion, the source of the fine sediments, and several sections showed evidence of recent deposition. This indicates the channel is likely trying to adjust to a different discharge regime or land use change.

Reach JC-13 runs through scrub forest and the riparian vegetation consists of tall herbaceous vegetation, shrubs, and trees with dense grasses on some banks and vegetation growing on mid-channel deposit. The materials supplied moderate amounts of woody debris. Bed material was fine clay to very coarse gravel. The channel itself was narrow and entrenched with straightened sections, deposition in the center of the channel at some cross-sections and channel splitting. The morphological evidence along with the amount of fine sediments in the channel bed, usually deposition of bank materials within the channel, suggests the channel is in adjustment.

The reach along Morrison Creek, MOC-4, ran through agricultural land and the riparian vegetation consisted of tall herbaceous vegetation, shrubs, and trees, although there was only minor woody debris. In channel vegetation was dense (cattails). The reach appeared straightened and banks were exposed below bankfull. There were also exposed tree roots along portions of the reach and the channel was generally displayed poorly defined morphology. The subpavement consisted of large pieces of shale surrounded by a silt and clay matrix. Again, this indicates deposition of bank materials within the channel.

The reach along Sixteen Mile Creek, SMA-4, runs through deciduous forest and had riparian vegetation of short grass, tall herbs, shrubs, and trees (maple, oak, hickory). These materials provided large amounts of organic debris. There was vegetation (herbaceous material) in the channel and stagnant water at some locations indicating poor water quality. Like several of the other channels it appears to have been previously straightened. Coarse material was embedded in clay/silt, which consisted of large pieces of shale at some cross-sections.

A comparison of tractive forces to the amount of critical shear stress required to move the D_{50} sediment sizes (**Table 4E.8.3**) shows that on all four study reaches 50 percent of the bed sediments could potentially be mobilized during bankfull conditions. Comparison of the tractive forces to the amount of critical shear stress required to move the D_{84} sediment sizes indicates that at three of the four reaches (MOC-4, SMA-4 and JC-13) bankfull flows could potentially mobilize the majority or all of the bed material. This illustrates the instability of the four reaches and their susceptibility to erosion and modification.

Table 4E.8.3 Bankfull Conditions, Bed Material Size and Erosion Threshold Measures for the Four Study Reaches				
	MOC-4	**SMA-4**	**JC-13**	**JC-3**
Average Bankfull Width (m)	3.14	4.58	2.92	4.99
Average Bankfull Depth (m)	0.26	0.26	0.24	0.31
Bankfull Gradient (%)	0.60	0.55	0.65	0.70
Bed Material D_{50} (m)	5.2E-06	0.0029	0.00083	0.0056
Bed Material D_{84} (m)	0.0053	0.027	0.00853	0.0439
Manning's n	0.033	0.033	0.03	0.033
Average Bankfull Velocity (ms^{-1})	0.96	0.92	1.04	1.18
Average Bankfull Discharge (m^3s^{-1})	0.78	1.09	0.73	1.82
Flow competence (ms^{-1}) @ D_{50}	N/A	0.32	0.18	0.44
Flow competence (ms^{-1}) @ D_{84}	0.43	0.90	0.53	1.13
Tractive Force (Nm^{-2})	15.30	14.03	15.30	21.29
Critical Shear (Nm^{-2}) @ D_{50}	0.0038	2.11	0.60	4.08
Critical Shear (Nm^{-2}) @ D_{84}	3.86	19.66	6.21	31.96
Erosion Potential ($Nm^{-1}s^{-1}$)	10.99	10.96	9.46	20.32
Stream Power (Wm^{-1})	45.95	58.82	46.38	125.14
Stream Power per Unit Width (Wm^{-2})	14.63	12.84	15.88	25.08

4E.8.6 Conclusions

Munn's Creek, Shannon's Creek and Morrison Creek (much of the drainage network within the study area) were small headwater channels that degraded into swales. These reaches were stable – but are susceptible to erosion if the discharge regime and/or land use changes. Joshua's Creek and Sixteen Mile Creek had more substantial channel networks within the study area.

Much of the drainage network within the study area is comprised of geomorphically stable channels or vegetated swales. This includes many of the first order streams in the Joshua's Creek and Sixteen Mile Creek watershed and all of the headwater streams of Morrison Creek (East and West), Munn's Creek, and Shannon's Creek.

The unstable reaches tended to be the second and third order streams in the Joshua's Creek and Sixteen Mile Creek watersheds. These streams tended to be associated with low gradient areas with agricultural land use or wooded high gradient areas. Generally the lower gradient channels that had low or moderate stability were aggrading, widening and in some cases showing signs of planform adjustment. These areas were associated with agricultural land use, which provided little bank protection and a ready supply of fine sediments. The low to moderate stability streams tended to show signs of degradation and widening.

4E.9 Natural Environment Existing Conditions

Comprehensive field surveys were performed throughout the study area to evaluate natural environment conditions (see **Table 4E.9.1**). For the first three-years, the Sixteen Mile Creek valley was not studied in

detail as it had already been extensively studied. However in 2005 and 2006, some field surveys of the Sixteen Mile Creek valley were conducted. The lands west of Sixteen Mile Creek were also surveyed and are documented in **Section 4W** of this report.

Table 4E9.1
North Oakville Creeks Subwatershed Field Survey Dates

	2002	2003	2004	2005	2006
January		16			23
February		10, 24			13, 24
March					
April	7, 16, 19, 23	22, 24, 30		4, 29	
May	2, 10, 16, 17, 22, 23, 29	1, 15, 30		9, 20	
June	6, 7, 10, 25, 27, 28	13, 17, 30	2	3, 15, 30	26,27
July	12	18			
August		6			
September	11, 12, 24	4			
October					
November					
December		9			

Note: Aerial surveys using a fixed wing airplane were conducted on February 10, 2003 and May 30, 2003.

A series of studies were conducted by other teams within the study area during this project. Several of these studies yielded detailed data that has been included in this characterization where feasible. A key series of investigations were conducted by the MNR which culminated in reports on wetlands, candidate ANSIs, and wildlife in May 2003. The original work completed by the MNR included vegetation community mapping, and species inventories. Extensive detailed mapping of wetlands occurred in 2002 and 2003 by staff of MNR and NRSI. This included a series of meetings to review field mapping and data, as well as review of oblique aerial photographs and the May 2003 fly-over. At the time of preparing this report, the wetlands within the study area had not been formally evaluated using the standard MNR Wetland Evaluation system.

The species lists and the vegetation mapping included in this report represent the culmination of this extensive review and agreement among biologists from NRSI, MNR, and Conservation Halton.

At roughly the same time, a team under the North Oakville Management Inc. completed similar studies of the lands east of Sixteen Mile Creek (Stantec *et al.,* 2004). Their assessment included some of the earlier data provided in draft versions of this Subwatershed Study, in conjunction with original work completed by their biologists and ecologists. Data from that assessment has also been included in this report where locational information was provided.
One ESA (No.16) and ANSI, the Sixteen Mile Creek Valley, is present within the study area. This area has been extensively analyzed by several groups (*e.g.,* MNR, 2003a; LGL, 1999; Ecoplans, 1996; 1995). Portions of the Oakville-Milton Wetlands and Uplands Candidate Life Science ANSI are found within the study area (MNR, 2003a).

Organization of Inventory and Information

Species inventories are organized at several 'layers' in this study as follows:

- The entire North Oakville area (including lands east and west of Sixteen Mile Creek);
- At the catchment level; and
- Within catchments, records from hedgerows, open fields, landscape areas, and "habitat units" (see below).

A total of 20 habitat units were delineated in the study area east of Sixteen Mile Creek: units 3 to 22 (units 1 and 2 are located in the lands west of Sixteen Mile Creek). Some of these units are similar to those utilized by LGL (1999). A similar approach with "vegetation inventory units" and "sectors" was used in the subwatershed study completed for the North Oakville Landowners Group (Stantec *et al.*, 2004), although delineations and numbering differ considerably from this report. Delineations were driven primarily by proximity of vegetation units as well as connectivity. The habitat units are identified for the collection of species inventory purposes only. Subsequent discussion of ecological extent is included in **Section 6.0 – Management Strategy** of this report. In some cases, habitat units fall within catchment areas, but since some vegetation communities span adjacent catchments, a number of the habitat units also span catchment areas. **Table 4E.9.2** lists the habitat units utilized in this report, and their corresponding designations used by LGL (1999). Units 3 to 22 are delineated in **Figure 4E.9.1**.

Table 4E.9.2
Habitat Unit Designations Used in this Report, Compared to Designations Described by LGL (1999)

Habitat Units	LGL Habitat Units	Catchment
3	S1	Sixteen Mile Creek
4	S2	Sixteen Mile Creek
5	S3	Sixteen Mile Creek
6	S4	Sixteen Mile Creek
7	S12	Sixteen Mile Creek
8	S5,S6,S8	Sixteen Mile Creek
9	S7	Joshua's Creek
10	M1	Morrison Creek
11	M2	Morrison Creek
12	M3	Morrison Creek
13	M4	Morrison Creek
14	M5	Morrison Creek
15	J8	Joshua's Creek
16	M6,J1,J4	Joshua's Creek
17	M7	Morrison Creek
18	J2	Joshua's Creek
19	J3	Joshua's Creek
20	J5	Joshua's Creek
21	J6	Joshua's Creek
22	J7	Joshua's Creek

As part of the Inter-Agency Review (IAR) process, several discussions between staff of MNR, Conservation Halton, and the subwatershed team focused on the recommended sources for species statuses. The sources of status listings for vascular plants and wildlife are listed in **Table 4E.9.3**.

Table 4E.9.3
Sources of Status Listings for Vascular Plants and Animals

Code	Description	Sources
Rare Plants		
P	Provincially Rare as identified by the Natural Heritage Information Centre (NHIC) (SRank S1-S3)	NHIC website
R	Regionally Rare in Site Region 7	Oldham, 1993; Hamilton Naturalist's Club, 1993; Riley *et al.,* 1996; Varga *et al.,* 2001
L	Locally rare in Site District 7E4	Varga *et al.,* 2001
h	Locally rare in the Regional Municipality of Halton	Crins, 1986 in Riley, 1989
E	Extirpated	Varga *et al.,* 2001
Rare Reptiles and Amphibians		
Committee on the Status of Endangered Wildlife in Canada (COSEWIC)	National status: END: endangered THR: threatened VUL: vulnerable SC: special concern NAR: not at risk DD: deficient data	COSEWIC website
MNR	Provincial status: END-R: regulated under provincial Endangered Species Act END: endangered THR: threatened VUL: vulnerable SC: special concern NIAC: not in any category IND: indeterminate	NHIC website
P	Provincially rare (SRank S1-S3)	NHIC website
L	Locally rare in Site District 7E4	Oldham and Weller, 2000
h	Locally rare in the Regional Municipality of Halton	Geomatics, 1993
Rare Mammals		
COSEWIC	National status: END: endangered THR: threatened VUL: vulnerable SC: special concern NAR: not at risk DD: deficient data	COSEWIC website
OMNR	Provincial status: END-R: regulated under provincial Endangered Species Act END: endangered THR: threatened VUL: vulnerable SC: special concern NIAC: not in any category IND: indeterminate	NHIC website
P	Provincially rare (SRank S1-S3)	NHIC website
h	Locally rare in the Regional Municipality of Halton	Geomatics, 1991

Table 4E.9.3 Sources of Status Listings for Vascular Plants and Animals		
Code	**Description**	**Sources**
Rare Birds		
COSEWIC	National status: END: endangered THR: threatened VUL: vulnerable SC: special concern NAR: not at risk DD: deficient data	COSEWIC website
OMNR	Provincial status: END-R: regulated under provincial Endangered Species Act END: endangered THR: threatened VUL: vulnerable SC: special concern NIAC: not in any category IND: indeterminate	NHIC website
P	Provincially rare (SRank S1-S3)	NHIC website
L	Locally rare in Site District 7E4	Cadman *et al.,* 1987
h	Locally rare in the Regional Municipality of Halton	Geomatics, 1991
L1 – 4	Conservation Priority	Bird Studies Canada website
f	Sensitive forest species	Couturier 1999
MC	Maintain Current Population	Ontario Partners in Flight 2005
HD	Halt Decline	Ontario Partners in Flight 2005
RD	Reverse Decline	Ontario Partners in Flight 2005
AS	Assess Status	Ontario Partners in Flight 2005
RE	Recovery	Ontario Partners in Flight 2005
HD	Moderate to highly habitat dependant	TRCA 2003
AS	Moderately area sensitive	TRCA 2003
Rare Butterflies		
COSEWIC	National status: END: endangered THR: threatened VUL: vulnerable SC: special concern NAR: not at risk DD: deficient data	COSEWIC website
OMNR	Provincial status: END-R: regulated under provincial Endangered Species Act END: endangered THR: threatened VUL: vulnerable SC: special concern NIAC: not in any category IND: indeterminate	NHIC website
P	Provincially rare (SRank S1-S3)	NHIC website
Rare Fish		
COSEWIC	National status:	COSEWIC website

Table 4E.9.3 Sources of Status Listings for Vascular Plants and Animals		
Code	**Description**	**Sources**
	END: endangered THR: threatened VUL: vulnerable SC: special concern NAR: not at risk DD: deficient data	
OMNR	Provincial status: END-R: regulated under provincial Endangered Species Act END: endangered THR: threatened VUL: vulnerable SC: special concern NIAC: not in any category IND: indeterminate	NHIC website
P	Provincially rare (SRank S1-S3)	NHIC website
L	Locally rare in Site District 7E4	MNR, 2003a, d, e, f

4E.9.1 Vegetation

Vegetation surveys were performed on the dates listed in **Table 4E.9.1**. Aerial surveys in February and May 2003 were used to supplement field surveys on the ground. In addition, a series of oblique aerial photographs (April 2003, May 2003, and April 2005) were reviewed to assist with vegetation mapping.

