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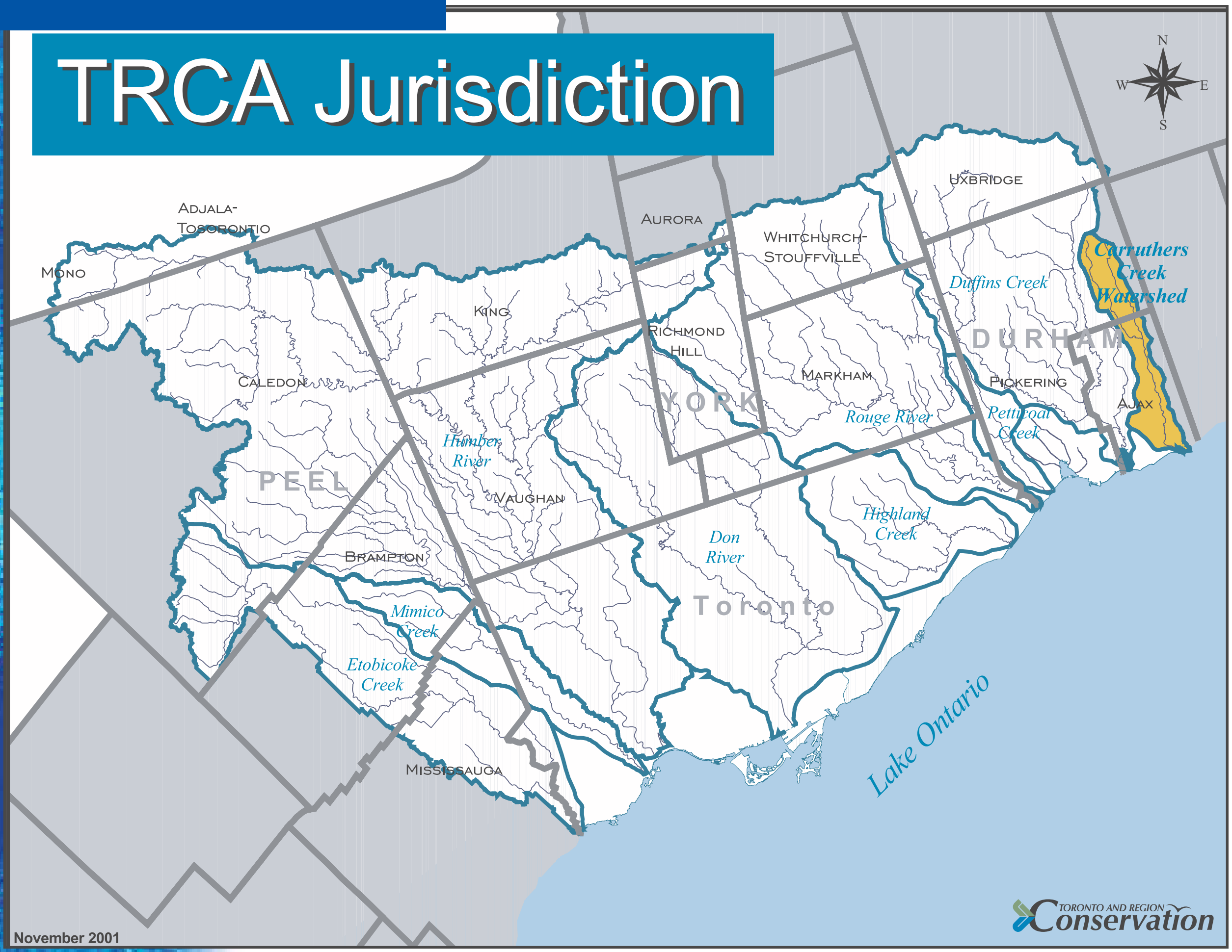

Carruthers Creek

State of the Watershed Report

Introduction

Introduction

June 2002

Other topics in this series for both the Duffins Creek and the Carruthers Creek include:

- Study Area
- Human Heritage
- Greenspace, Trails and Recreation
- Land Use
- Air Quality
- Climate
- Surface Water Quality
- Surface Water Quantity
- Stormwater Management
- Fluvial Geomorphology
- Hydrogeology
- Aquatic Habitat and Species
- Terrestrial Natural Heritage

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Toronto and Region Conservation

Duffins and Carruthers Watersheds

Toronto and Region Conservation, 5 Shoreham Drive, Downsview, Ontario M3N 1S4
Telephone: (416) 661-6600 • Fax: (416) 661-6898 • www.trca.on.ca

Carruthers Creek
State of the Watershed Report

Introduction

In 1989, The Metropolitan Toronto and Region Conservation Authority (now The Toronto and Region Conservation Authority) completed the Greenspace Strategy for the Greater Toronto Region, a strategic planning exercise that provided direction for the conservation of the Lake Ontario waterfront, river valleys and the Oak Ridges Moraine. The Greenspace Strategy identified the need for greater cooperation to achieve more integrated natural resource planning and management. To this end, the Greenspace Strategy proposed the establishment of planning task forces for each major watershed within its jurisdiction to guide the development of individual watershed strategies.

The watershed strategy planning process components include:

- Compiling background material into a State of the Watershed Report (SOW)
- Establishing a Planning Task Force
- Developing a Watershed Management Strategy
- Implementing the action items in the Watershed Management Strategy
- Developing a Report Card to monitor conditions and report on the progress

This State of the Watershed Report has been prepared as a key reference document for land use planning decision makers who have jurisdiction within and adjacent to the Carruthers Creek watershed. The State of the Watershed Report is a key reference document to its companion document, the Watershed Management Strategy.

The State of the Watershed chapters have been prepared by a number of technical experts. Each chapter author(s) has gathered the information available in their specific discipline, provided a summary of the past and existing conditions, identified gaps in data and the implications of that missing data for decision making purposes. It is very important to understand that this report and the information it contains draws on the current knowledge base. Any gaps in information and monitoring requirements will be addressed in the Watershed Management Strategy.

In the following pages you will find the following information about the Carruthers Creek watershed:

- The Study Area
- Human Heritage
- Greenspace, Trails and Recreation
- Land Use and Policy Framework
- Air Quality, Climate
- Surface Water Quality and Quantity and Stormwater Management
- Fluvial Geomorphology and Hydrogeology
- Aquatic Habitat and Species
- Terrestrial Natural Heritage

The information contained within the State of the Watershed Report is being used by the Carruthers Creek Task Force and their technical advisors to prepare a Watershed Management Strategy.

A Watershed Management Strategy provides a framework to guide municipal environmental planning policies in the Official Plan and subwatershed plans. It also provides the “tools” that the municipal planners need on a daily basis to evaluate environmental impacts on a watershed basis rather than a site-by-site basis. It will provide various growth scenarios and the potential impacts of each scenario on the environment and enable the criteria to be set in advance of development. These tools will take on a variety of forms, such as digital maps, models, text and tables.

INTRODUCTION

The Carruthers Creek Task Force was formed in 2000 through a resolution of The Toronto and Region Conservation Authority (TRCA). The Task Force reports to the TRCA Full Authority through its Watershed Management Advisory Board.

The Carruthers Creek Task Force consists of one elected and one alternate representative from each of the two local, as well as the one regional, municipalities within the Carruthers Creek watershed, plus other local representatives, including:

- Town of Ajax
- City of Pickering
- Durham Region
- Ministry of Transportation
- Agricultural Community
- Golf Course Industry
- Citizens for Carruthers
- Residents
- Urban Development Institute
- Aggregate Producers of Ontario

The Chair and the Vice Chair of the Carruthers Creek Task Force were elected from among its members. The Carruthers Task Force is chaired by Dr. Neil Burnett, a resident, with its Vice Chair being Scott Crawford, a Regional Councillor from the Town of Ajax.

The TRCA would like to thank the participants on the Carruthers Creek Task Force, the technical staff at the local and regional municipalities mentioned above and all of the provincial and federal technical support that is being provided. All of these people and numerous staff at the TRCA have put many hours into completing the State of the Watershed report and ensuring that the development of a Watershed Management Strategy is implementable for land use planning at the local level.

Duffins and
Carruthers
Watersheds

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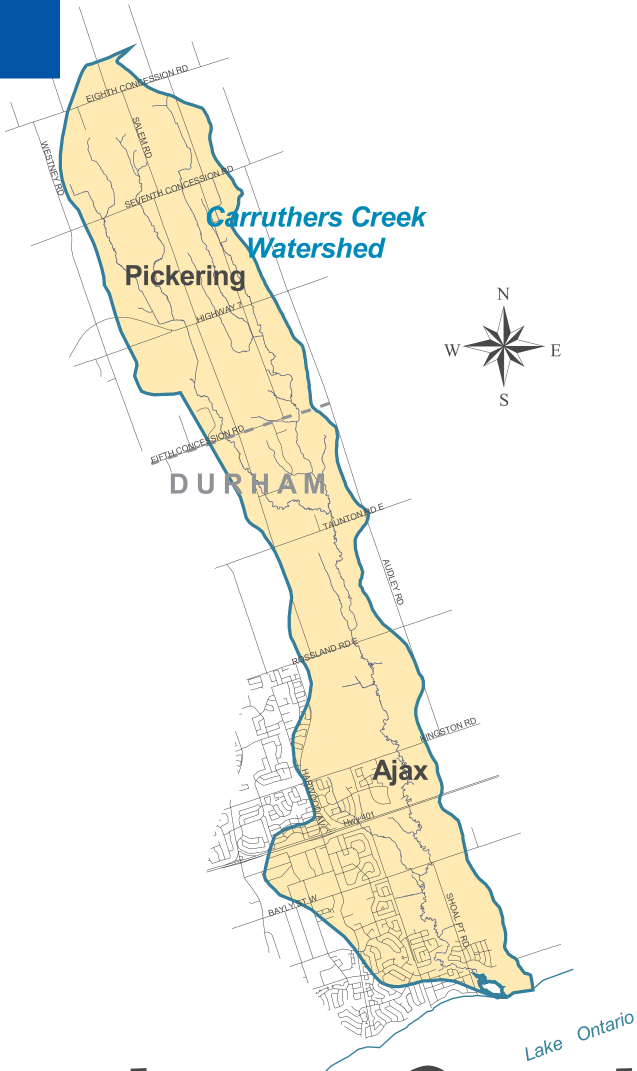

Carruthers Creek

State of the Watershed Report

Study Area

Study Area

June 2002

Other topics in this series for both the Duffins Creek and the Carruthers Creek include:

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Carruthers Creek

State of the Watershed Report

Study Area

Carruthers Creek is situated entirely within Durham Region and two local area municipalities, the City of Pickering and the Town of Ajax (Figure 1). Representing the most easterly watershed within the TRCA jurisdiction (Figure 2), Carruthers Creek is not only the smallest (38.4 km^2) watershed in the Greater Toronto Area, but one of the least studied.

Moving across the landscape from its headwaters to Lake Ontario, Carruthers Creek is 20 km long but only 3 m at its widest point and can be divided into three physiographic regions. Its headwaters are found near the community of Mount Zion in the City of Pickering. The first 10 km flows over the South Slope where agricultural practices and rural uses still predominate. Pressure from urban encroachment is beginning to impact this landscape, however, as rural areas are being converted to country residential and suburban land uses.

From its headwaters, Carruthers Creek weaves its way toward Lake Ontario over the shoreline of glacial Lake Iroquois and continues further south across the Lake Iroquois Plain, both physical remnants of the last ice age. Farming was commonplace in the southern reaches until the 1940s when the area became increasingly urbanized. This portion of the watershed is within the urban boundary of the Town of Ajax but lies directly in the path of urban development. Already, significant development has occurred adjacent to the area in the Town of Whitby, placing increased pressure on the area. Population statistics and growth projections suggest that growth will continue for the next 25 years. There is a real opportunity at this time to make critical decisions and implement strategic management actions to protect and enhance the future of the Carruthers Creek watershed.

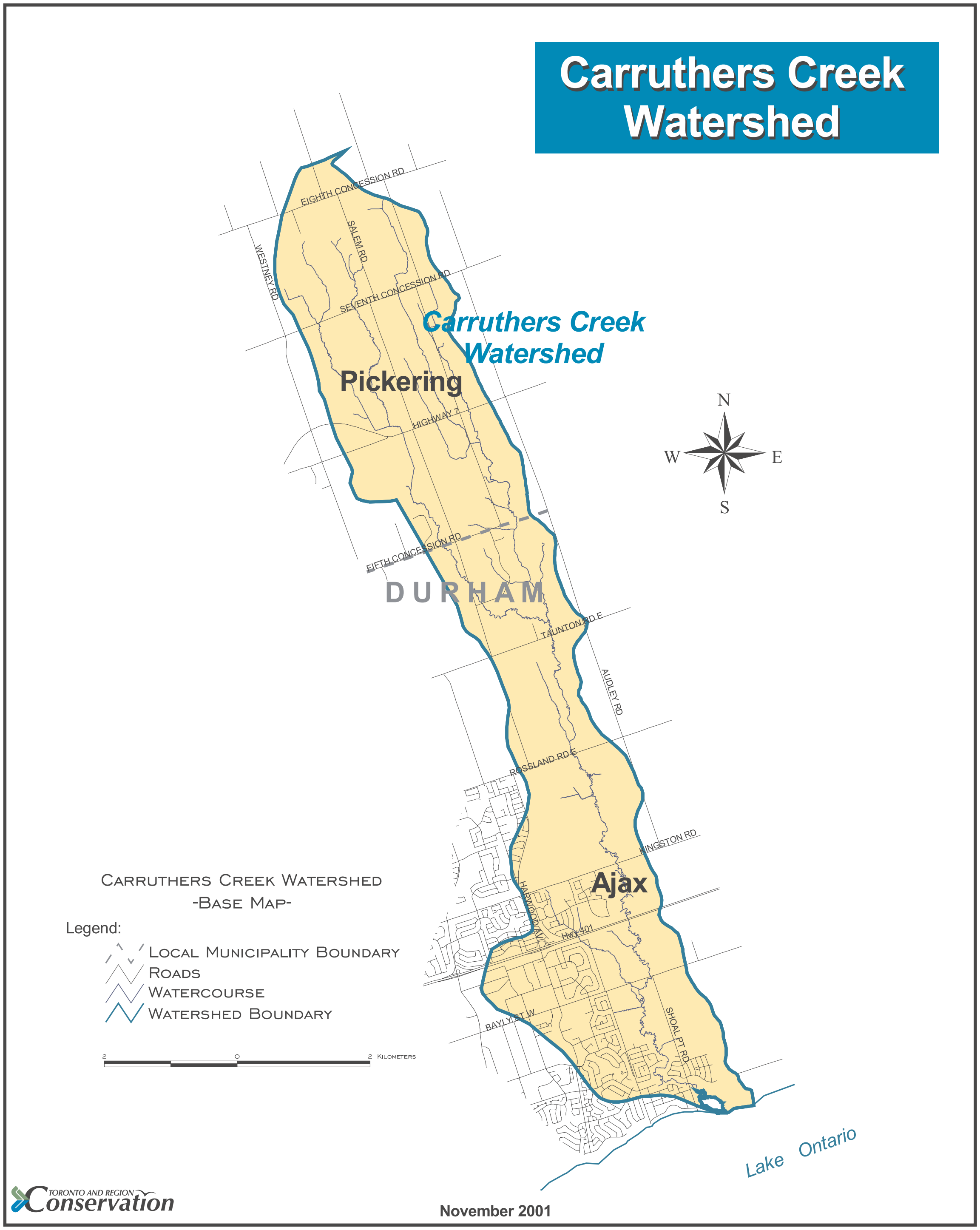

Figure 1:
Carruthers Creek Watershed Municipalities.