Vascular plant inventories, as well as vegetation community descriptions, were made for each habitat unit. Additional plant records were compiled from background information reports and field surveys, including inventories conducted by MNR in the spring of 2003 (MNR, 2003a, c, d).

Two distinctive forest regions are represented within the North Oakville area: the Huron-Ontario forest section of the Great Lakes-St. Lawrence Forest Region; and the Niagara forest section of the Deciduous ("Carolinian") Forest Region (Farrar, 1995). The Great Lakes-St. Lawrence Forest Region is characterized by stands of sugar maple, American beech, red oak, white ash, and several other associates. This forest occurs on shallower, gravely, and less fertile soils, and is less affected by lake effect climates than the Carolinian Forest Region. Characteristic of the warmer and moister lake effect climate, the Carolinian Forest Region occurs on deep, fertile soils, and is dominated by oaks and hickories, with associates including black walnut, sycamore, and sassafras.

4E.9.1.1 Vascular Flora

A list of vascular flora is included in **Appendix G**. A total of 681 species of vascular plants were observed or have been recorded in the study area, of which 667 are known from the east portion of the study area.

Of the vascular plant species reported from the study area, a total of 172 were either provincially rare, rare in Site Region 7, locally rare in Site District 7E4, or rare in Halton Region (see **Table 4E.9.3** for status codes). Of these, 165 were found in the east portion of the study area. One of these species is nationally and provincially rare; Butternut (*Juglans cinerea*) is considered endangered. Butternut was recorded in Habitat Unit 8. **Table 4E.9.4** includes a list of the rare plant species from Sixteen Mile

Creek and east.

Table 4E.9.4
Significant Flora Reported within the North Oakville Lands East of Sixteen Mile Creek

Status	Common Name	Scientific Name
L	Balsam Fir	*Abies balsamea*
L	Autumn Bent Grass	*Agrostis perennans*
L,h	Rough Hair Grass	*Agrostis scabra*
L	Wild Garlic	*Allium oleraceum*
R,L	Short-awned Foxtail	*Alopecurus aequalis*
L,h	Big Bluestem	*Andropogon gerardii*
L	Long-fruited Anemone	*Anemone cylindrica*
R,L	Sicklepod	*Arabis canadensis*
L,h	Arrow-leaved Aster	*Aster urophyllus*
L,h	Canada Milk Vetch	*Astragalus canadensis*
P,R,L,h	Cooper's Milk Vetch	*Astragalus neglecta*
P,R,L,h	Slender Yellow False Foxglove	*Aureolaria flava*
L	Beggarticks	*Bidens tripartitus*
L	Rattlesnake Fern	*Botrychium virginianum*
L,h	Bearded Shorthusk	*Brachyelytrum erectum*
L	Fringed Brome	*Bromus ciliatus*
L	Water-arum (Wild Calla)	*Calla palustris*
L	Bitter Cress	*Cardamine pensylvanica*
L	Foxtail Sedge	*Carex alopecoidea*
L	Brome-like Sedge	*Carex bromoides*
L,h	Brownish Sedge	*Carex brunnescens*
L,h	Sedge	*Carex buxbaumii*
L	Oval-headed Sedge	*Carex cephalophora*
L	Fringed Sedge	*Carex crinita*
L	Finger Sedge	*Carex digitalis*
L	Bristle-leaf Sedge	*Carex eburnea*
L	Yellow Sedge	*Carex flava*
P,R,L,h	Slender Sedge	*Carex gracillescens*
L,h	Sedge	*Carex grayi*
L,h	Sedge	*Carex grisea*
L	Inland Sedge	*Carex interior*
L	Troublesome Sedge	*Carex molesta*
P,L,h	Muhlenberg Sedge	*Carex muhlenbergii*
L	Sedge	*Carex projecta*
h	Richardson's Sedge	*Carex richardsonii*
L,h	Wrinkle-seeded Sedge	*Carex rugosperma*
L,h	Pointed broom sedge	*Carex scoparia*
L	Stiff Sedge	*Carex stricta*
L	Blunt-broom Sedge	*Carex tribuloides*
L	Sedge	*Carex tuckermani*
L,h	Buttonbush	*Cephalanthus occidentalis*
L,h	Coontail	*Ceratophyllum demersum*
L,h	Pipsissewa	*Chimaphila umbellata*
L	Bulbous Water-hemlock	*Cicuta bulbifera*
L	Stout Wood Grass	*Cinna arundinacea*
L	Nodding Wood Grass	*Cinna latifolia*
L	Field Thistle	*Cirsium discolor*
R,L	Broad-leaved Spring Beauty	*Claytonia caroliniana*

Table 4E.9.4 Significant Flora Reported within the North Oakville Lands East of Sixteen Mile Creek		
Status	**Common Name**	**Scientific Name**
L	Bluebead-lily	*Clintonia borealis*
L	Gold-thread	*Coptis trifolia*
L	Narrow-leaved Dogwood	*Cornus obliqua*
P,h	Hawthorn	*Crataegus dissona*
E,h	Hawthorn	*Crataegus dodgei*
L,h	Hawthorn	*Crataegus macrosperma*
L	Hawthorn	*Crataegus pringlei*
L	Hawthorn	*Crataegus pruinosa*
P?,L,h	Hawthorn	*Crataegus scabrida*
L,h	Hawthorn	*Crataegus schuettii*
L	Emerson's Hawthorn	*Crataegus submollis*
L,h	Shining Cyperus	*Cyperus bipartitus*
L	Silvery Glade Fern	*Deparia acrostichoides*
R,L,h	Common Hair Grass	*Deschampsia flexuosa*
L,h	Dutchman's-breeches	*Dicentra cucullaria*
L	Leatherwood	*Dirca palustris*
L	Crested Wood Fern	*Dryopteris cristata*
L	Small-spiked Barnyard Grass	*Echinochloa microstachya*
L	Blunt Spike Rush	*Eleocharis obtusa*
L,h	Canada Waterweed	*Elodea canadensis*
L,h	Slender Wheat Grass	*Elymus trachycaulus*
L,h	Meadow Horsetail	*Equisetum pratense*
P,E,h	Burning Bush	*Euonymus atropurpurea*
L,h	Dyer's Bedstraw	*Galium tinctorium*
L,h	Three-cleft Bedstraw	*Galium trifidum*
L	Black Huckleberry	*Gaylussacia baccata*
L,h	Closed Gentian	*Gentiana andrewsii*
P	Honey Locust	*Gleditsia triacanthos*
L	Eastern Manna Grass	*Glyceria septentrionalis*
L	American Pennyroyal	*Hedeoma pulegioides*
L	Round-lobed Hepatica	*Hepatica americana*
h	Cow-parsnip	*Heracleum maximum*
L	Canada Waterleaf	*Hydrophyllum canadense*
L	Spotted St. John's Wort	*Hypericum punctatum*
L	Winterberry	*Ilex verticillata*
L	Twinleaf	*Jefferson diphylla*
END,P?	Butternut	*Juglans cinerea*
L,h	Tall Blue Lettuce	*Lactuca biennis*
R,L,h	Narrow-leaved Pinweed	*Lechea intermedia*
L	White Grass	*Leersia virginica*
L,h	Star Duckweed	*Lemna trisulca*
L,h	False Pimpernel	*Lindernia dubia*
P,L,h	Virginia Yellow Flax	*Linum virginianum*
P,R,E,h	American Gromwell	*Lithospermum latifolium*
L	Cardinal Flower	*Lobelia cardinalis*
L	Water-purslane	*Ludwigia palustris*
L	Common Wood-rush	*Luzula multiflora*
L	Crowfoot Clubmoss	*Lycopodium digitatum*
L	Tufted Loosestrife	*Lysimachia thrysiflora*
P	Scentless Chamomile	*Matricaria maritima*

Table 4E.9.4 Significant Flora Reported within the North Oakville Lands East of Sixteen Mile Creek		
Status	**Common Name**	**Scientific Name**
L	Cow-wheat	*Melampyrum lineare*
P,R,L,h	Virginia Bluebells	*Mertensia virginica*
L,h	Slender Najas	*Najas flexilis*
L	Mountain Rice	*Oryzopsis racemosa*
L	American Royal Fern	*Osmunda regalis*
L,h	Upland Virginia Creeper	*Parthenocissus quinquefolia*
L	Foxglove Beardtongue	*Penstemon digitalis*
L	Hairy Beardtongue	*Penstemon hirsutus*
L	Blue Phlox	*Phlox divaricata*
L,h	Ninebark	*Physocarpus opulifolius*
L,h	Spring Clearweed	*Pilea fontana*
L,h	Sycamore	*Platanus occidentalis*
L	Fringed Polygala	*Polygala paucifolia*
L	Seneca Snakeroot	*Polygala senega*
R,L,h	Whorled Milkwort	*Polygala verticillata*
L	Water Smartweed	*Polygonum amphibium*
L,h	Pinkweed	*Polygonum pensylvanicum*
L	Rock Polypody	*Polypodium virginianum*
L,h	Leafy Pondweed	*Potamogeton foliosus*
R,L,h	Variable-leaved Pondweed	*Potamogeton gramineus*
E,h	Common Floating Pondweed	*Potamogeton natans*
R,L,h	Knotty Pondweed	*Potamogeton nodosus*
L,h	Flat-stemmed Pondweed	*Potamogeton zosteriformis*
L	Canada Plum	*Prunus nigra*
L,h	Swamp White Oak	*Quercus bicolor*
L,h	Chinquapin Oak	*Quercus muhlenbergii*
L,h	Black Oak	*Quercus velutina*
L	Bristly crowfoot	*Ranunculus pensylvanicus*
L,h	Swamp Rose	*Rosa palustris*
L,h	Northern Dewberry	*Rubus flagellaris*
L,h	Swamp Dewberry	*Rubus hispidus*
L	Shining Willow	*Salix lucida*
L	Slender Willow	*Salix petiolaris*
R,L,h	Water Pimpernel	*Samolus valerandi*
L	Sassafras	*Sassafras albidum*
R,L	Early Saxifrage	*Saxifraga virginiensis*
L	False Melic Grass	*Schizachne purpurascens*
R,L,h	River Bulrush	*Scirpus fluviatilis*
L	Carpenter's-square	*Scrophularia marilandica*
L	Soapberry	*Shepherdia canadensis*
P,R,L,h	Cut-leaved Goldenrod	*Solidago arguta*
R,L	White Goldenrod	*Solidago bicolor*
R,L,h	Hairy Goldenrod	*Solidago hispida*
L	Rough Goldenrod	*Solidago rugosa*
R,L,h	Stout Goldenrod	*Solidago squarrosa*
E,h	American Bur-reed	*Sparganium americanum*
R,L	Green-fruited Bur-reed	*Sparganium emersum*
L,h	Giant Bur-Reed	*Sparganium eurycarpum*
R,L,h	Venus' Looking Glass	*Specularia perfoliata*
L	Meadowsweet	*Spiraea alba*

Table 4E.9.4 Significant Flora Reported within the North Oakville Lands East of Sixteen Mile Creek		
Status	**Common Name**	**Scientific Name**
L,h	Greater Duckweed	*Spirodela polyrhiza*
L,h	Woundwort	*Stachys palustris*
L	Yellow Pimpernel	*Taenidia integerrima*
L,h	Wood Sage	*Teucrium canadense*
L,h	Marsh St. John's-wort	*Triadenum fraseri*
L	Wild Coffee	*Triosteum aurantiacum*
R,L,h	Rock Elm	*Ulmus thomasii*
L	Lowbush Blueberry	*Vaccinium angustifolium*
L	Dryland Blueberry	*Vaccinium pallidum*
L,h	Marsh Speedwell	*Veronica scutellata*
L	Downy Arrow-wood	*Viburnum rafinesquianam*
L	Sweet White Violet	*Viola blanda*
L	Long-spurred Violet	*Viola rostrata*
L,h	Northern Water-meal	*Wolffia borealis*
L,h	Columbia Water-meal	*Wolffia columbiana*
R,L,h	Horned Pondweed	*Zannichellia palustris*
L	Prickly-ash	*Zanthoxylum americanum*

4E.9.1.2 Vegetation Types

Vegetation communities in the study area have been mapped previously in several studies including:

- North Oakville Natural Heritage Inventory and Analysis (LGL, 1999);
- Fourteen Mile Creek East Branch, Scoped Subwatershed Plan (Philips Engineering Ltd., 2000a);
- Fourteen Mile Creek Main and West Branches Subwatershed Plan (Philips Engineering Ltd., 2000b);
- Fourteen Mile Creek - McCraney Creek Watershed Planning Study (Triton *et al.,* 1992);
- MNR mapping and descriptions of woodlands with the candidate ANSI (MNR, 2003a);
- MNR mapping of wetlands west of Sixteen Mile Creek (MNR, 2003c); and
- MNR mapping of woodlands associated with Fourteen Mile Creek (MNR, 2003f).