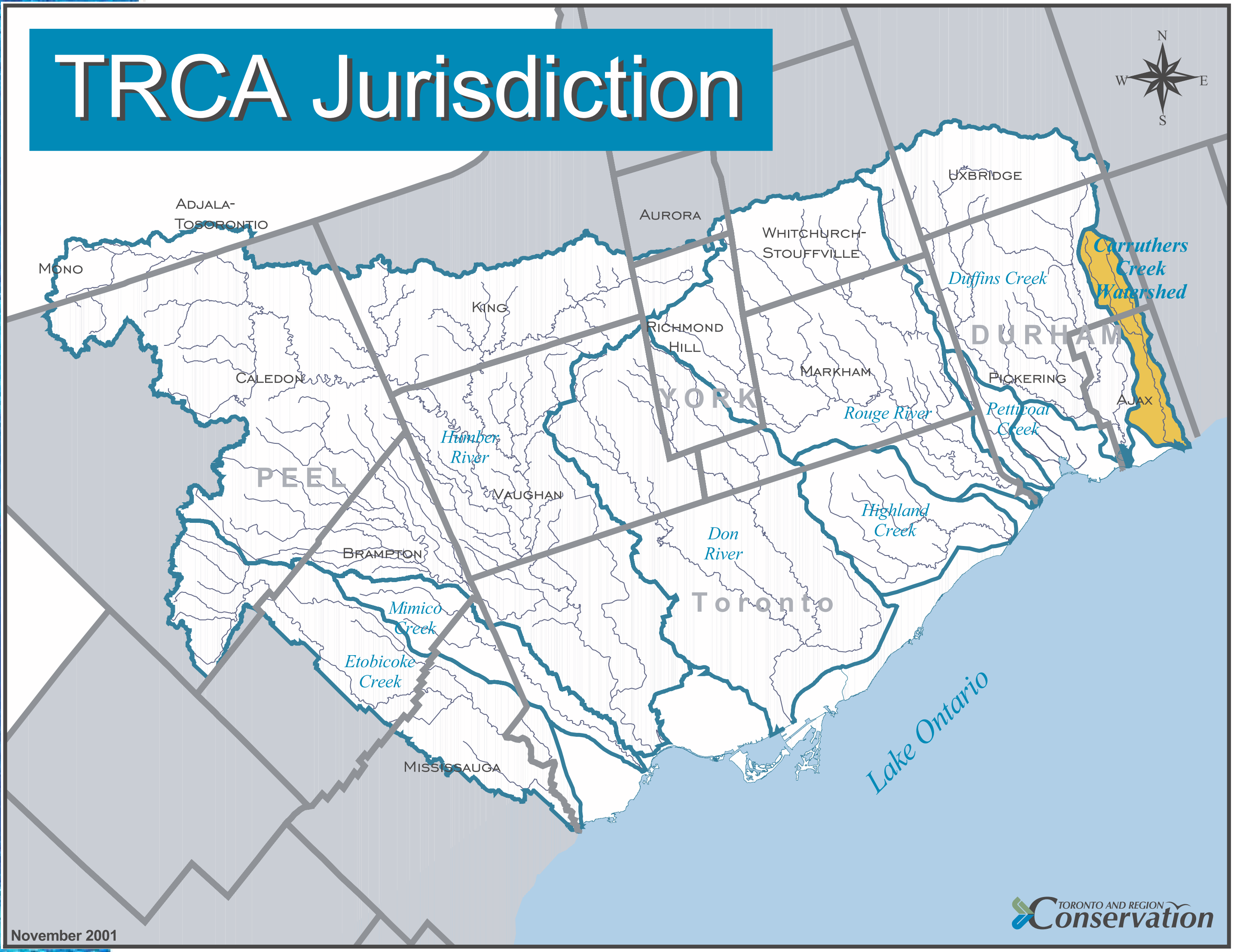

Figure 2:

TRCA watersheds including Carruthers Creek.

Duffins and
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Carruthers Creek

State of the Watershed Report

Human Heritage

Human Heritage

June 2002

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Cover photograph: This 19th century Georgian-style residence is maintained as a residential/commercial structure with historic character on Bayly Street in Ajax.

Photo credit: TRCA

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Duffins and Carruthers Watersheds

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Introduction to Human Heritage

Over thousands of years and into the present, geological processes such as glaciation, erosion, flooding and deposition have shaped the natural heritage features within the Carruthers Creek watershed. Physiographic features such as the Lake Iroquois Shoreline and the Carruthers Marsh provide critical habitat for flora and fauna, in addition to providing a diverse and resource-rich environment for human occupation. This chapter details the known human heritage resources, in other words the history of the people – both Aboriginal and non-Aboriginal – and the remnants of the human past, in the Carruthers Creek watershed.

The study area consists of the entire Carruthers Creek watershed. In contemporary political terms, this watershed falls within the boundaries of the municipalities of Pickering and Ajax in Durham Region. The less urbanized northern portions potentially contain greater numbers of preserved human heritage resources, since there has been less pressure to remove the old to make way for the new in these rural areas.

An analysis was undertaken in 1999-2000 to begin an open-ended inventory of the human heritage resources within the Carruthers Creek watershed. These non-renewable resources included archaeological sites that have been registered with the Ontario Ministry of Culture, and heritage buildings and other structures, plus plaques and cemeteries, that have been identified by municipal and provincial heritage agencies. Each feature or resource was researched and mapped in order to obtain a basic understanding of the relationships between these, as well as their relationships to the natural features within the watershed. This information will form the basis of future planning, stewardship, consultation and regeneration efforts.

The methodology employed in the 1999-2000 study is detailed in Appendix A. Working definitions of basic terminology appear in Appendix B which identify the types of assessments that were involved in the Carruthers human heritage study.

Current Inventory of Human Heritage Features

A total of 59 individual human heritage features were defined during the Resource Definition component of the project. These heritage features are defined below in Table 1. The built heritage features have all been field surveyed to determine such characteristics as precise location, subwatershed association, architectural style and original use.

Archaeological Sites

It is well established that human activity has always centred on a region's rivers and lakes in order to fill the need for a stable water supply to utilize associated resources and to take advantage of transportation potential. The main channels of the Carruthers Creek, particularly near the Lake Iroquois Shoreline, provided ample opportunity for the utilization of aquatic resources.

A total of 32 archaeological sites (Figure 1, **Table** 2) have been located within the Carruthers Creek watershed. These sites represent a use of the watershed by Aboriginal people and Euro-Canadians for thousands of years. Of note, is that while many historic mills were in use during the Euro-Canadian settlement of this area, very little specific spatial information is available to assist in the location of these structures in the Carruthers Creek watershed. While each of these properties is considered to be an archaeological site, most have not been registered with the Ministry of Culture, and consequently, these resources have not been defined in the present project. It is important to note that mills were fundamental to the development of communities in Upper Canada and while, in most instances, these mills are represented now as archaeological sites, they must be included in any inventory of an historic landscape. Future studies should endeavour to define the locations of the mill sites which are not presently known, although it is unlikely that the flow of water along the Carruthers Creek during the nineteenth and twentieth centuries was enough to support a mill operation without the assistance of steam power.

Local Architectural Conservation Advisory Committee Heritage Inventories

Both of the municipalities found within the Carruthers Creek watershed, through their Local Architectural Conservation Advisory Committee (LACAC), have prepared an inventory of buildings of architectural and historic importance.

Examination of the inventory identified a total of 27 built heritage features and their original uses, three of which are Designated properties, which fall within the study area (Table 3, Figure 2). It should be noted that this list is not definitive. If an individual structure is not classified as Designated or Listed by a municipality, it is not included in the local inventory and consequently is not included in the present study, with the exception of cemeteries, cenotaphs and plaques. Table 4 defines the distribution of the built heritage features for each municipality.

Table 1:Human Heritage Designation of Sites

Listed	Designated	Cemeteries and Burial Places	Plaques	Borden Archaeological	Total
22	3	1	1	32	59