Vegetation communities were mapped and described during this study based on background information from the above reports, aerial photograph interpretation and field surveys. The Ecological Land Classification (ELC) method was used to distinguish and name communities with some modifications (Lee *et al*., 1998). Vegetation communities were described to the "vegetation type" level in the ELC system, with the exception of cultural thickets (CUT) that were classified to the "ecosite" level (cultural vegetation community designations are currently under review by the MNR). LGL's (1999) woodlot tree tally data were also reviewed and compared to the current conditions in the surveyed woodlots. Vegetation communities delineated in this study are shown on **Figure 4E.9.1**. A sample ELC data form is included in **Appendix H**.

Previous studies focused on mapping woodlots found within the North Oakville lands, whereas this study included woodlots, as well as hedgerows and early successional growth (*e.g.,* old field and scrub). The polygons delineated in this study were comparable to past studies (*e.g.,* MMM & LGL, 1992; Ecoplans, 1995; LGL 1999) although most background studies utilized the NHIC vegetation community classification system developed by Bakowsky (1996) or another classification system prior to the development of ELC (Lee *et al.,* 1998). Discrepancies in the description of cultural vegetation units occurred in some occasions, as cultural woodlands (CUW) were reclassified as cultural thickets (CUT 1).

MNR staff provided some vegetation community description information which was used as input to the mapping and descriptions in this report (MNR, 2003a). Vegetation community mapping included in the North Oakville Landowners Subwatersheds Study (Stantec *et al.,* 2004) was also reviewed in the preparation of the vegetation mapping in this report.

Upland Units

Table 4E.9.5 summarizes the types of the upland vegetation communities found in the study area. A total of 16 terrestrial vegetation types were observed, 5 of which are culturally influenced. Two of these communities, the 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 based on listings provided by NHIC. These communities were observed in both the Sixteen Mile Creek (Units 8 and 9) and Joshua's Creek (Unit 18) catchment.

Many of the woodlots surveyed in this study (Units 3, 8, 14, 16, 17, 20, 21, and 22) are associated with creek valleys, as well as headwaters of low order streams. A number of preserved, isolated woodlots (Units 5, 6, 7, 9, 10, 11, 12, 13, 15, 18, and 19) were also found along the backs of lots, which were historically retained for activities such as maple production and lumber.

Wetland Units

Wetlands in the study area were extensively studied by MNR as well as staff of NRSI. **Table 4E.9.6** summarizes the types of the wetland vegetation communities found in the study area. The MNR has mapped two wetland complexes in the study area known as the North Oakville-Milton West and East Wetland Complexes. This network of wetlands extends from Dundas Street in the south to lands north of Highway 407 (MNR, 2003c). Of the 327 wetlands identified by MNR in these two complexes, 191 are within the study area.

As part of the IAR process, the wetland areas mapped by the MNR and staff of NRSI were compared and unified, and mapping of the wetlands was produced for the lands within the study area. **Figure 4E.9.1** shows the extent of wetland areas within the study area. Details regarding the wetland community boundaries within the wetland polygons as well as wetland community descriptions are shown in the mapping prepared by the MNR (2003c). As part of this study, the MNR wetland mapping and descriptions were integrated with the overall vegetation mapping completed by the study team, and MNR wetland descriptions were translated into standard ELC codes and are included in **Appendix H**. In some cases, insufficient data was provided to determine a specific ELC translation (*e.g.,* if wetland is (i) meadow marsh or shallow marsh and/or (ii) organic marsh or mineral marsh).

Translation of wetland evaluations to ELC vegetation types required certain assumptions be made regarding the wetland evaluation document and information:

- The dominant vegetation forms in the wetland evaluations are equivalent to dominant vegetation for ELC vegetation types;
- In the wetland evaluations, species are listed in order of dominance within the dominant vegetation forms;
- In wetland evaluations, narrow-leaved emergent (ne) with dominant *Carex* species translates to a narrow-leaved sedge vegetation type in ELC; and
- It is possible for both 6E and 7E ELC communities to be present.

Table 4E.9.7 is a list of significant wetland community types identified by the MNR (2003c), within the North Oakville-Milton West and East Wetland Complexes:

Table 4E.9.7
Significant Wetland Community Types Identified by the MNR

Provincially Rare
• Buttonbush Thicket Swamp • Swamp White Oak Swamp • Bur Oak Swamp
Locally Rare
• Blunt Spike-Rush Graminoid Shallow Marsh • Common Coontail Shallow Water Aquatic Community • Cursed Crowfoot Herbaceous Shallow Marsh • Eastern Manna Grass Graminoid Shallow Marsh • Fringed Sedge Graminoid Shallow Marsh • Giant Bur-Reed Graminoid Shallow Marsh • Great Duckweed Shallow Water Aquatic Community • Hop Sedge Graminoid Shallow Marsh • Lake Sedge Graminoid Shallow Marsh • Leafy Pondweed Shallow Water Aquatic Community • River Bulrush Graminoid Shallow Marsh • Slender Willow Thicket Swamp • Small's Spike Rush Graminoid Shallow Marsh • Star Duckweed Shallow Water Aquatic Community • Three-parted Beggar-ticks Herbaceous Shallow Marsh • Tuckerman's Sedge Graminoid Shallow Marsh • Water Parsnip Herbaceous Shallow Marsh • Water-meal Shallow Water Aquatic Community • Winterberry Thicket Swamp

Three general types of wetlands are found within the study area, and are listed below.

1. The first include a series of wetland areas found within upland wooded blocks. These are found scattered through the study area, but notably in the northern portion of the study area.
2. Wetland areas found associated with the drainage courses. These linear wetlands are generally marsh habitats dominated by grasses (especially reed canary grass) or cattails.
3. Spatially isolated wetland pockets scattered through the area, outside of forests, mostly in agricultural fields.

4E.9.2 Wildlife

The North Oakville lands have been described in background reports as supporting important wildlife habitat features such as areas of seasonal wildlife concentration, specialized wildlife habitats, habitat for species of concern, and wildlife movement corridors. Background reports, especially LGL (1999), describe locally significant numbers of migrant land birds being attracted to the larger woodlands, as well as locally significant numbers of diurnal birds of prey. LGL (1999) also noted that extensive vernal pooling on the agricultural lands played a key role in the spring migration of waterfowl (*e.g.,* Mallard, Blue-winged Teal, and Canada Goose) and the reproduction of amphibians (*e.g.,* frogs, toads, salamanders, and newts). Reproducing amphibians also find refuge in the numerous wetlands and watercourses found throughout the site (LGL, 1999). Many mammal species rely on the blend of forest, hedgerow, and agricultural habitats found in the North Oakville lands, including white-tailed deer,

raccoon, coyote, and red fox. As a result of the diversity of habitats contained within the study area, a substantial number of wildlife species of conservation concern utilize these lands for all or some portion of their life cycle.

4E.9.2.1 Birds

A variety of bird surveys were undertaken within the study area, as well as a background review of existing sources. Breeding bird observations were made in 2002 on April 7 and 23, May 2, 17, 22, 23, and 29, June 7, 10, 27, and 28, in 2003 on May 30 and June 13, 17, and 30, in 2004 on June 2, and in 2005 on April 29, May 9, and 20, June 3, 15, and 30. The activity of bird species encountered during visits was documented using standard breeding bird monitoring methodology outlined in the Ontario Breeding Bird Atlas (CWS, 2001). The surveys consisted of point counts as well as transect surveys through the area. Winter bird surveys were undertaken January 23, February 13, and 24, 2006. All station and survey locations are shown on **Figure 4E.9.2**. Besides reviewing bird species recorded from the study area in other reports (see **Appendix I** legend for reports reviewed), the Ontario Breeding Bird Atlas (OBBA) was consulted, as well as the Christmas Bird Count (CBC) for the area. The study area falls within squares 17NJ90, 17NJ91, and 17PJ01 of the OBBA, and the Peel-Halton Counties CBC count circle (CBC count code: ONPH).

A complete list of bird species observed in the study area is included in **Appendix I**. A total of 217 bird species were recorded. Where possible, breeding evidence has been noted for the reported bird species (**Appendix I**).

A list of rare bird species reported from the study area east of Sixteen Mile Creek is included in **Table 4E.9.8**. This includes species recorded from Sixteen Mile Creek. The table also includes a description of the habitat preferred by these species as well as comments on the breeding evidence found for each species (based on the original field assessments conducted as part of the Subwatershed Study, as well as background sources where breeding evidence is provided). A total of 33 bird species with some level of rarity were identified. Based on the highest rarity ranking of these species, seven species were endangered, threatened, vulnerable, or of special concern. Of the remaining species, 13 were described as provincially rare, while 18 were rare within Site District 7E4 and 5 were rare within Halton Region. In addition, 11 other rare birds were recorded from either the OBBA or the CBC, without locational data. All of these birds are provincially rare (S1-S3), as designated by NHIC (2005). One, Hooded Warbler (*Wilsonia citrine*), is considered threatened by COSEWIC and the MNR. Nine of the bird species were noted from the CBC and are mostly shorebirds and waterfowl. Four species were recorded from the OBBA (Trumpeter Swan, Tufted Titmouse, Carolina Wren, and Hooded Warbler).

Table 4E.9.8
Significant Bird Species Reported from the Subwatershed Study Area, East

Common Name	Scientific Name	Status	Typical Habitat	Habitat in Eastern Portion of Study Area? Breeding Evidence?
Turkey Vulture	*Cathartes aura*	L	• Bottomland hardwood forests and thickets, rocky cliffs, various habitats, except heavy unbroken forest. • Roost in tall woods of live or dead trees with limbs >18 inches diameter. • Feed on carrion.	• Habitat is present in study area, but not recorded as breeding. • Noted to breed throughout the vicinity of the study area in OBBA.
Cooper's Hawk	*Accipiter cooperii*	L,h	• Dense, extensive mixed or deciduous forests, preferably in Carolinian forest zone. • Usually near pools of water or streams. • Woodlots interspersed with open fields, floodplain forests, and wooded swamps. • Will nest near human activity where habitat and food are available. • Nesting territory must be at least 6ha with 60 to 70% canopy closure. • Hunting territory extends over 3 to 5 km^2. • Requires minimum of 10 to 15ha of habitat, but prefers forests > 50ha.	• Habitat present in study area, and noted as a probable breeder. • Noted to breed throughout the vicinity of the study area in OBBA
Sharp-shinned Hawk	*Accipiter striatus*	L	• Dense, coniferous or mixed forests. • Usually near a lake or river and sometimes wet forest. • Uses more open areas like forest edges or forest clearings for hunting.	• Habitat is present in study area, and observed during breeding season (without actual evidence of nesting). • Noted to breed throughout the vicinity of the study area in OBBA.