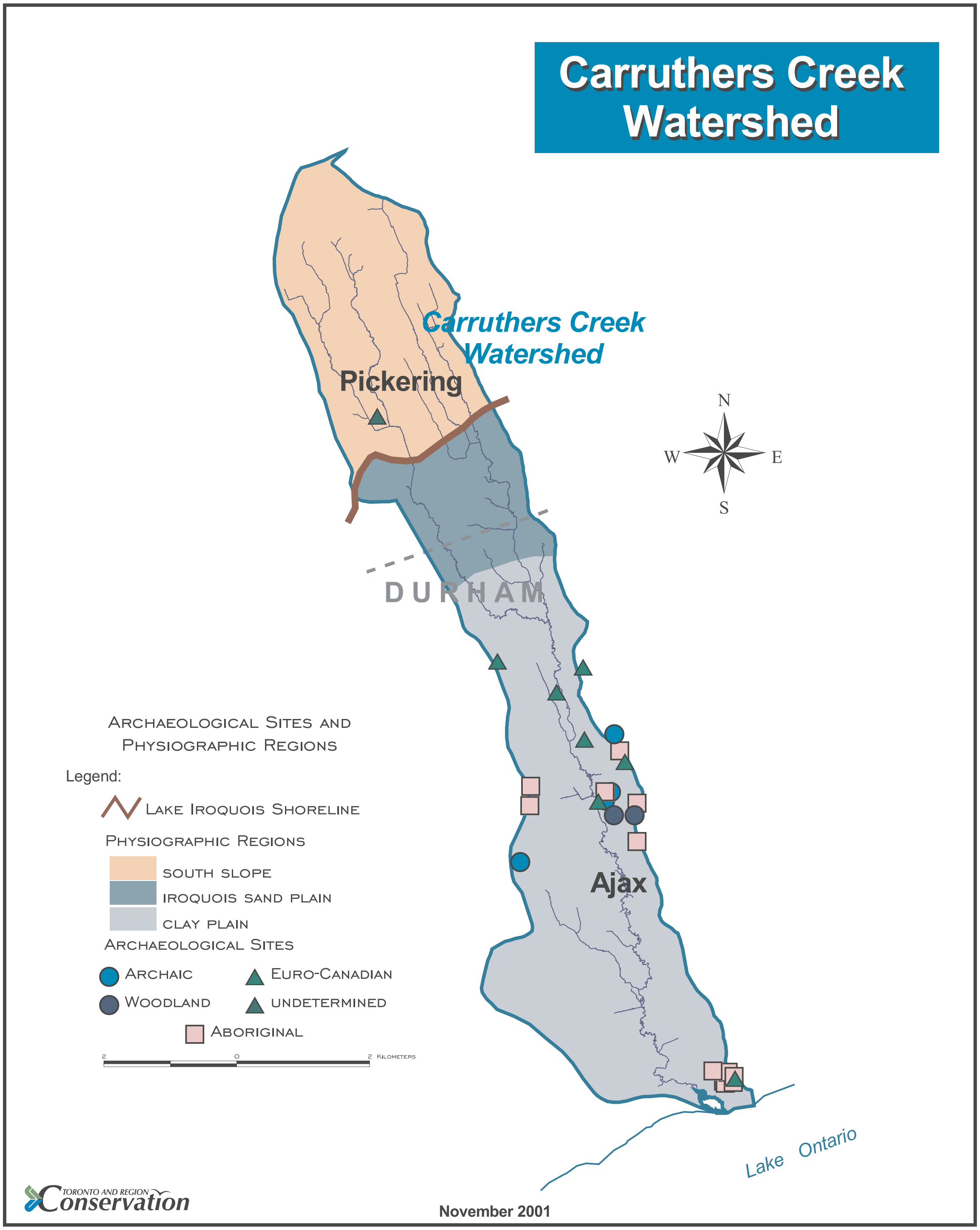


Figure 1:

Carruthers Creek Watershed Registered Archaeological Sites. The apparent lack of sites reflects the lack of fieldwork that has been required to-date in the rural areas.

Table 2: Archaeological Sites: Cultural Affiliations

Culture / Time Period	Number
Palaeo-Indian	**0**
Undetermined	0
Late	0
Archaic	**5**
Undetermined	0
Early	2
Middle	3
Late	0
Woodland	**2**
Undetermined	0
Early	1
Middle	1
Late (Iroquoian)	0
Early Iroquoian	0
Middle Iroquoian	0
Late Iroquoian	0
Undetermined Iroquoian	0
Undetermined Aboriginal	**17**
Pre-contact	17
Undetermined	0
Historic Mississauga	**0**
Multi-component	**0**
Historic Euro-Canadian	**7**
Undetermined	**1**
TOTAL	**32**

The sophistication and complexity of the Euro-Canadian settlement of the Carruthers Creek watershed is demonstrated in the variety of architectural styles found in the heritage structures defined in this project. The variety of different architectural styles (Table 5) lends a unique identity to the 19th century Carruthers Creek landscape which sets it apart from elsewhere in the Toronto area. Appendix C provides a description of these individual architectural styles.

Table 3: Built Heritage Structures and Other Visible Features: Original Uses

Type	Number
Residential	20
Educational	1
Institutional	1
Industrial	2
Barn	1
Plaque	1
Cemetery	1
TOTAL	**27**

Table 4: Built Heritage Structures and Other Visible Features: Municipalities

Municipality	Number
Ajax	24
Pickering	3
TOTAL	**27**

Table 5: Built Heritage Structures: Architectural Styles

Architectural Style	Frequency
Vernacular	8
Ontario House	5
War-time Bungalow	4
Georgian	4
Georgian Revival	1
Edwardian/Foursquare	1
Modern	1
Unknown	1
Total	**25**

Note: Architectural style does not apply to the remaining two built heritage features which include one cemetery and one plaque.

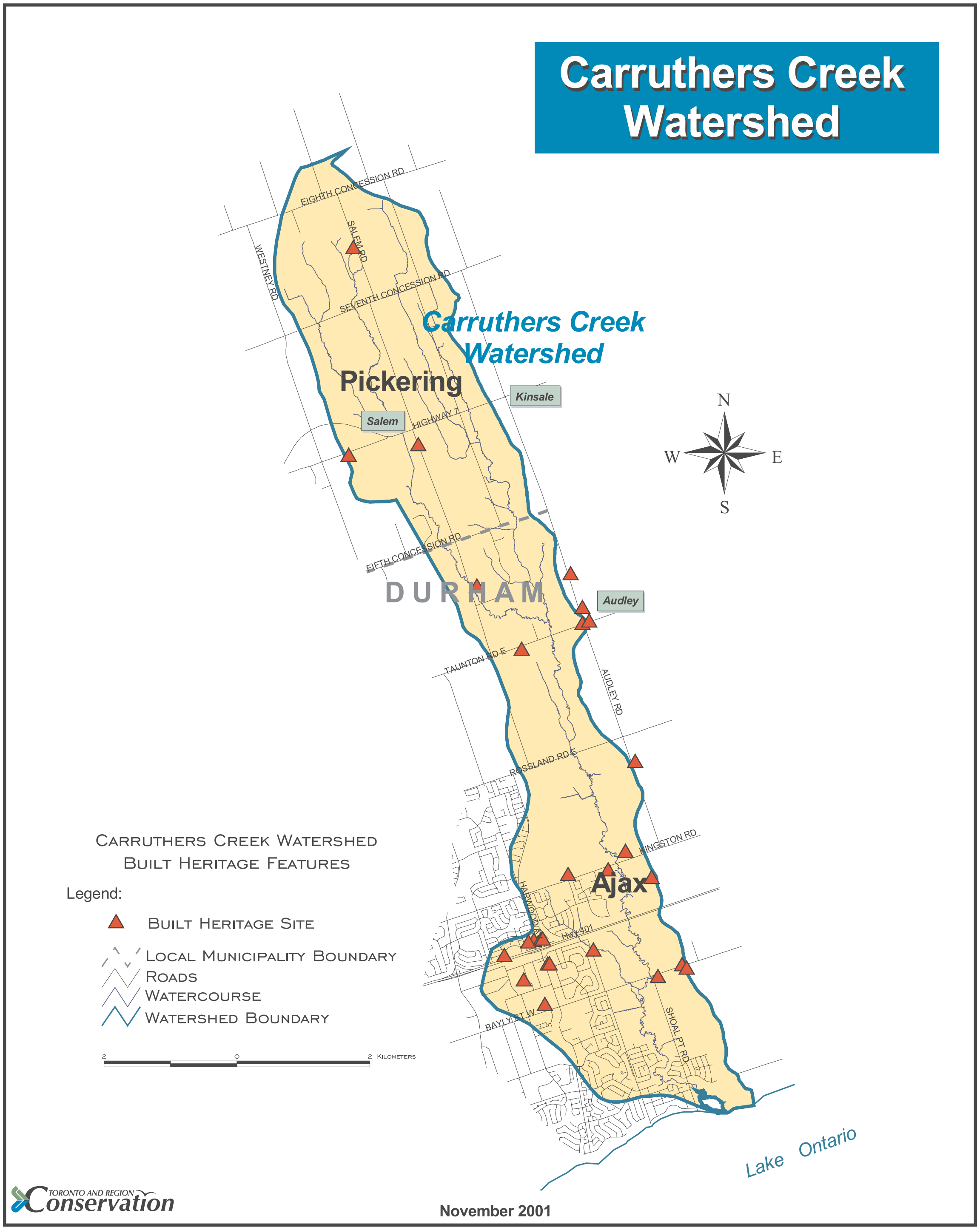


Figure 2:

Carruthers Creek Watershed Built Heritage Features and Historic Hamlets

Historical Review of the Carruthers Creek Watershed

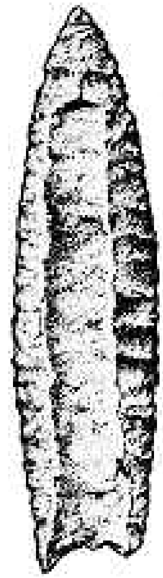
Archaeological Resources

To place the human history of the Carruthers Creek watershed into the proper context, the following descriptions briefly encapsulate the Aboriginal and historic Euro-Canadian cultural periods (and associated diachronic positions) for the archaeological record of southern Ontario.

Palaeo-Indian Period: 10,000 to 7,000 BC

As the glaciers retreated from southern Ontario, nomadic people gradually moved into the areas recently vacated by the massive ice sheets. These Palaeo-Indians lived in small family groups and it is presumed that they hunted caribou and other fauna associated with the cooler environment of this time period. It should be remembered that as the glaciers melted at the end of the last ice age 12,000 years ago, the landscape of southern Ontario was very much like the tundra of the present day eastern sub-arctic. This reconstruction is substantiated by the location of a single toe bone of a caribou at a site in Detroit, and by the presence of arctic hare, arctic fox and a large ungulate at the Udora site (a Palaeo-Indian encampment) near the south shore of Lake Simcoe.

Palaeo-Indian Hunters



A Palaeo Fluted Point

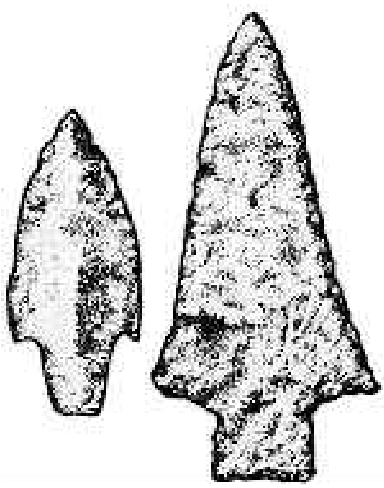
During this time, the water levels and shorelines of lakes Huron and Ontario were fluctuating due to the runoff of the melting glaciers. Traditionally, the Palaeo-Indian occupation of southern Ontario has been associated with these glacial lake shorelines. However, recent investigations in the vicinity of Toronto indicate that these people also exploited interior locations away from the glacial lakes.

While at present no Palaeo-Indian sites have been located in the Carruthers Creek watershed, it is possible that such sites may be located in the future.

Archaic Period: 7,000 to 1,000 BC

As the climate in southern Ontario warmed, the Aboriginal populations adapted to these new environments and associated fauna. Thus, many new technologies and subsistence strategies were introduced and developed by the Archaic peoples of this time period. Wood-working implements such as groundstone axes, adzes and gouges begin to appear, as do net-sinkers (for fishing), numerous types of spear points and items made from native copper, which was mined from the Lake Superior Region. The presence of native copper on archaeological sites in southern Ontario and adjacent areas suggests that Archaic groups were already involved in long-range exchange and interaction with one another. The trade networks established at this time were to persist between Native groups until European contact.

To harvest the new riches of the warming climate, the Archaic bands of southern Ontario followed an annual cycle which exploited seasonably available resources in differing geographic locales with unique watersheds. For example, from the spring through to the fall, bands would have joined together and inhabited sites in lakeshore environments where abundant foodstuffs such as fish, waterfowl and wild rice enabled the establishment of larger multi-season occupations (Ellis *et al*. 1990). As the seasons changed, and aquatic resources became scarce, these bands split into smaller groups and moved inland to exploit other resources which were available during the fall and winter, such as deer, rabbit, squirrel and bear, who thrived on the forest margins of these areas.



Archaic Points

Due to the fluctuating Lake Ontario water levels at the end of the ice age, the mouth of the Carruthers Creek would have entered into Lake Ontario at a location ten to 20 metres below the present surface level. Aboriginal groups of the era would have exploited the shoreline environments in this now submerged location and, as a result, any archaeological sites representing these seasonal activities are now under water. Consequently, our understanding of the Archaic uses of the Lake Ontario shoreline in the vicinity of this creek is poor.

There have, however, been five findspots located in the Carruthers Creek watershed that can be attributed to "inland" exploitation by Archaic groups. Typically, sites for this time period are "interior camps," which appear on the landscape as scatters of chert (flint) tools and flakes.[1] The presence of these five isolated artifacts indicates that Archaic people hunted and camped in the Carruthers Creek watershed, although very little

Archaic canoe makers

else can be said regarding specifics as to their habitation here. This is due in part to the lack of detailed excavation of these sites in general, and part to the changes in water levels as discussed above. Archaeological sites representative of these activities elsewhere are small and, therefore, are often deemed as 'not significant.' Without more detailed investigations of the landscape to uncover sites from this time period as well as protection and investigation of these small extraction/processing and habitation localities, our understanding of the Archaic use of the Carruthers Creek, and indeed of Ontario, will never be complete.

Initial (Early and Middle) Woodland Period: 1,000 BC to AD 700

Early in the Initial Woodland period (1,000 – 1 BC), band sizes and subsistence activities were generally consistent with the groups of the preceding Archaic. Associated with the earliest components of this cultural period is the introduction of clay pots. Ceramic vessels provide a means for longer term storage of foodstuffs. With the ability to store foodstuffs during times of plenty, the stress of harder times was greatly reduced as it would have been possible to take advantage of the accumulated goods. Additionally, at around AD 1 a revolutionary new technology, the bow and arrow, was brought into southern Ontario and radically changed the approach to hunting. These two technological innovations allowed for major changes in subsistence and settlement patterns. As populations became larger, camps and villages with more permanent structures were occupied longer and more consistently. Generally,

[1] The term "flake" is used by archaeologists to describe the pieces of chert that are "flaked" off during the stages of stone tool manufacturing.

Initial Woodland Campsite

Initial Woodland Pottery

these larger sites are associated with the gathering of two or more band groups into what are referred to as 'macrobands.' Often these larger groups would reside in favourable locations to cooperatively take advantage of readily exploitable resources such as fish.

It was also during this period that more elaborate burial rituals, such as cremation, burial mound construction (as seen at the Serpent Mounds near Peterborough, Ontario, for example) and the interment of numerous exotic grave goods with the deceased began to take place. In fact, these goods, which include large caches of well-crafted lithic blades, sheets of mica, marine shells, shark teeth, silver and copper beads, and artifacts such as platform smoking pipes and decorative ear ornaments, all indicate that the Initial Woodland period was one of increased trade and interaction between southern Ontario populations and groups as far away as the east coast and the Ohio Valley.

To date, there are two sites in the Carruthers Creek watershed that can be attributed to the Initial Woodland period. While these sites appear to represent short term campsites, neither of them have received any detailed archaeological investigations and, therefore, not much can be said regarding their function and/or possible settlement patterns. Due to the Initial Woodland peoples' exploitation of seasonally available resources (as seen with earlier Archaic and Palaeo-Indian groups), their habitation sites do not display evidence of substantial structures, lengthy occupations, or deep or extensive middens (garbage deposits) (Spence *et al*. 1990:167). Therefore, their visibility on the landscape is minimal, making them difficult for archaeologists to find. Thus, when they are happened upon, it is important for these sites to be properly investigated so that this crucial period of Aboriginal history can be better understood.

Iroquoian Camp

Late Woodland (Ontario Iroquoian) Period: AD 700 to 1651

Around AD 700 maize (corn) was introduced into southern Ontario from the south. With the development of horticulture as the predominant subsistence base, the Late Woodland period gave rise to a tremendous population increase and to the establishment of permanent villages (which were occupied from five to 30 years). These villages consisted of numerous "cigar shaped" structures, or "longhouses," made from wooden posts placed in the ground and tied together at the top in an arch-like fashion. Although these windowless structures were only six metres (20 feet) wide (and the same in height) they extended anywhere from nine to 45 metres (30 to 150 feet) in length providing shelter for up to 50 people[2]. Quite often these villages, some of which were one to four hectares (three to ten acres) in size, were surrounded by multiple rows of palisades suggesting that defence was a community concern during this period.

After centuries of small-scale warfare and the gradual depletion of such resources as soil nutrients and firewood, the Late Woodland groups who inhabited the north shore of Lake Ontario began moving their villages northward towards Georgian Bay. It was these groups that eventually evolved into the Tionontati (Petun) and Wendat (Huron) Nations witnessed and recorded by the early French missionaries and explorers during the seventeenth century.

While at present no Late Woodland sites have been encountered in the Carruthers Creek watershed, it is possible that such sites may be located in the future.

Early Contact and Euro-Canadian History

For more than 10,000 years the Carruthers Creek watershed has served as a stage upon which the drama of history unfolded: Aboriginal hunters and farmers, European explorers, traders, soldiers, surveyors, farmers, holiday makers, and finally, city dwellers and suburbanites. They all came to use this creek in some way; to make it their home and to earn a living.

[2] This number is based on a longhouse with four hearths, one family on either side of each hearth, and six people in each family. Past researchers have employed similar models based on what is known from the early missionaries that lived among these Iroquoian groups in the seventeenth century.

Contact Period: AD 1650 to 1800

Following the dispersal of the Tionontati (Petun) and Wendat (Huron) by the Iroquois in 1650, southern Ontario lay vacant for fifteen years. Then, during the mid-to-late 1600s, in an attempt to expand their fur hunting grounds to the north, Iroquois groups established a number of villages along the north shore of Lake Ontario. Two of these, called Ganatsekiagon and Teiaiagon, were built by the Seneca upstream from the mouths of the Rouge and Humber Rivers, respectively. Current research shows that no villages of this size and importance were built in the Carruthers Creek watershed. After the Seneca abandoned the north shore of Lake Ontario in the last half of the seventeenth century, the Algonkian-speaking Mississauga moved in to the Greater Toronto area, particularly in the western reaches, where they were flourishing when the French, and later the British, arrived. However, local resources near the Carruthers Creek were without doubt used by Native people in this late period as is evidenced by the numerous archaeological sites in the general area. The mouth of this creek would have been particularly useful for hunting and fishing as a part of the seasonal round of the Native populations living in the area. In addition, parties of canoe-travellers would have stopped here for resting or camping on journeys between the St. Lawrence River and the Toronto Carrying Place Trail, the head-of-the-lake (modern day Hamilton) and points farther south.