Table 4E.9.8
Significant Bird Species Reported from the Subwatershed Study Area, East

Common Name	Scientific Name	Status	Typical Habitat	Habitat in Eastern Portion of Study Area? Breeding Evidence?
			• Requires minimum of 4ha of dense (>80%) canopy closure for nesting. • Forests >30ha appear to be preferred.	
Rough-legged Hawk	*Buteo lagopus*	P	tundra, farmland, marshes and other expansive open habitats; nests on cliff ledges or in conifer tree in tundra	-species noted as migrant and winter resident only -study area not within typical breeding range of this species
Red-shouldered Hawk	*Buteo lineatus*	L,h,SC	moist, mature hardwood forests; woody swamps or wooded margins of marshes; wet bottomlands; restricted to mature, closed (>80%) closed forests; nests reused; requires a minimum of 10 ha of continuous forest to meet territorial requirements; prefers >100 ha of forest; tends to nest in interior	-habitat present in study area, reported as present during breeding season without actual evidence of nesting -some records of breeding in 1st OBBA, but not in vicinity in recent OBBA
Bald Eagle	*Haliaeetus leucocephalus*	END-R	require continuous forests, either deciduous or mixed woods around large lakes or rivers; requires 255 ha for nesting, shelter, feeding, roosting; prefer open woods with canopy closure between 30 and 50%; nest in tall trees 50-200m from shore; also require tall dead or partially dead trees within 400m of nest for roosting	-species noted from CBC and observed by NRSI in April 2005 -breeding habitat is not available, but Bald Eagles may use the area for migration or wintering
Ruffed Grouse	*Bonasa umbellus*	L	dry, deciduous forests with dense woody overhead cover, herbaceous ground cover; prefers second growth stands of poplar; requires sunny, open areas; uses fallen logs	-habitat present within study area, reported as possible breeder -noted from a few are in 1st OBBA and several areas in vicinity of study area in recent OBBA

Table 4E.9.8
Significant Bird Species Reported from the Subwatershed Study Area, East

Common Name	Scientific Name	Status	Typical Habitat	Habitat in Eastern Portion of Study Area? Breeding Evidence?
			for drumming and cover for nesting	
Virginia Rail	*Rallus limicola*	L	freshwater, shallow marshes, sloughs or roadside ditches with a mix of open water; emergent vegetation (sedges, cattails); wetlands and ponds, lakes with sedge and cattail edge; fluctuating water levels are a threat to nests; territories are from 0.25 to 1 ha in size	-habitat present in study area and recorded as confirmed breeder by OBBA
Stilt Sandpiper	*Calidris himantopus*	P	Shallow pools, mud flats, marshes, sedge tundra near water (summer)	-species noted as migrant only -study area not within typical breeding range of this species
Semipalmated Sandpiper	*Calidris pusilla*	P	Beaches, mudflats, grassy or mossy tundra (summer)	-species noted as migrant only -study area not within typical breeding range of this species
Marbled Godwit	*Limosa fedora*	P	wetlands, sloughs, lakes or ponds with grassy edges; feed largely on insects; protection of coastal marshes is important	-species noted as migrant only -study area not within typical breeding range of this species
Little Gull	*Larus minutus*	P	predominantly marshes, occasionally on islands; inland marshes and marshy border lakes; nests on floating to semi-floating mats	-species noted as migrant only -study area not within typical breeding range of this species
Black Tern	*Chlidonias niger*	P, SC	wetlands, coastal or inland marshes; large cattail marshes, marshy edges of rivers, lakes or ponds, wet open fens, wet meadows; returns to same area to nest each year in loose colonies; must have shallow (0.5 to 1m deep) water and areas of open water near nests; requires marshes >20 ha in size; feeds over adjacent grasslands for insects; also feeds on fish,	-species noted as migrant only -study area not within typical breeding range of this species

Table 4E.9.8
Significant Bird Species Reported from the Subwatershed Study Area, East

Common Name	Scientific Name	Status	Typical Habitat	Habitat in Eastern Portion of Study Area? Breeding Evidence?
			crayfish and frogs	
Caspian Tern	*Sterna caspia*	P	open habitat near large lakes or rivers, beaches, shorelines, rocky or sandy beaches, offshore islands; negatively affected by elevated water levels during nesting season; feeds on fish; found in association with Ring-billed Gulls	-species noted as migrant only -study area not within typical breeding range of this species
Red-bellied Woodpecker	*Melanerpes carolinus*	h	mature deciduous forests with numerous dead trees; open woodlands, suburbs or parks; both wet bottomland or dry upland areas; requires at least 4 ha of continuous forest and cavity trees at least 35 cm dbh	-marginal habitat present in study area -reported as confirmed breeder in OBBA
Red-headed Woodpecker	*Melanerpes erythrocephalus*	P, SC	open, deciduous forest with little understorey; fields or pasture lands with scattered large trees; wooded swamps; orchards, small woodlots or forest edges; groves of dead or dying trees; feeds on insects and stores nuts or acorns for winter; loss of habitat is limiting factor; requires cavity trees with at least 40 cm dbh; require about 4 ha for a territory	-habitat present in study area, and reported as observed during breeding season -numerous records of breeding in vicinity in 1st OBBA, but fewer in recent OBBA, none from within study area
Acadian Flycatcher	*Empidonax virescens*	P, END	mature, shady, deciduous forests; heavily wooded ravines; creek bottoms or river swamps; availability of good quality habitat is limiting factor; needs at least 30 ha of forest	-habitat present in study area (primarily Sixteen Mile Creek valley), but reported as migrant -not reported from the vicinity of study area in OBBA
Brown Creeper	*Certhia americana*	L	mature dense, coniferous, deciduous,	-habitat present in study area and Brown Creeper was observed,

Table 4E.9.8
Significant Bird Species Reported from the Subwatershed Study Area, East

Common Name	Scientific Name	Status	Typical Habitat	Habitat in Eastern Portion of Study Area? Breeding Evidence?
			mixed woodlands; particularly wet areas with large dead trees; bogs; wooded swamps; older second growth forest; riparian areas; requires dead trees >25 cm dbh with loose bark for nesting; occasionally nests in tree cavity; requires a minimum of 30 ha	although without breeding evidence -reported as confirmed breeder by OBBA
Blue-gray Gnatcatcher	*Polioptila caerulea*	L	Carolinian and Great Lakes-St. Lawrence Forest zones in deciduous or mixed woods; oak-pine woods or oak savannahs; open, moist woodlands with brushy clearings; bottomland forests with closed canopies; wooded swamps; stream-side thickets; needs about 30 ha of forest	-habitat present in study area, but only observed in east portion of study area during breeding season (no other evidence of nesting) -reported as confirmed breeder by OBBA
Gray-cheeked Thrush	*Catharus minimus*	P	Moist woodland to arctic tundra, coniferous forest edge, riparian thickets, scrub, in migration other woodlands (generalist)	-species noted as migrant only -study area not within typical breeding range of this species
Eastern Bluebird	*Sialia sialis*	L,h	agricultural area, clearings, fields, pastures, lawns, cemeteries, golf courses or forest clearings; savannahs; swamps, edges; orchards; low cavities in trees >20 cm dbh; territories are 4-8 ha	-habitat present in study area, but only observed in study area during breeding season (no other evidence of nesting) - reported as confirmed breeder by OBBA
Northern Mockingbird	*Mimus polyglottos*	L	pastures, gardens or orchards with edible fruit- bearing shrubs; woodland edges, hedgerows; groves of large trees, low, dense woody vegetation; needs elevated perches	-habitat present in study area, and reported as possible breeder (esp. Joshua's Creek area and Sixteen Mile Creek valley) - reported as confirmed breeder by OBBA and possible breeder by NRSI

Table 4E.9.8
Significant Bird Species Reported from the Subwatershed Study Area, East

Common Name	Scientific Name	Status	Typical Habitat	Habitat in Eastern Portion of Study Area? Breeding Evidence?
Northern Shrike	*Lanius excubitor*	P	Semi-open country with lookout posts. Open deciduous and coniferous woodland, taiga, scrub, thickets	-species noted as migrant only -study area not within typical breeding range of this species
Cerulean Warbler	*Dendroica cerulea*	L,h,P, SC	mature deciduous woodland of Great Lakes- St. Lawrence and Carolinian forests, sometimes coniferous; swamps or bottomlands with large trees; area sensitive species needing extensive areas of forest (>100 ha)	-habitat present in study area, and reported as breeding from the Sixteen Mile Creek valley -not reported from the vicinity of the study area in OBBA
Pine Warbler	*Dendroica pinus*	L	mature white pine (red to lesser degree) forests that are somewhat open; 40 to 50 year old pine plantations; area sensitive needing at least 15-30 ha	-very limited amount of pine dominated habitat in study area, but reported as breeder -reported from the vicinity of the study area in OBBA
Black-throated Green Warbler	*Dendroica virens*	L	prefer dense, mixed forest, but also coniferous or more open woods; hemlock, fir are favoured conifers; wet cedar swamps; beech, maple, birches with multi-layered canopy and well developed shrub layer; requires about 30 ha	-habitat present in study area, and reported as possible breeder
Yellow-breasted Chat	*Icteria virens*	P, SC	thickets, tall tangles of shrubbery beside streams, ponds; overgrown bushy clearings with deciduous thickets; nests above ground in bush, vines etc.	-habitat present in the study area, but species noted as migrant -not reported from the vicinity in OBBA
Black-and-white Warbler	*Mniotilta varia*	L	breeds at edges of large continuous stands of mature or old second growth deciduous or mixed forest; cedar swamps or bogs; riparian habitat; during migration prefer bottomland forests and	-habitat present in study area (but few of preferred size), and reported as probable breeder in larger woodlots like Habitat Unit 5, 8 and 21

Table 4E.9.8
Significant Bird Species Reported from the Subwatershed Study Area, East

Common Name	Scientific Name	Status	Typical Habitat	Habitat in Eastern Portion of Study Area? Breeding Evidence?
			forest edges; nests in interior in the south; area sensitive, requiring in excess of 100 ha of continuous forest	
Blue-winged Warbler	*Vermivora pinus*	L	• Brushy, overgrown fields or meadows or old fields with saplings >3m tall, second growth woodlands and edges, borders of wooded swamps and willow swamps, streamsides, and woodland openings; • Requires >20ha of habitat.	• Habitat present in study area, and reported from Joshua Creek area. • Reported as confirmed breeder from OBBA.
Nashville Warbler	*Vermivora ruficapilla*	L	• Wet, open coniferous, deciduous or mixed woods of young secondary growth, cedar and spruce swamps, dry or moist overgrown pastures and old field with scattered trees and shrubs, and edges. • Nests in depressions in ground under dead, dry bracken fern.	• Habitat present in study area but scattered, and reported as breeding. • Reported as probable breeder in OBBA.
Grasshopper Sparrow	*Ammodramus savannarum*	L	• Well-drained grassland or prairie with low cover of grasses and taller weeds on sandy soil, hayfields or weedy fallow fields, uplands with ground vegetation of various densities. • Perches for singing. • Requires tracts of grassland > 10ha.	• Habitat present in study area and reported as possible breeder by NRSI. • Reported as probable breeder by OBBA.
Clay-coloured Sparrow	*Spizella pallida*	L	• Brushy, open areas in prairies, young pine plantations,	• Habitat present in study area, and reported as breeder in Sixteen Mile Creek valley.

Table 4E.9.8 Significant Bird Species Reported from the Subwatershed Study Area, East				
Common Name	**Scientific Name**	**Status**	**Typical Habitat**	**Habitat in Eastern Portion of Study Area? Breeding Evidence?**
			abandoned fields with shrubs and small trees, regenerating burns, and thickets along edges of waterways.	• Reported only from first OBBA.
Orchard Oriole	*Icterus spurius*	h	• Wood edges, orchards, shade trees, scrub, open woodland.	• Habitat present in study area, and reported as breeder in Joshua Creek area. • Reported as confirmed breeder in OBBA.

Based on the habitat preferences and breeding evidence of the species in the above table, it is noted that 12 of the species are not anticipated to nest in the study area, and have been reported as migrants or wintering birds. The remaining species have either been found to exhibit some evidence of breeding in the study area, or have suitable habitat and reports of confirmed breeding in the vicinity of the study area from the OBBA. A variety of habitat types are used by the significant bird species observed in the study area. The study area provides habitat for many interior forest bird species. A further discussion of forest interior and area-sensitive bird species is included in **Section 5.0 - Analysis**. Although the majority of these species rely on forest or forest edge habitats, many also rely on early successional habitats such as old field, meadows, agricultural lands, and thickets that have become increasingly vulnerable to fragmentation and development.

4E.9.2.2 Mammals

Data for mammals was collected based on both direct observations during all field surveys and signs/material evidence (*e.g.,* tracks, scat, carcass, bones, and raptor pellets). Additional mammal records were compiled from background information reports and field surveys.

A list of mammals observed in the study area is included in **Appendix J**. A total of 33 mammals were recorded, of which 30 were reported from the eastern portion of the study area. Two species, Little Brown Bat and Hairy-tailed Mole, do not have locational information given with their reporting's (from Stantec *et al.,* 2004; 2002). None of the mammals reported from the eastern portion of the study area are provincially, regionally or locally rare.