Euro-Canadian History

Carruthers Creek is located in the present day Regional Municipality of Durham and flows through the City of Pickering and the Town of Ajax from Concession 7 southward to Richardson Point on Lake Ontario. Although not as large as some of the other watercourses in Durham such as Duffins Creek or Lynde Creek, the history of Euro-Canadians in the Carruthers Creek watershed extends back prior to the Loyalist settlement of the late 18th century.

During the late 17th century there were Sulpician missions and trading posts established along the north shore of Lake Ontario, and French maps (such as Joliet's map of 1673) show some of the rivers and creeks in this area. Although Carruthers Creek is not shown on these early maps, the French were undoubtedly aware of its existence.

Following the Revolutionary War in the early 1780s, subjects who chose to remain loyal to Great Britain (known as United Empire Loyalists) were displaced from their former American homes and emigrated north to the safety of Canada. Land for the settlement of the Loyalists was required but, according to the Royal Proclamation of 1763, the area that is now Ontario was "reserved to the said Indians." No settlers were allowed to locate there without government permission and the Native people were only allowed to sell their lands to the Crown. Thus in 1784 and 1787 the Mississauga conveyed large tracts of land in Ontario to the Crown, which formed part of the Province of Québec until the Constitutional Act created the Province of Upper Canada in 1791. A Proclamation in 1788 broke this land up into five new districts for administrative reasons. Each possessed a Land Board and Court in order to administer justice, to take oaths of loyalty, and to begin collecting evidence of Loyalist losses. The "Golden Horseshoe" area was under the administration of the Nassau District. In 1792 Durham County was created by Proclamation and Nassau was renamed the Home District (referenced from 32 Geo III, c. 5).

The Land Boards, from 1789 until John Graves Simcoe disbanded them in 1794, began to assign allotments to those Loyalists wishing to settle on a permanent basis since the colonial government at Québec passed an ordnance which allowed settlers to take up these "waste lands." In February 1791 instructions were issued by Samuel Holland at Québec to John Collins calling for the survey of various townships to begin in the upper part of the province. Augustus Jones was appointed to survey the baselines and the first few concessions of the various townships in the District of Nassau including Pickering Township, or township number nine, which was to have originally been called Edinburgh Township.[3] Jones and his men must have faced a formidable task in 1791 working with their early theodolite and chains, not to mention the difficult terrain, dense underbrush, bad weather and illness. It is no wonder that errors were found in the survey of the township, requiring new surveys to be undertaken in 1831 and 1833.[4]

There is some controversy over the identity of the first settler to take up land in Pickering Township. Some claim that an Irish trader named Mike Duffin settled along the creek that bears his name sometime around 1788. Legend tells us that he was a genial man who willingly took in travellers, and he was possibly murdered by one around 1791. His name was recorded on the township survey map by Augustus Jones, and the creek has been referred to by this name ever since. Another early settler was said to have been Benjamin Wilson, a native of Vermont, who may have resided in Pickering for a time but actually settled permanently in Whitby in 1794.

The initial settlement in Pickering Township and especially along Carruthers Creek was slow. In part, this is because early settlers desired land in other locations – such as at York or Niagara where they would be closer to roads and markets – but also because the lands were granted to absentee owners who were members of the governing elite at York, or were held as either Crown or Clergy Reserves. The members of the "elite" at York were not anxious to dispose of their holdings too quickly; although they encouraged settlement of the province, they realized that the sale of their land holdings would provide them with a steady income. Attorney-General Thomas Scott realized this fact and advised David William Smith that once all the available lands were either patented or sold, officials would have "killed the goose that produced the golden eggs."

As a result it was not until the 1820s that increased settlement of the township began, first by Quakers (including Irish Quakers such as the Richardsons) and followed in the early 1830s by a mixture of Scotch, English and Irish settlers. See Appendix D for a detailed description of many of the early settlers and their families. The population of Pickering is recorded at 187 inhabitants in 1809. In 1820 it had increased to 375, and by 1828 it had nearly tripled to 1,042. There was a steady increase in the number of inhabitants to the middle of the 19th century, followed by a slight decrease in number by the turn of the 20th century.[5]

One early land holding "absentee" family along Carruthers Creek was the Smith family. Major John Smith (d.1795) had been born in England and was a career soldier serving in His Majesty's forces for over 40 years. Smith had seen action in Germany, France, Ireland, the West Indies and during the American Revolution. By the 1780s he was serving in the fifth Regiment of Foot and had been posted at Detroit. His son, Sir David William Smith (1764- 1837) was also at Detroit and served as clerk of the Hesse District Land Board until his Regiment was moved to Niagara

[3] Bureau of the Ontario Archives Report 3 (1906) page 389. The instructions also specify rates of pay and provisions for Jones' party.

[4] In April and May of 1831 David Gibson re-surveyed part of the line between Pickering and Whitby. In June and July of 1833 John Galbraith re-surveyed the entire Broken Front Range (Concessions 1-3) along the lakeshore. On June 11, 1833 Galbraith notes that the terrain on the line between Scarborough and Pickering is "so rough that it was almost impossible to chain it accurately." On June 17 the party began to survey the "marish" at Duffins Creek "where we found we could do nothing without a canoe or boat of some sort." On June 18 work stopped because of "almost an impenetrable thicket of brush and a heavy shower of rain...fell in the afternoon." Both journals may be found at the Archives of Ontario, "Crown Lands Department, Survey Diaries and Field Notes, 1790-1928" RG1 CB-1 Box 31 (MS 924 reel 21).

[5] The 1842 census enumerated a population of 3,752 and in 1850 it stood at 6,385. The 1901 census numbered the township at 5,285 inhabitants.

in 1792. During his tenure on the board, Smith processed over 500 land petitions and issued 100 certificates without any fees from the public. It was a matter of "pride...to have continued Clerk to the Board without emolument and to have seen the settlers assured in their possessions" (Upper Canada Land Petitions, S miscellaneous/186 (1790) and S1/159 (1792)). As a result of his services, Simcoe offered D.W. Smith the post of Acting Surveyor General for Upper Canada in 1792, a civil office that was confirmed in 1798 and which Smith held until he retired to England and resigned his offices in 1804.[6] Smith, however, was not without his critics and it was felt that there must have been some machinations allowing himself, his father and his daughter Anne Smith to accumulate more than 20,000 acres of land in Upper Canada – 7,800 acres of which was concentrated in Pickering around Carruthers Creek.[7] Lord Selkirk, writing in 1803, caustically observed "the lots marked D.W.S. are sure to be the choice spots." In many instances the lots held by the Smith family remained unsold until the late 1820s or into the early 1830s.

The Smiths were not the only absentee freeholders retarding the progress of the township. The Honourable John Elmsley (1762-1805), Chief Justice of Upper Canada, received an Order in Council in 1797 for 5,000 acres of land (part of which was located along Carruthers Creek). It would appear that Elmsley did not take out the Crown Patent for much of this land since he purchased large tracts from the original Crown patentees in 1799 and other lands for which Elmsley was issued a warrant were patented to Major John Smith.[8] An examination of the Land Registry abstract index books shows that the Elmsley family retained these lands until the mid-to-late 1830s, which would indicate that they were speculating and selling to their own advantage.

Jacob Farrand (d. 1803) was not a member of the York elite yet he was not without influential connections.[9] He was granted approximately 1,800 acres of land all along Carruthers Creek by a Crown Patent in December 1798. He did not retain his land holdings in Pickering very long, selling them to Chief Justice John Elmsley in April, 1799. These lands sat unoccupied for approximately 35 years before being sold to new settlers arriving from Britain.

Other lands along Carruthers Creek were not patented until a much later time, and were held as Crown or Clergy Reserves. Some of these lands appear to have had pineries, a fact that is reflected in the "agricultural returns" of the 1861 and 1871 census for Pickering, and these timber stands would have been reserved by the Crown for the use of His Majesty's navy. By the late 1820s the importance of timber had diminished. The province

[6] Smith was also a licenced attorney, a published author in later life, a member of the Executive Council, an elected representative in the House of Assembly for various ridings and was Speaker of the House. He was one of Simcoe's most trusted advisors, and it was at his recommendation that new townships were surveyed and opened for settlement. The various amendments made to the settlement requirements, as well as the "chequered plan" of Clergy Reserves, was Smith's work.