4E.9.2.3 Reptiles and Amphibians

Reptile and amphibian observations were made during all field surveys, but specific observations were made in 2002 on April 7, 19, May 2, 22, 23, 17, June 7, and 27, as well as in 2003 on April 22, 24, 30, and May 1, 15, 30. Breeding amphibian call monitoring followed the Great Lakes Marsh Monitoring Program protocol (BSC, 2001). The locations of the point count stations in the study area are shown on **Figure 4E.9.2**. These stations were selected based on field reconnaissance within the study area, revealing the presence of wetlands in these locations. Data included direct observations in suitable habitat (*e.g.,* salamanders under debris, frogs in vernal pools, and creeks). Additional reptile and amphibian records were compiled from background information reports and field surveys.

A list of reptiles and amphibians observed in the entire subwatershed study area is included in **Appendix K**. A total of 13 reptile species and 15 amphibian species (excluding hybrids) have been recorded in the vicinity of the study area, of which several were only reported from the Ontario Herpetofaunal database (Oldham and Weller, 2000) and no specific records were found within the study area itself. Within the eastern portion of the study area, 7 reptiles and 11 amphibians were reported. Two provincially and locally rare reptiles, the Eastern Milksnake and the Northern Ribbonsnake, were reported from this area. These species are also described as being of "special concern" by COSEWIC. The Eastern Milksnake is found in a variety of habitats ranging from open woodlands to wetlands, but is often found associated with old stone foundations, rock piles, and fences. The Northern Ribbonsnake is found in sunny grassy areas with low dense vegetation near bodies of shallow permanent water, wet meadows, grassy marshes, borders of ponds, and lakes or streams.

One additional species, Northern Ring-necked Snake, was recorded from the study area by LGL (2000), but no specific locational information was given. The Ring-necked Snake is locally and regionally rare. Eleven other species are known from one of the herpetofaunal atlases, but not directly from within the study area; seven of these are rare. In total, six species of reptiles, and four species of amphibians were reported from the vicinity of the study area that have national, provincial, or local statuses. These are listed in **Table 4E.9.9**, along with their habitat preferences, and whether or not they are likely to be found within the study area. Of these the Wood Turtle, Northern Map Turtle, and Jefferson Complex Salamanders are noted only from the atlas databases.

Habitats for most of the other significant species and hybrids are available in the study area.

Table 4E.9.9
Significant Reptiles and Amphibians Reported from the Subwatershed Study Area, East

Status	Common Name	Scientific Name	Typical Habitat	Habitat Found in Eastern Portion of Study Area?
Reptiles				
SC, VUL, P	Wood Turtle	*Glyptemys insculpta*	• Slow-moving streams with sandy bottoms and woody edges; ponds, marshes, swamps; woodlands in floodplains. • Lives within 150m of stream shores. • Home range may be 5 to 25ha, sometimes as much as 115ha. • Riparian corridors are important.	• Very little sandy substrate found in the study area. • Reported from regional atlases, but not the Ontario Herp Atlas.
L,h	Northern Ring-necked Snake	*Diadophis punctatus edwardsi*	• Moist shady woodlands with lots of cover, stony woodland pasture, shrubby old fields, under rocks, logs or debris, and in stone walls or old junk piles. • Eggs are laid in or under logs or stones and several females may use the same nest.	• Habitat is present in the study area. • Species has been reported from the study area.
P	Blanding's Turtle	*Emydoidea blandingii*	• Shallow water marshes, bogs, ponds or swamps, or coves in larger lakes with soft muddy bottoms and aquatic	• Habitat is present in the study area, but species not observed. • Reported from

Table 4E.9.9 Significant Reptiles and Amphibians Reported from the Subwatershed Study Area, East				
Status	**Common Name**	**Scientific Name**	**Typical Habitat**	**Habitat Found in Eastern Portion of Study Area?**
			vegetation. • Basks on logs, stumps, or banks. • Surrounding natural habitat is important in summer as they frequently move from aquatic habitat to terrestrial habitats; hibernates in bogs. • Not readily observed.	atlases.
SC, P	Northern Map Turtle	*Graptemys geographica*	• Large bodies of water with soft bottoms, and aquatic vegetation. • Basks on logs or rocks or on beaches and grassy edges, will bask in groups; • Uses soft soil or clean dry sand for nest sites and may nest at some distance from water. • Home range size is larger for females (about 70ha) than males (about 30ha) and includes hibernation, basking, nesting and feeding areas. • Aquatic corridors (*e.g.,* stream) are required for movement; not readily observed.	• Habitat is marginal with few/no large water bodies. • Species not observed. • Reported from atlases.
SC,P,L	Eastern Milksnake	*Lampropeltis triangulum*	• Farmlands, meadows, hardwood or aspen stands; pine forest with brushy or woody cover; river bottoms or bog woods; • Hides under logs, stones, or boards or in outbuildings. • Often uses communal nest sites.	• Habitat is present in study area, and species observed.
SC, P,L,h	Northern Ribbonsnake	*Thamnophis sauritus septentrionalis*	• Sunny grassy areas with low dense vegetation near bodies of shallow permanent quiet water, wet meadows, grassy marshes or sphagnum bogs, borders of ponds, and lakes or streams. • Hibernates in groups.	• Habitat is present in study area, and species observed.
Amphibians				
THR,P	Jefferson Salamander	*Ambystoma jeffersonianum*	• Damp shady deciduous forest, swamps and moist pasture, lakeshores, temporary woodland pools for breeding, and hides under leaf litter, stones or in decomposing logs.	• Habitat is present but species only reported from atlases

Table 4E.9.9
Significant Reptiles and Amphibians Reported from the Subwatershed Study Area, East

Status	Common Name	Scientific Name	Typical Habitat	Habitat Found in Eastern Portion of Study Area?
P	Jefferson x Blue-spotted Salamander Complex	*Ambystoma jeffersonianum - laterale "complex"*	• See above.	• Habitat is present but species only reported from atlases.
P	Jefferson x Blue-spotted Salamander Polyploids	*Ambystoma jeffersonianum - laterale polyploids*	• See above.	• Habitat is present but species only reported from atlases.
L	Blue-spotted Salamander	*Ambystoma laterale*	• Moist woods in floodplains, ponds, sedge meadows, bogs, swamps or areas with semi-permanent water, occasionally in overgrown fields or in sandy soil, and found under logs or other forest debris. • Home range size 250m^2	• Habitat is present in study area, and species observed.

4E.9.2.4 Butterflies

Butterfly observations were recorded during all field surveys. Data for butterflies was collected based on direct observations during other field investigations. As such, it is presumed that the list of species observed is a subset of butterflies that could occur in this area.

Background information reports and field surveys were reviewed to extract additional butterfly records, however few background sources were found to include butterfly sightings and it is assumed that this list represents a limited number of the butterflies that would be found in the study area. A list of butterfly species observed in the study area is included in **Appendix L**. Many of the butterfly species included in this appendix are from the Ontario Butterfly Atlas, and as such locational information specific to the study area can only be approximated based on the mapping within the atlas.

A total of 65 butterfly species have been recorded in the vicinity of the study area. Of these, 15 species were observed in the eastern portion of the study area during the field surveys. **Table 4E.9.10** summarizes the rare butterflies that were reported from the atlas in the vicinity of the study area. The table identifies typical habitats and notes whether that type of habitat is present in the eastern portion of the study area. Habitat for all rare butterfly species is found in the study area. Only Monarch (*Danaus plexippus*), however, was observed by NRSI.

The species observed in the eastern portion of the study area were associated with a range of open and wooded habitats. It is anticipated that a number of butterfly species are found widespread throughout the remainder of the study area but were not noted during the field surveys.

Table 4E.9.10 Rare Butterflies Reported From the Vicinity of the Study Area				
Status	**Common Names**	**Scientific Name**	**Typical Habitat**	**Habitat in Study Area?**
P	Delaware Skipper	*Anatrytone logan*	• Open spaces and woodland trails, widespread but mainly restricted to the Carolinian zone	yes
SC, THR	Monarch	*Danaus plexippus*	• Any open areas, not in deep forest	yes
P	Common Sootywing	*Pholisora catullus*	• Gardens, disturbed areas, roadsides and edges of woods, most common is southwestern portion of province	yes
SC, P	West Virginia White	*Pieris virginiensis*	• Open woods and woodland trails	yes
P	Little Glassywing	*Pompeius verna*	• Grassy fields and roadsides, particularly long grasses, most common is southwestern portion of province	yes
P	Hickory Hairstreak	*Satyrium caryaevorum*	• Roadsides and edges of woods, associated with its larval host plant (hickories)	yes

4E.9.3 Aquatic Resources

4E.9.3.1 Aquatic Habitats

Past studies of watercourses in the study area included fish habitat and reach delineations along the entire course of each creek (LGL 1999; MMM & LGL 1992) or at specific road crossings (SNC Lavalin-Ferrovial 1999). Fish species inventories for each reach (*e.g.,* MMM & LGL 1992) or at specific locations along the creeks (*e.g.,* primarily at Dundas Street crossings - LGL 1999; at Highway 407 corridor crossings - SNC Lavalin-Ferrovial 1999) were also performed where permanent or seasonal flow was observed.

A considerable number of the stream reaches within the study area function as agricultural drains, but have not been officially designated as municipal agricultural drains (Featherstone, personal communication 2002). Therefore, these streams were not classified under the Municipal Drain Class Authorization System initiated in 1999 by DFO and the southwestern Conservation Authorities.

Aquatic habitat investigations and mapping were initiated in April 2002, with detailed mapping of habitats between May 10 and July 15, 2002. Subsequent habitat refinements occurred through the duration of the study. Headwater sections of the systems most likely to have intermittent flow were assessed earlier in the season such that habitat assessments could be made while flowing water was present. The various streams were divided into study reaches (see **Figure 4E.9.3**) based on the homogeneity of habitat. In addition, the attributes of the habitats observed in each homogenous reach were recorded on field data forms (a copy of the field form can be found in **Appendix M**). **Appendix N** lists habitat characteristics recorded for the surveyed reaches.

Sixteen Mile Creek

Sixteen Mile Creek is the largest watercourse in the study area, draining an area of approximately 377 km^2. It consists of three branches, the west and middle branches (originating in the Niagara Escarpment), and the east branch that originates north of the village of Drumquin at Brittania and Trafalgar Roads. The upstream reaches of the west and middle branches exhibit coldwater temperatures, while the headwaters of the east branch display cool – coldwater temperatures. These reaches support resident populations of brook trout and brown trout, as well as migratory runs of rainbow trout (Ecoplans 1995). Tributaries of the upper middle and east branches also support resident populations of redside dace (*Clinostomus elongatus*) a nationally, provincially and regionally rare fish species. The confluence of the east branch with the west and middle branches occurs directly north of the study area at which point the creek becomes deeply incised in a ravine.

Within the study area, Sixteen Mile Creek has been classified as a permanent, warmwater/coolwater system supporting migratory runs of salmonids (rainbow trout, chinook and coho salmon), and resident populations of smallmouth bass and several forage fish species (LGL 1999).

The field investigations did not include examinations of the main creek, but did include a number of the tributaries.

North Tributary to Sixteen Mile Creek

The north tributary of Sixteen Mile Creek originates in a farm field where it flows into an online pond (approximately 12m wide) just north of Burnhamthorpe Road. There were 5 survey reaches (**see Figure 4E.9.3** labelled as SMC-1 to SMC-5). There is a lack of riparian vegetation through this section of creek as it is plowed through and planted with crops. The online pond does have a riparian zone consisting of grasses and some shrubs. There is aquatic vegetation within the pond. Water temperature was 23°C (July 12, 2002) and air temperature was 24°C. There is a second online pond slightly larger than the first located just downstream of Burnhamthorpe Road. Water temperature of the second pond was 28°C (July 12, 2002). Downstream of Burnhamthorpe Road, large trees and shrubs line the creek on one side of the pond providing some canopy cover. Channel substrate, between the two ponds consists of silt and muck. Downstream of the second pond the stream gradient steepens to Sixteen Mile Creek. The creek runs through a large woodlot that borders Sixteen Mile Creek. In-stream habitat includes woody debris, cobble, and boulders. The channel was dry on July 12, 2002, however there were remnant pools present throughout this section of creek. The woodlot provides good canopy cover, and channel substrate consists of clay, sand, gravel, cobble, and boulder.