[7] Despite this large accumulation of land, Smith never made a vast fortune from the disposition of the acreage. Other members of the elite such as John Small and John McGill held their lands in the town of York and the adjacent townships which commanded higher prices and sold very quickly. Also see Smith's other Upper Canada Land Petitions: S miscellaneous/185 (1794), S4/143 (1799) and Anne Smith's fiat and warrant, "Pickering Township papers" RG1 C-IV (MS 658 reel 394, p. 658.) The charge of machinations may contain some truth since Anne Smith should not have been eligible for lands until she was age 21 sometime after 1809, yet her warrant was issued in 1797 or 1798 when she would have been barely ten.

[8] See Elmsley's warrant and fiat in the "Pickering Township Papers" RG1 C-IV (MS 658 reel 394, p. 661-663)

[9] Jacob Farrand, a Loyalist, had served in the Royal Regiment of New York during the Revolutionary War and was granted land for his military service. He was a member of the Law Society of Upper Canada, and was related by mariage to the Bethune family.

was found to be rich in this resource and so tracts that had been held as reserves in an earlier period were now patented. Such reserved land in the vicinity of Carruthers Creek was patented to either King's College (now known as the University of Toronto) in 1828 or to the Canada Company in 1829.[10] These two corporations did not retain title to their lands for very long, disposing of much of their holdings between 1831 and 1838. Subsequent owners, such as Richard Carruthers, were able to augment their income and amass some wealth by selectively cutting timber from their holdings into the 1880s.

There was some confusion over these reserved lands along Carruthers Creek due to the practice of leasing the lands to prospective settlers. One particularly good example may be found in the "Township papers" for Lot 6, Concession 4. In July of 1828 John T. Willson, an early Quaker settler in Pickering, made an inquiry at the Crown Land office in York regarding this lot and expressed a desire to purchase it. Having received no reply he wrote and repeated his request once again in January, 1829. Unknown to Willson, another settler named Patrick McNamara had also expressed an interest in this lot in February of the same year. In March Willson once again wrote to Peter Robinson at the land office in some exasperation:

> *{T}here has been a man gone on and built a house on lot no. 6 in the 4th Con. of pickering which I made application to the{e} for the first refusal of in the 6th or 7th month last, again this winter I called at thy office to see further about it, and only saw thy Clerk, who told me there was still no application for that Lot but mine though he could not find it just then so I maade {sic} application again for it he said the lot was not yet prised nor would not be until march or April when I should have a letter concerning it, he said it would not be safe to do any thing on the lot until it was prised besides this I saw advetisements {sic} against cuting {sic} a stick or doing any thing on the reserves, I still desire to hold the lot or the south half at any rate I wish to know whether the gentleman has a right on to the lot or not as I think it very unfair for him to take my place in such a manner, his name I have not ascertained for certain, I have understood he has gone for his family. thy answer will be impatiently waited for, I now conclude and deem myself thy humble obedient servant.*

McNamara secured his right to the land by paying the patent fees in November 1829. He had completed the required settlement duties by April 1831 when the patent was issued in his name, but it does not appear to have been registered in the Land Registry office. In a complex series of unregistered transactions between 1831 and 1847, which were recorded on loose sheets of paper or on the back of the original patent itself, the ownership of this land or the rights to lease it passed through various hands.[11] In a final attempt to settle ownership of this lot, three Crown Patents were issued: George O'Leary (in 1847 for the N½ 100 acres), Henry Cowan (in 1852 for the SW¼ 50 acres) and to James McQuay (in 1856 for the SE¼ 50 acres).

[10] King's College was founded by royal charter in 1827 as a denominational (Anglican) institution and had been the long-term dream of Archbishop John Strachan (1778-1867), and was not secularized until 1850. The Canada Company was established in 1824 and chartered in 1825 by John Galt (1779-1839) as a land and Colonization Company. In the late 1820s through either purchases or grants the company acquired 2.5 million acres in southern Ontario for which they initially paid $295,000. Reformers at the time complained that the company, due to its Tory connections at York, was not efficiently run and settlement would have proceeded as quickly without it. They also claimed that the company treated settlers badly, almost "dictatorially." Nevertheless the company had a long life, only ceasing operations in the 1950s when it disposed of the last of its' holdings.

[11] The owners were William Webb (1831), "Squire" Francis Leys (1832-4), Thomas, Hugh and Bryan Quigby (1834-1845), Jeremiah and George O'Leary (1835-1845), Charles Jewett (1844) and Henry Cowan (1847.) For this chain of ownership refer to Pickering "Township Papers" RG1 C-IV, film MS658 reel 394 pages 776-810. Up until 1850-51 registration of land related documents was strictly by "election" (voluntary) but was not required. Difficulties concerning legal (registered) ownership were becoming more common due to these unregistered instruments and by 13/14 Vict. c. 63 (1850) title documents were required to be registered in order to be valid or if they were to be used as evidence in court proceedings.

Early Settlement

A similar case existed further north along Carruthers Creek on Lot 8, Concession 7. This instance is somewhat less confusing because there are no conflicting claims to the land. Here the patent fees were paid by Horace Foster in December 1830 and the patent was issued in his name in October 1833. Through a series of unregistered conveyances the land passed through three owners between 1836 and 1844. Finally, it was acquired by John Little in 1846 who, in order to quiet the title to the farm, was issued a new Crown Patent in January 1857.[12]

Settlement along Carruthers Creek was sporadic in the early years with great distances between neighbours. The first permanent settlers arrived in the opening years of the 19th century and often purchased their lands from the original patentees. Among them was the family of James Powell who arrived in Pickering from New Brunswick in 1808. They bought Lot 6 in the Broken Front Concession Range 3 from Charles Annis. Their farm passed down through the family until 1865 when the north half was sold to David L. Reed. By 1906 Reed had sold to the family of William S. and Mary T. Gold. The Powell's conveyed the remaining south half of their farm to Frederick Watson and Leslie Pallett in 1911. Bought for speculation purposes, between 1911 and 1912 this section of the lot was resold to three successive owners named Benjamin Hobbs, Henry B. Gee and John Linden.

Further north, the next permanent settlers were located along the Kingston Road which had been opened through Pickering by Asa Danforth by 1798. In May 1812 George Washington Post bought Lot 4, Concession 2 where he built the Post Tavern in 1814, a landmark which still stands to this day.[13] The Post family retained ownership of this land well into the 20th century. Although there was no action seen in Pickering during the War of 1812, (with the exception of local lore which tells of a reputed 'minor skirmish' near Petticoat Creek in 1813), General Sir Roger Hale Sheaffe and Colonel Hardy would certainly have passed by the Post farm on their retreat from York to Kingston, possibly stopping to water both men and horses at this point. During the years 1812-14 the Post, Lynde and Farewell family homes were forwarding stations for official despatches between York and Newcastle. Until the completion of the Grand Trunk Railway through the township in 1856, the Post Tavern was a major stopping point where travellers could refresh themselves and, since a blacksmith was located on the premises, horses could be re-shod.

[12] The owners were David Bowes, Edward Dunn, and William Paxton. (see Pickering "Township Papers" RG1 C-IV, on film MS 658 reel 394 pages 1352-1373).

[13] The Post family had originally come to Upper Canada around 1799 from Hebron, Connecticut and settled in York. Jordan Post the elder had established himself as an early baker. His son, George Washington Post (1779-1828) had moved from York to Scarborough by 1802. He held early municipal offices such as overseer of highways and township assessor, and his name is recorded in court evidence regarding repairs to the Rouge River bridge in 1813. He was a tavern keeper in both York and Pickering.

The tavern was infected with asiatic cholera during the summer of 1832. During the 1850s the tavern was the location for the local agricultural fairs. The Post family holdings in 1871 had an assessed value of $20,000 (a considerable sum for the period) excluding $300 in farm machinery. The agricultural census indicates that the Posts were growing spring wheat, barley, peas, oats, ‘Indian corn,’ potatoes, turnip, carrots, and had cut 20 tons of hay. Livestock included steers, milch cows, horses and pigs. In addition, 750 pounds of butter was produced, as well as $100 worth of orchard produce.

Picov Downs, internationally known for horse and harness racing, established a track on the opposite side of Kingston Road in the 1930s where races are still held. A plaque has been erected on the site.