South Tributary to Sixteen Mile Creek

The south tributary to Sixteen Mile Creek has two branches, which originate from Neyagawa Boulevard and is divided into nine survey reaches (**Figure 4E.9.3** labeled SMA-1 to SMA-9). The east branch crosses Neyagawa Boulevard twice and flows through a large woodlot on the east side of Neyagawa Boulevard. This woodlot provides excellent canopy cover and contributes woody debris to the stream. Habitat features include woody debris, vegetation, backwater areas, boulders, and some undercut banks. There are wetland areas within the woodlot that periodically drain into the creek. Substrate consists of silt, muck, gravel, and cobble. The water temperature was 24°C (July 12, 2002) and air temperature was 27°C. To the west of Neyagawa Boulevard the creek has been channelized (SMA-3) to skirt the landfill. Habitat features are the same, however there is a lack of meander to the stream channel. The creek enters the woodlot along Sixteen Mile Creek where the gradient becomes steep. Riffle pool sequences with

woody debris, cobble, and boulder are present within this stretch. The west branch (SMA-8 and SMA-9) is channelized with little to no meanders. This branch was dry in mid July 2002 with a few remnant pools present which had water temperatures of 28°C (July 12, 2002). There is a small riparian zone with large trees, shrubs, and grasses. Channel substrate consisted of silt, sand, gravel, and cobble.

Shannon's Creek

Shannon's Creek originates as a poorly defined, intermittent agricultural swale within the study area. Little fisheries information exists for this creek, and in past studies, it has been deemed as having no fisheries potential (LGL 1999). Part of the Shannon's Creek channel does, however, fall within the Sixteen Mile Creek ESA (No. 16).

Shannon Creek drains a watershed used heavily for agriculture. It originates from a small pond (ten metre diameter) south of Burnhamthorpe Road. Three survey reaches were determined (**Figure 4E.9.3** labeled SHC-1 to SHC-3). The temperature of the creek at the outflow from this pond was 16.5°C (May 10, 2002) and air temperature was 13°C. There are remnant pools present just upstream from a small woodlot where water temperature was 20°C. Substrate throughout this creek consisted of silt, clay, and muck. There is a narrow riparian zone along this creek as the majority of the adjacent land is plowed. This creek runs through a cattail marsh and has two online ponds just upstream from Dundas Street (ten metres wide). Water temperature below these ponds was 12°C on May 10, 2002.

Munn's Creek

Munn's Creek also originates as a poorly defined, intermittent agricultural swale within the study area. Little fisheries information exists for this creek, and in past studies, it has been deemed as having no fisheries potential (LGL, 1999).

Munn's Creek consists of two tributaries within the study area. Both originate from cattail marshes just north of Dundas Street. This creek was divided into 3 survey reaches. Substrate in the west tributary (MUN-2 and MUN-3) consisted mostly of silt, clay, and muck with isolated sections having gravel and boulder. Sedges and cattails provided in-stream habitat. Outside the cattail dominated area the remaining reaches of the creek are plowed through and presently used for cattle pasture. In the north end of the creek, where it originates, the water temperature was 12°C (on May 10, 2002) and air temperature was 13°C. Below the cattle pasture the temperature was 14°C. Both the riparian zone and canopy cover are absent throughout this system.

The east tributary (MUN-1) also originates from a cattail marsh. The substrate of this creek was silt, clay, muck and a few scattered boulders. The channel was dry with no flow or remnant pools. Through the cattail marsh the channel appears natural but the remainder of the creek is channelized and plowed through; there is no riparian zone and a lack of canopy cover.

Morrison Creek

Morrison Creek consists of two branches, both of which originate within the boundaries of the study area. The western branch has flow throughout most of the year, and is dammed directly above and below Dundas Street. The lower reaches of the eastern branch have been designated as potential coldwater habitat due to reports of redside dace downstream of the study area in the vicinity of Upper Middle Road (see below). The upper reaches of the eastern branch display seasonal flow with some isolated pooling.

West Morrison Creek

West Morrison Creek crosses Sixth Line and then runs south parallel to it. This creek was divided into four survey reaches. West of Sixth Line (MOC-W2) the creek substrate is silt, and muck. In June 2002, the channel was dry with a remnant pool located at the culvert. The water temperature of this pool was 25°C on June 25 and air temperature was 33°C. There are no habitat features through this section of stream as it is plowed through with crops. Tilling has also eliminated riparian cover for the creek. To the north, West Morrison Creek originates from swales in agricultural fields (WOC-W5) before flowing though the Sixth Line Road side ditch (MOC-W3). The channel substrates within these reaches are consistent with that of Reach MOC-W2. Downstream of the Sixth Line crossing (MOC-W1) there is a riparian zone consisting of grasses and some shrubs. Farther downstream larger trees provide canopy cover for the creek (approximately 40%). The substrate in this area includes sands, gravels, and some cobble material. Habitat includes riffles, pools and vegetation. Water temperature through this section of creek was 19°C (on June 25, 2002). Just upstream of Dundas Street there is a small cattail marsh within the stream banks. The channel is less defined through this marsh and silts and muck dominate the substrate.

East Morrison Creek

East Morrison Creek is made up of two tributaries that join just north of Dundas Street. The western tributary (MOC-4, MOC-5 and MOC-5A) originates from just east of Sixth Line where it is ploughed through with crops. There is no riparian vegetation or canopy cover in this reach. The substrate consists of silt and muck. On June 25, 2002 the upstream half of the creek channel was dry. There was however a large remnant pool located at the upstream end of the creek. There are two large cattail marshes located on this system. The lower end of the system has a riparian zone with grasses, large trees and shrubs. These trees and shrubs provide canopy cover for this section of stream. Upstream of Dundas Street there is an online pond (approximately 10m diameter). Water temperature in the pond was 22°C (on June 25, 2002) and air temperature was 34°C. Channel substrate just upstream of the pond consists of silt, muck, gravel, and root mats from the large willow trees located on the shoreline.

The eastern tributary of East Morrison Creek (MOC-2 and MOC-6) originates from just south of Burnhamthorpe Road where it flows south through ploughed fields. This section of the creek was dry on June 25, 2002 until it crossed Trafalgar Road the second time. At that point, a minor flow was present originating in a pool just downstream of the culvert. No riparian zone exists upstream of the northern crossing as it is ploughed through. The substrate consists of silt and muck through these ploughed fields. Downstream of the northern crossing, on the east side of Trafalgar Road the creek flows through a woodlot. Habitat features include woody debris and vegetation. There is moderate/good canopy cover through this woodlot. Downstream of the woodlot, the creek flows between crops with riparian vegetation consisting of grasses and shrubs. Channel substrate here consists of silt, muck, sand, gravel and cobble. There are remnant pools present through this section of stream with a water temperature of 20°C (June 26, 2002). Downstream of the woodlot, along Trafalgar Road there has been some construction work done and a cobble substrate has been created just north of Dundas Street. The creek is channelized through a small section directly behind the gas station located at Trafalgar Road and Dundas Street. The stream banks consist of rock gabion baskets. The remainder of the creek flows through a meadow where it meets the west tributary.

Joshua's Creek

Joshua Creek has been classified as a warmwater baitfish stream within the study area, displaying intermittent to near permanent flow with little groundwater contribution (MMM & LGL 1992; Ecoplans

1995). Many tributaries occur in its headwaters, all of which originate between Burnhamthorpe Road and Highway 407. Below the study area, the channel at this creek is heavily altered and urbanized.

With the exception of Sixteen Mile Creek, Joshua Creek is the largest system in the study area. It is located west of Ninth Line and originates from just south of Highway 407. There is a central section of this creek located in a large woodlot where three tributaries meet to create a main channel. In the extreme western reaches (JC-8 to JC-10) water temperature on May 16, 2002 was 20^{o}C and air temperature was 19^{o}C. Channel substrate consists of silt, clay, muck, sand, and gravel. Habitat features include vegetation, with scattered cattails and woody debris. Isolated sections of this tributary are channelized. Canopy cover is absent although there are isolated sections with sporadic trees and shrubs. There is no riparian zone in the headwaters of this branch, but downstream towards Burnhamthorpe Road and south (JC9), there is a riparian zone consisting of grasses and some shrubs. There is a buttonbush swamp located just south of this branch that periodically drains into it.

Another portion of the western branch (JC-11) drains into the western tributary just south of Burnhamthorpe Road. In the flowing sections, water temperature was 19°C (May 16, 2002) with an air temperature of 19°C. There was also remnant standing water in the extreme headwaters with a temperature of 25°C (May 16, 2002). There is no defined baseflow channel in this tributary as it flows through ploughed fields and pastures. There is no canopy cover as this tributary is lacking a riparian zone as a result of vegetation removal to accommodate agriculture.

After the confluence of these two branches, the western tributary (JC-5 to JC-7) begins to have a defined channel with substrate consisting of silt, muck, clay, sand, gravels, cobble, and boulder. In-stream habitat includes vegetation, riffles, pools, and some woody debris. The creek flows through an old pasture that is no longer maintained, as trees and shrubs are scattered along the shoreline. The number of trees and shrubs increases with distance downstream providing more canopy cover as a woodlot is entered. There appears to be some groundwater influence through this section of creek as varying water temperatures were measured within a short distance of the western tributary. Watercress was also observed through this section.

Another branch (Reaches JC-12 to JC-15) flows into the western tributary within the woodlot (**Figure 4E.9.3**). The majority of this tributary upstream of Burnhamthorpe Road flows through meadow and pastures, though there is a large cattail marsh located in the centre of the pasture. Water temperature upstream of the cattail marsh (headwaters) was 10^{o}C and downstream of the cattail marsh was 18^{o}C (May 22, 2002) confirming the warming influence of water standing in the marsh. Air temperature was 23^{o}C. Channel substrate consisted of silt and clay, and in-stream aquatic vegetation is the only habitat feature. Just upstream of Burnhamthorpe Road there is an online pond (approximately 10m wide). Downstream of the pond, extending to the confluence with the western tributary, the channel substrate included silt, clay, muck, sand, gravel, and boulder, and habitat features include woody debris, undercut banks, and boulders. Further downstream of Burnhamthorpe Road the riparian zone includes grasses, trees, and shrubs until entering the woodlot where canopy cover is provided by large trees.

The eastern tributary (JC-19, JC-20, JC-20A) was assessed on April 16, 2002 and those downstream of Burnhamthorpe Road were assessed on May 22, 2002. There is a cattail marsh in the headwaters where it originates with no defined channel. Substrate consists of silts and muck. Canopy cover is provided by a few scattered trees and shrubs but is predominately open. Water temperature was 17^{o}C with an air temperature of 22^{o}C (May 22, 2002). Downstream of Burnhamthorpe Road canopy cover is provided by small trees and shrubs in the riparian zone before flowing through a woodlot where canopy cover is provided by large mature trees. Channel substrate consists of silt, muck, sand, gravel, and cobble. Through the woodlot, habitat features include riffle, pool, woody debris, undercut banks and vegetation.

Water temperature through this section of creek was 16°C (May 22, 2002) and air temperature was 22°C.

The main branch of the eastern tributary (JC-1 to JC-3) of Joshua Creek extending from the woodlot downstream through the White Oaks Golf Course property to Dundas Street was assessed on June 25, 2002. Channel substrate consists of silt, muck, sand, gravel, cobble, and some scattered boulders. Habitat features include riffle, pool, woody debris, undercut banks, and vegetation. Canopy cover is provided by large trees through the woodlot, and trees and shrubs downstream of the woodlot within the riparian zone. There are a few sections of this creek that do not have any canopy cover in the riparian zone as it flows through the golf course. Water temperature was 18°C (June 25, 2002) and air temperature was 25°C.

There are two other small tributaries that enter the main branch just upstream of Dundas Street. The west tributary (JC-30) traverses the golf course and was dry on June 25, 2002. There is no canopy cover and a very small riparian zone as it runs through the golf course. The eastern tributary (JC-20) has very similar habitat features and substrate as the main branch. Water temperature was 18°C (June 25, 2002) and air temperature was 25°C. Riparian zone consists of large trees, shrubs, and grasses.

A small tributary (JC-36) enters the main branch via reach JC-27A. JC-36 is heavily wooded with good channel form and a well sorted substrate of gravel and cobble.

Fish Species

A list of fish species reported from all tributaries of each creek is included in **Appendix O**. A total of 33 fish species are known from the study area. This list was prepared using all available background reports as well as information collected for this study and in 2002/2003 by the MNR.

One nationally, provincially and regionally significant species, redside dace (*Clinostomus elongatus*), has been observed in Morrison Creek (Holm and Crossman, 1986, MNR, 2001; LGL, 1999).

A *Recovery Strategy for Redside Dace in Canada, 2005 – 2009 (Draft)* was prepared by the Redside Dace Recovery Team (RDRT) in 2005. The redside dace is a small colourful cyprinid that requires cool, clear flowing water with riffle-pool sequences and overhanging bank vegetation for its survival (Dextrase *et al.,* 2005). In Canada, redside dace is found only in southern Ontario and most frequently found in small streams flowing into western Lake Ontario (Dextrase *et al.,* 2005). In 1987, COSEWIC updated the national status of redside dace from vulnerable to special concern (Parker *et al.,* 1988). In Ontario, redside dace was designated as a threatened species in 2000 due to loss of habitat and deteriorating water quality. The RDRT (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. Redside dace were most recently reported from the study area in East Morrison Creek by E. Holm of the Royal Ontario Museum in 2000 (ROM, 2000) and Fourteen Mile Creek by the Study Team in 2002.

Fish Sampling Results

Fish sampling occurred on April 17 and April 23, 2002 and Dec 13, 2004 for streams to the east of the main channel of Sixteen Mile Creek. The sampling technique used was backpack electrofishing with the use of a Smith Root Model 12 backpack electrofishing unit.

A condition of the License to Collect Fish for Scientific Purposes NRSI obtained through the MNR (Aurora District Office) was to discontinue shocking efforts immediately upon finding redside dace.

The fish sample stations were selected based on several criteria:

- Available flow;
- Fish habitat characteristics;
- Presence of previous sample stations from background studies; and
- Proximity of previous sample stations from background studies.

Sampling was conducted at 13 stations in the following watercourses: two tributaries of Sixteen Mile Creek; West Morrison Creek; East Morrison Creek; and Joshua Creek. Shannon's Creek and Munn's Creek could not be sampled due to the lack of flow. The location of the thirteen fish sampling stations is presented in **Figure 4E.9.3**.

A total of five fish species (rock bass *Ambloplites rupestris*, goldfish *Carassius auratus*, creek chub *Semotilus atromaculatus*, blacknose dace *Rhinichthys atratulus*, and brook stickleback *Culaea inconstans*) were sampled from one tributary (AB) of Sixteen Mile Creek and East Morrison Creek. One fish species (fathead minnow, *Pimephales promelas*) was found in a small wetland pond located in reach JC-31A of Joshua's Creek. No fish were found in the second tributary (AC) of Sixteen Mile Creek, and West Morrison Creek. Results of the fish sampling are presented in **Appendix P.**

Redside dace was not found in the watercourses east of Sixteen Mile Creek. Gartner Lee Limited conducted a fisheries inventory of East Morrision Creek on May 10, 2005 as part of a Redside Dace Habitat Monitoring and Assessment Program but did not sample any redside dace. Four fish species were sampled including blacknose dace, fathead minnow, creek chub, and brook stickleback.

The fish assemblage is comprised of generalist species, which are tolerant of warmwater temperatures and moderate amounts of organic enrichment. None of the species found in the study area are considered rare or endangered and all are listed as common and secure in Ontario (NHIC 2000).

The MNR conducted fish sampling in 2002/2003 in the North Oakville study area (MNR, 2003g). The location of these sample stations is shown in **Figure 4E.9.3**. Data tables provided by the MNR are included in **Appendix O**.

None of the fish sampled by the MNR are VTE species and all are demonstrably secure in Ontario. The species captured by MNR confirm the warmwater status of the creeks within the study area.

4E.9.3.2 Benthic Invertebrate Communities

The term "benthic" refers to bottom living organisms, which inhabit substrates for at least part of their life cycle. The ability of benthic invertebrates to withstand pollution and environmental degradation varies from species to species. Because of this, benthic invertebrates are very useful in assessing water quality.

There are a number of advantages in using benthic invertebrates for water quality assessment:

- They are typically found in all aquatic habitats;
- They are often available in large numbers;
- Their size makes them easy to collect in comparison to larger organisms, such as fish, which also

requires more elaborate sampling equipment;
- They are less mobile than other groups of animals (*i.e.*, fish and birds) and usually cannot escape any adverse alteration in their environment;
- They integrate all the surrounding parameters of their environment into one easily assessable sampling unit;
- Some benthic invertebrate species have a narrow range of environmental requirements within which they can survive and any change outside this narrow range is intolerable to that species; and
- Many have complex life cycles, which last one or more years and require conditions to remain within their tolerable range throughout this period.

Benthic community surveys undertaken by Gore & Storrie and Ecoplans (1996) in Sixteen Mile Creek revealed that indicators of good water quality were present in upstream reaches of the creek, north of the Town of Milton, where clean, clear water conditions prevail with few periodic incidences of nutrient enrichment. A rare taxon in southern Ontario, *Tricorythodes*, was found at most of the cleaner upstream sites. Indicators of poor water quality, with high abundances of tolerant taxa and no ecologically sensitive taxa, however, dominated benthic invertebrate samples from the lower reaches of Sixteen Mile Creek. These reaches tended to be affected by nutrient enrichment, high turbidity, organic pollution and rapid temperature fluctuations.

Station Selection

The habitat characterization described in Section 4E.9.3.2 was used to guide sample station selection.

Benthic invertebrate communities respond to a wide variety of abiotic factors. Therefore, to the extent possible, an attempt was made to position all stations in similar habitats such that substrate type, gradient, current velocity, depth, and riparian habitat would be as consistent as possible. This ensures a degree of comparability among the stations.

Traditionally, benthic invertebrate sampling has focused on riffle communities. This is due to the ease of sampling, increased sampling precision, higher diversity in riffles, the presence of pollution-sensitive taxa, and the abundance of supporting literature describing riffle communities. However, contaminants can be carried past a riffle habitat to a depositional run or pool area where it may accumulate in the sediments. This would leave invertebrates inhabiting pool and run areas more susceptible to a more direct and consistent exposure to contaminants and pollution than riffle communities. An attempt was made to choose stations that possessed characteristic features of riffle, run, pool and vegetated areas to decrease the variability among the total stations.

Stations were not located where the benthic invertebrate community may be influenced by atypical conditions, such as bridges, channelization, dredging or culverts. Although, the majority of the stations were located close to a road crossing for access purposes, efforts were made to avoid sampling directly under or in close proximity to a crossing.

Sampling Methodology

Benthic invertebrate samples were collected on June 6 and June 7, 2002 from West Morrison Creek, East Morrison Creek (West and East Branch) and Joshua Creek (at a downstream and upstream location). Sampling did not occur on Shannon's and Munn's Creek due to lack of streamflow. The locations of the five stations are shown on **Figure 4E.9.3**. The sampling methodology and detail on the process used for sorting, identification and enumeration of the benthic invertebrate samples are provided in **Appendix R**. A list of references used for the identification of the benthic invertebrate sampled is provided in **Appendix S**.

Habitat Assessment

A brief summary listing the instream habitat found and qualitatively sampled at the five stations is provided in **Table 4E.9.11**.

Table 4E.9.11
Summary of Instream and Bank Habitat Present at the Five Benthic Invertebrate Sampling Stations

Station #	Watercourse	Instream and Bank Habitat
5	• West Morrison Creek	• Riffle, pool, cobble/gravels, margins, instream vegetation and overhanging vegetative areas.
6	• East Morrison Creek (West Tributary)	• Woody debris, margins, instream vegetation and overhanging vegetative areas.
7	• East Morrison Creek (East Tributary)	• Riffle, boulder, margins, instream vegetation and overhanging vegetation.
8	• Joshua Creek • (Upstream)	• Riffle, pool, boulder, cobbles/gravels, woody debris, undercut banks, instream vegetation and overhanging vegetative areas.
9	• Joshua Creek (Downstream)	• Riffle, pool, boulder, cobbles/gravels, woody debris, margins, undercut banks, instream vegetation and overhanging vegetative areas.

Note: Stations 1 – 4 are located west of Sixteen Mile Creek and are described in the West Side Characterization section.

The Aquatic Habitat Assessment - Benthic Invertebrate Monitoring Form designed specifically for the North Oakville Subwatershed Study may be found in **Appendix T**.

Data Analysis and Approach

This study included the following analytical tools to assess stream health within the study area:

- BioMAP (d);
- BioMAP (q);
- Percent Model Affinity (PMA);
- Species Richness; and
- Ephemeroptera, Plecoptera and Trichoptera (EPT) Index.

The BioMAP (d) water quality index as described in MMHA (1998) is used to quantitatively indicate the degree of water quality impairment present in the stream. The BioMAP (q) water quality index is a qualitative approach used to estimate water quality (MMHA 1998). This index is based entirely on the taxa present at a given sample station by pooling both the quantitative and qualitative samples together.

The PMA methodology was developed as a means of measuring benthic invertebrate community composition and relating it to aquatic ecosystem health (Novak and Bode 1992). The development of this method involved the collection of 300 benthic invertebrate samples from 46 non-degraded streams in New York State to form a model community to which a qualitative sample community can be compared (Novak and Bode, 1992).

The species richness index represents the total number of species or taxa found in the sample. Generally, habitats with good water quality have a high number of taxa in a sample.

The EPT index denotes the total number of species of mayflies (*Ephemeroptera*), stoneflies (*Plecoptera*) and caddisflies (*Trichoptera*) found in a qualitative sample. These organisms are considered to be mostly clean-water species, and their presence generally is correlated with good water quality.

The detection criteria for PMA, Species Richness and EPT indices are based on non-degraded streams sampled in New York State (Novak and Bode, 1992). Details of the methodologies and assessment criteria for the indices used in this study are presented in **Appendix U**.

Some of the analytical tools can be used to analyze the quantitative surber sample results while others are applied to the qualitative results from the kick and sweep. The type of samples to which each of the analytical methods was applied is summarized in **Table 4E9.12**.

Table 4E9.12
Analytical Tools and Sample Types

Analytical Tool	Sample Type	
	Quantitative Surber Samples	Qualitative Kick and Sweep Sample
BioMap(d)	X	
BioMap(q)	X	
PMA		X
Species Richness	X	X
EPT		X

Results

There were a total of 15 samples taken from 5 stations east of Sixteen Mile Creek. There was a general consistency in the invertebrate community among the stations, which suggests uniformity in the habitat present in the watercourses for the study area.

The results of the benthic invertebrate sampling are summarized in **Table 4E.9.13**. The benthic invertebrate identification and enumeration raw data is presented in **Appendix V**. Overall assessment of the findings from **Table 4E.9.13** is described below.

- **West Morrison Creek** – The BioMAP (d) and (q) analysis indicates that the water quality of West Morrison Creek is impaired. The PMA and Species Richness indices results showed a moderate impact to stream health, which support the BioMAP assessment. The EPT index indicates a severe impact, due to the presence of only 1 EPT species. This is not surprising given the agricultural impacts present in the watershed.

- **East Morrison Creek** – The BioMAP (d) and (q) analysis indicates that the water quality of the west tributary of East Morrison Creek is impaired. The PMA, Species Richness and EPT indices support this finding by showing a moderate impact, with the exception of the surber replicate No. 2, indicating a severe impact to water quality.

  The BioMAP (d) and (q) analysis indicates that the water quality of the east tributary of East Morrison Creek is impaired. Replicates 1 and 2 (quantitative surber samples) for Species Richness

and PMA results indicate a moderate impact to water quality. Species Richness for the kick and sweep sample and the EPT index show a severe impact, which is based on the qualitative sample results. The low number of taxa found in this sample and the absence of any EPT species is likely a result of the poor benthic habitat present at this station. The substrate primarily consists of silt and fine material and the current was slow. These conditions are not favourable to EPT or to most benthic invertebrate species.

- **Joshua Creek** – The BioMAP (d) and (q) analysis for both the upstream and downstream stations of Joshua Creek indicate impaired water quality conditions. The results of the PMA and EPT analysis indicate a moderate impact for both stations, which supports the BioMAP assessment. The Species Richness parameter for both the upstream and downstream stations indicates a moderate impact from Replicates 1 and 2 (quantitative surber samples), which also supports the BioMAP, PMA and EPT indices results.

  Species Richness for the qualitative kick and sweep sample for the upstream station indicates a slight impact, and no impact for the downstream station. Both the upstream and downstream stations for Joshua Creek consist of a very diverse instream and bank habitat, which provides suitable habitat for a range of benthic invertebrate species. Although it was found that there were a high number of benthic invertebrate species present, they were all indicators of poor water quality.

To summarize, the results of the benthic invertebrate samples are consistent throughout the study area, generally indicating a moderate impact to water quality.

4E.9.4 Ecological Linkages

The North Oakville lands contain a variety of habitat types including agricultural fields, pasture, hedgerow, pioneer vegetation, mature woodlands, wetlands, and valleys, and have been described as a remnant agricultural landscape (Gore & Storrie and Ecoplans, 1996; LGL, 1999). The function of these lands has been influenced by urbanization to the immediate south, and by the local road network throughout the area. These roads have increased the amount of habitat fragmentation and have created barriers to ground travelling wildlife within the area and to areas adjacent to the subject lands. Connectivity between some northern and southern patches of habitat within the site appears to be maintained by the vegetated creek corridors, mainly Sixteen Mile Creek and Joshua's Creek.

Observations of wildlife movement within the study area included direct observations of wildlife during field surveys, as well as a winter (February 2003) aerial survey of wildlife tracks. Staff of the MNR also conducted winter wildlife tracks surveys in 2002 (MNR, 2003d). The natural communities associated with Joshua's Creek were noted to include a number of deer tracks, but few distinct, well-used trails. A well-used deer trail was noted along the south margin of a series of woodland habitats found east of Neyagawa Boulevard (Habitat Unit #8).

Potential ecological linkages and restoration areas were identified in the report prepared by LGL (1999). These linkages connected most of the currently isolated wooded habitats within the study area. In the Sixteen Mile Creek Watershed Study, a main connection is identified running east-west north of the study area.

Based on field mapping, the existing habitat connections appear to be of five main types:

- Agricultural fields and open field habitats;
- 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;
- Stepping stones created by proximity of habitat types with little connecting habitat; and
- Connectivity created by contiguous woodland habitats.

The potential linkage of habitats is further assessed in **Section 5.0 - Analysis** of this report.

4E.10 Water Quality

Water quality samples were collected from five sites from November 2002 to August 2003. Sampling locations are shown on **Figure 4E.10.1.** Results of the water quality analyses are presented in **Appendix W** and discussed below.

Data collected by Stantec *et al*. (2002) in May 2002 was also reviewed. The results are similar to this study. It is noted that aluminium and iron exceed the Provincial Water Quality Objectives (PWQO) and may represent a low level of chronic toxicity to aquatic life. However it is believed that the source of these metals is natural soil conditions (the characteristic red soils are high in iron). Dissolved oxygen and temperature conditions were acceptable, however since the data was collected in May, the results are not representative of conditions that may prevail later in the summer.

Table 4E.10.1
Water Quality Sampling Program

Sample Id	*Description*	**Sample Dates**	**Parameters**
JC1	Joshua Creek	26 Nov. 02 - Dry 20 Dec 02 - Wet 2 May 03 – Wet Aug. 13 2003 – Dry (metals and pesticides only sampled on Aug. 13 2003)	• E. coli/Fecal Coliform • Total Phosphorus • Ammonia • Total Kjeldahl Nitrogen • Nitrite and Nitrate – nitrogen • Biological Oxygen Demand • Total Suspended Solids • Pesticides • Total Metals
JC2	Joshua Creek		
EM	East Morrison Creek		
WM	West Morrison Creek		
SH	Shannon's Creek		

- **Bacteria (E. coli and Fecal Coliform) –** High levels indicate a potential health risk, primarily to body contact recreation. Levels of E. coli should be below the PWQO of 100 counts per 100 mL to protect public health at bathing beaches. The results indicate that levels of E. coli are often above the PWQO with wet weather data being consistently higher than the dry weather case. This is an expected result and probably results from farming activity or wildlife.
- **Total Phosphorus –** PWQO of 0.03 mg/L was established to prevent nuisance aquatic growths of algae and plants. Phosphorus and algae are also a problem on the Lake Ontario shoreline of Oakville, which is the ultimate receiver of the flows from these tributaries. The results indicate that all samples were above the PWQO with wet sample results significantly above the dry weather samples. This is likely the result of agricultural activities in general and the resulting soil erosion during wet weather.
- **Ammonia nitrogen, Total Kjeldahl Nitrogen (TKN), Nitrite and Nitrate Nitrogen –** A portion (un-ionized ammonia) of the ammonia is toxic to aquatic life, depending on the temperature and

pH of the water. TKN represents the organic nitrogen plus the ammonia. Nitrite and nitrate are nutrients similar to phosphorus and can stimulate plant growth. Nitrate has no PWQO, however a Canadian Water Quality Guideline of 2.93 mg/L (NO3 - N) has been set to protect fish spawning areas. As a result, although the pH and temperature are not available for the specific sampling times, to calculate the un-ionized fraction the levels of ammonia are generally not toxic at temperatures and pH expected in spring (pH 8.0 and T of 10ºC) and winter (pH 8 an T of 5ºC). However, the high value of 1.37 mg/L for the May sample in the Fourteen Mile Creek tributary (FM 4) is likely toxic to aquatic organisms (at pH 8.0 and T of 10ºC). TKN levels are fairly stable with higher levels in wet weather indicating washoff of organic plant material. The levels of nitrate nitrogen often exceed the guideline level indicating a potential problem for aquatic life

- **Chloride –** A component of road salt, this ion is receiving increasing scrutiny from the federal government. It provides a good measure of urbanization and road activity. No PWQO is available, however Environment Canada has designated road salt as a Toxic Substance (Canada Gazzette Notice, April 2005), referring to levels above 250 mg/L as a cause for concern for aquatic organisms. No chloride data collected for these locations.
- **Total Suspended Solids (TSS) –** Targets are often set on this parameter for control of urban runoff. TSS is a good surrogate for other water quality parameters. No PWQO is available. The results for this study indicate that the levels vary significantly with expected higher values in wet weather. This is not being observed consistently, however, most likely because the majority of the watershed is well vegetated and limited construction is occurring. Also, there was a significantly high value in dry the weather sample in East Morrison Creek in August 2003, likely due to some construction activity.
- **Biological Oxygen Demand (BOD) –** This parameter measures the oxygen requirement to decompose material in the water, bacterially with the BOD test. There is no PWQO for this parameter. High levels of BOD can indicate organic pollution from human wastes or manure. For this study, no BOD was detected above the lab detection limits of 3 and 4 mg/L.
- **Metals –** Heavy metals in runoff can indicate urban or highway runoff or the presence of an industrial discharge. Also, metals are sometimes high due to natural sources. PWQO exist for many of the metals tested. For this study, aluminium was above the PWQO for all of the locations, likely due to the presence of clay in the sample (the PWQO is for clay free water). Copper was marginally above the PWQO for three out of five stations, a result noted for many other southern Ontario locations, likely due to background mineral sources. Iron was above the PWQO likely due to the characteristic red soils in the area which are high in iron

Two temperature data loggers were installed to record continuous data (same locations as the flow monitors for Morrison Creek and Joshua's Creek).

For Joshua's Creek, daily differences in temperature were greater than 15°C in the spring and even higher in the summer. For Morrison Creek, daily differences in temperature were about 15°C to 20°C in the spring and approximately 10°C in the summer. It should be noted that both Joshua's Creek and Morrison Creek became dry from June to August which makes the summer water temperature readings ineffective (*i.e.,* the gauges were not submerged in water but were lying on dry creek bed

4E.11 Servicing

A review of the Water and Wastewater Master Plan Review in support of the Halton Urban Structure Plan (HUSP) has identified a number of proposed water and wastewater servicing facilities within the study area. The types of facilities include trunk and local servicing watermains, sanitary sewers and forcemains, and two sanitary pumping stations.

At this time, it appears only four direct watercourse crossings will be required for these facilities within the study area, all of which are associated with watermains. Several other watermains and sanitary sewers will be constructed in locations in proximity to local watercourses (see **Table 4E.11.1**). The extent of the potential impacts of these proposed works will need to be established.

Appropriate mitigative measures will need to be identified and implemented to address potential impacts on surface water and groundwater associated with each servicing project at the time of construction.

Table 4E.11.1
Servicing Infrastructure Halton Urban Structure Plan (HUSP)

Infrastructure Location	Servicing/Facility Type	Stream Crossings
Water Servicing*		
Burnamthorpe Road - Hwy 25 to 6th Line	Trunk	Sixteen Mile Creek
Burnamthorpe Road - 6th Line to 9th Line	Servicing	East Morrison Creek Joshua's Creek
9th Line - Dundas Street to Burnamthorpe Road	9th Line - Dundas Street to Burnamthorpe Road	9th Line - Dundas Street to Burnamthorpe Road
New Alignment East of Trafalgar Road - Dundas Street to Burnamthorpe Road	Servicing	No direct crossings Could impact East Morrison Creek and/or Joshua's Creek during construction (surface runoff impacts)
6th Line - Dundas Street to Hwy 401	Trunk	Small tributary of East 16 Mile Creek just north of Hwy 407
Neyagawa Boulevard - Dundas Street to Burnamthorpe Road	Servicing	No crossings
Wastewater Servicing		
Dundas Street east of Neyagawa Boulevard	Sanitary Pumping Station (deferred until 2013, Phase 2)	N/A
Dundas Street between 8th Line and 9th Line	Sanitary Pumping Station (deferred until 2016)	N/A
New Road Allowance Between Neyagawa Boulevard and 16 Mile Creek North of Dundas Street	Sanitary Sewer Main (deferred until 2013, Phase 2)	None
New Road Allowance West of 9th Line North of Dundas Street	525mm to 750mm Sanitary Sewer Main (Deferred until 2016)	None
* Future water services HUSP Alternatives 1, 2, and 3 are outside the study area of the North Oakville (East) Creeks Subwatershed Study		

4E.12 Characterization Summary

The characteristics of the North Oakville Creeks Subwatershed, based upon background review and collected field data, are outlined in the preceding sections. This information provides the basis of the analysis which further details the subwatershed processes (function) that influence the subwatershed form as well as the potential impacts of land use and activity changes and potential management opportunities.

A brief summary of key items identified in the characterization is provided in this section.

- The overall topography of the area is gently undulating with low relief and moderate drainage. This characteristic changes with the deeply incised valley system of Sixteen Mile Creek to the west. The watercourses typically do not have a well defined valley system except for Joshua's Creek (in the lower reaches) and Sixteen Mile Creek.
- The area referred to as the Trafalgar Moraine is located in a portion of the area and consists of a defined ridge that separates the East Sixteen Mile Creek from the other watersheds in the study area. Although there is no fluting mapped in the study area, there are some areas of localized small topographic depressions typical of a moraine area.
- Many of these small, localized, low relief depressions in the terrain do not have direct outlets to streams. The soils are clayey silt Halton Till which has a low infiltration rate. This leads to water standing in these depressions following precipitation events, particularly in the spring when soil moisture is higher.
- The shallow groundwater system provides a very small contribution to stream flow. No localized discharge points were found. All of the streams (upstream of Dundas Street), other than Sixteen Mile Creek, had zero baseflow by June 2002. Being a dry year, however, it is suspected that at least Joshua's Creek has baseflow for a longer period in an average year. The presence of baseflow in each of the watercourses is dependant upon the amount of average precipitation.
- The deeper regional groundwater system flows to the southeast toward Lake Ontario.
- The groundwater is used for domestic water supply in the area; however, well yields are generally low and groundwater quality is poor.
- The available background reports provide preliminary information on design flows and recommended SWM requirements. The information, being developed at different times for varying purposes, is somewhat inconsistent and incomplete. In general, however, the need for SWM for water quantity, quality and erosion control has been recognized in the past reports.
- The fluvial geomorphologic conditions indicate that streambank erosion varies between streams, but is occurring on a localized basis. No particular problem areas were identified that were significant in nature. Agricultural practices, the occurrence of some straightened streams, and lack of riparian cover in some streams has led to flashy response during rainfall events and sediment loads to downstream reaches, as a result of associated erosion.
- Downstream of Dundas Street most of the streams have been altered through urbanization.
- The streams within the study area vary but are generally stable with some localized reaches being unstable. The unstable reaches tend to be second or third order streams in Joshua's and Sixteen Mile Creek. The streams draining directly to Sixteen Mile Creek are steep and incised.
- Generally all of the streams would be subject to increased erosion with changes to the discharge regime or land use.
- The habitat function of a number of the terrestrial units appear to be interrelated based upon the field work carried out.
- A number of provincially and regionally rare plant species have been found.
- Linkages between habitats results from physical connections such as hedgerows, agricultural fields, riparian habitats and contiguous woodlands, as well as functionally through proximity of habitats. Existing road systems and remnant habitats outside the study area affect the connections
- The study area provides a diversity of habitats with a substantial number of provincially and regionally rare wildlife species utilizing these lands for all or part of their life cycles.
- The creeks upstream of Dundas Street are all headwater systems that appear to have intermittent flow. Joshua's Creek is somewhat more substantial with possible permanent to intermittent flow. The presence of flow during summer months in each of the streams is dependant upon the level of average precixpitation. Joshua's Creek was observed as having the highest potential for permanent

flow during summer months. The aquatic conditions reflect the agricultural impacts showing degraded aquatic and benthic conditions. Limited species and numbers of fish were found during sampling.

- Riparian cover varies considerably along the creeks. The riparian cover that does exist was found to improve aquatic conditions (*i.e.,* temperature, habitat).
- Channel substrate was typically found to be limiting for aquatic habitat (silt).
- Some past data and site reconnaissance indicated that Joshua's Creek may be a losing stream (*i.e.,* base flow decreasing) however, field data did not support this.
- Information from HUSP indicates a number of creek crossings for servicing. The crossings and potential impacts will be considered in the strategy development.