In September 1812 the family of Nicholas Brown, Quakers who had lived in Vermont and New York State, purchased the farm lot next to the Post family on Lot 5, Concession 2 from Asa Rogers. The Brown family farmed this land until 1909 when they sold to John J. Grills. Grills conveyed the land in the same year to Sir Henry Pellatt, remembered today as the builder of Casa Loma. A small two acre parcel of land on this farm lot was purchased from Brown in May 1819 by Caleb Crawford and the Yonge Street Society of Friends for the site of a Quaker Meeting House, the ownership of which has passed down through the various trustees until the 1940s. The Brown family was equally as prosperous as their Post neighbours. The 1871 agricultural census placed an assessed value of $20,000 on their land (excluding $500 in farm equipment). Their crops included spring and fall wheat, peas, oats, ‘Indian corn,’ potatoes, orchard produce, hay, wool, cider, butter and cheese. Livestock included steers, milch cows, horses, colts, sheep and pigs. The family also owned four “pleasure carriages.”

The only land owner along the length of Carruthers Creek who held the original Crown Patent for any length of time was James Coffin.[14] He received the patent for Lot 4, Concession 5 in August 1799. The farm was left to his son, William Coffin, who sold the south half to Lawrence Heyden in 1845. It was purchased in 1861 by William Stephenson, a man who seems to have had financial misfortunes. The land exchanged hands twice during the 1870s and Stephenson was the owner once again in 1881. He took out a mortgage for $2400 with Joseph Cawthra in 1881 upon which he defaulted in his payments. In 1888 Cawthra exercised power of sale and sold the farm to Albert Asa Post. Unfortunately Post also defaulted on a mortgage and the Ontario Loan and Savings Company sold to Charles H. Pilkey in 1896. Subsequent owners to 1922 were John A. O’Connor (1912), Theo A. McGillivray (1914), Otilla K. Morrissey (1920) and Joseph Quinlan (1922).

The north half of the Coffin farm had passed to John McDonell who sold to John Clerke in December 1840. Passed on through the Clerke family, it was later bought by Aaron Parkins (1880), Victor J. Parkins (1916) and Archie A. Bunker (1946).

The land in Pickering township was lauded by writers in the 19th century. In June, 1830 William Weller “respectfully informed” the public in a newspaper advertisement that his line of stages would regularly run between York and the Carrying Place on the Bay of Quinte “passing through the beautiful township of Pickering” (Christian Guardian, June 9, 1830). The 1878 Atlas describes Pickering as “a fine, fruited, well-tilled, well-farmed and well-settled township, the character of the soil a loamy clay, and the face of the country well watered” (1878:11). Most of the 19th century farms were a combination of cultivated and pasture land, with some wild or wooded land as well as small “orchard” plots. Several farmers were tenants on the land, and the 1861 census records rents ranging between $2.50 to as much

[14] James Coffin was likely a member of the wealthy Coffin family of Boston who were merchants, distillers and ship owners. James was a loyalist who was granted land in Upper Canada in 1797-98.

as $5.00 per acre; the average rent paid by the majority was $3.00 per acre. The land was rich and supported a wide variety of crops and livestock based upon the data recorded in the 1861 and 1871 "Agricultural" census returns for the township. The main crops included hay, fall and spring wheat, barley, oats, peas, potatoes, turnip, carrots, beans, 'Indian corn,' and mangel-wurzel (a variety of large beet, mainly used as cattle fodder). Fruit growing is indicated in 1861 by a column showing the value of "orchard produce," and cider production indicates the presence of apple trees. The 1861 agricultural census notes a small yield of fall wheat partly due to winter killing of the plants followed by midges and rust, while the spring wheat was "cut off by the warm weather." Another marginal notation records that in the previous summer of 1860 "a severe hail storm destroyed a great deal of crop... particularly peas and oats, and several complain of a failure in the potato crop from the rot."

The 1861 agricultural census shows crops of lesser importance being grown by farmers in this area including clover and grass seed, flax and hemp, buckwheat and hops. There was some limited maple sugar production in 1861, but with an increased production of this commodity reflected in the census of 1871. Other farm goods included wool and the production of both fulled and flannel cloth and one household (that of John Little) had produced linen cloth. Nearly every household produced their own butter and cheese, the latter showing an increased production by 1871, and barrels of cured beef and pork were commonly enumerated.

Livestock in the years 1861 and 1871 included horses, colts and fillies, bulls, steers, heifers and milch cows, sheep and pigs. There is no evidence for other farm animals such as chickens and geese, goats, or domestic animals such as dogs and cats although they would have presumably been found on nearly every farm. A few families indicated "muskrat pelts" as a product on the 1871 census.

The 1861 agricultural census did not record the specific types of machinery found on each farm except for a statement of their aggregate value. In 1871 most of the farms owned one or more wagons, ploughs, reapers, horse rakes, threshing machines and fanning mills, not to mention sleighs and "pleasure carriages."

By 1871 fruit growing in Ontario had increased sufficiently in importance that apples, pears and plums are specifically named and the Post family was growing grapes on their land. Rye was being cultivated in limited numbers along the watershed. A few families possessed beehives (ranging in number from one to as many as four hives) and listed honey as part of their farm produce. Every household in 1871 along the length of the creek indicated cords of firewood, ranging in number anywhere from between four and 100 cords, while some farmers were producing both standard pine logs as well as squared red and white pine.

Very few industries were established along Carruthers Creek, probably due to the fact there is an unreliable supply (insufficient head) of water for any milling enterprises. An examination of the historical maps for Pickering shows that the largest number of saw and grist mills in the township were located along Duffins Creek which would have provided a more consistent supply of water power. Although most families along the watershed were primarily farmers by profession, a number of small family-run businesses were established which would have provided additional income and were operational for varying lengths of time throughout the year. Based upon the census records it is possible that there were other small businesses in operation within the watershed; however due to the vague nature of Victorian data recording a more detailed study would be required in order to determine whether they were located within the Carruthers Creek or Duffins Creek watersheds.

One of the earliest was the blacksmith establishment run by John Brander, a settler from Scotland, who lived on the Kingston Road "near" Post's Tavern on Concession 2, shoeing horses for the Toronto-Kingston stages. Brander was a member of the first Presbyterian congregation. He died in May 1841.[15]

James Carpenter, a settler from Vermont, arrived in Pickering around 1825 and settled on Lot 3, Concession 3. He was another early blacksmith in the area.

Daniel McBrady (1818-1907) came to Canada from Co. Donegal, Ireland, in 1837. He initially settled for a few years near Whitby but soon relocated to Concession 3 west of Audley where, in addition to farming, he set up as a wheelwright and wagon-maker producing a variety of wagons and sleighs. The 1861 census indicates he had sufficient business to enable him to employ one hired man with a yearly wage of $250. He served as the postmaster at Audley between 1871 and 1878. His wife was Ellen Broderick (1830-1907).

John Adamson (1804-1856), a settler from Yorkshire, had located his family on Lot 7, Concession 5 as early as 1840 although he did not purchase this land until October 1852. The family farmed but Adamson was also described in the 1851 census as "bricklayer." When Adamson died on July 31, 1856 he willed the farm to his son, Samuel Adamson, who had taken up his father's trade. It is not clear on the basis of surviving evidence whether John established a brick and drain tile kiln, but it is certain that one was operational under Samuel by 1860-61. Undoubtedly all the raw materials required, such as clay, sand and wood for firing the kiln, could have been found along the creek or within a short distance of the brickyard. The 1861 census indicates that 15,000 bricks and tiles were manufactured worth $700. By 1871 the company had $900 invested in capital and employed eight people, producing 40,000 draining tiles and 10,000 red bricks. The brickyard is shown on the Pickering township map in the Ontario County atlas in 1878.[16]

[15] for his death date see Letters of Administration, York County Surrogate Court Register 6 (1838- 1842) page 407 (Archives of Ontario film #GS2-238)

[16] see Pickering 1851 census division 1 page 139 (reel C11742); will of John Adamson, Whitby Surrogate Court #58 (1856); 1861 Pickering census (reel C1057); 1871 Pickering census div. 3 schedule 6 (reel C9973)

George O'Leary (1796-1881) came from Ireland to Upper Canada in 1831 and had settled on Lot 6, Concession 4 which the family purchased from Bryan Quigley in December 1834. The patent for this land was re-issued to O'Leary in July 1847 after a complex series of unregistered conveyances which was described earlier in this overview. The 1861 and 1871 census shows that O'Leary had established a lime kiln employing as many as seven men, with production of 500 bushels of lime worth $120. O'Leary sold his holdings to Richard Squire in January 1874 for $2,830, after which O'Leary retired to Pickering Village where he died.[17] Three small communities sprang up within the watershed during the mid-19th century (Figure 2). In importance they were soon eclipsed by other nearby communities such as Claremont, Greenwood, Brougham and Whitevale which had grown up along Duffins Creek where there was greater hydraulic power for milling enterprises. Also, by 1856 the Grand Trunk Rail Road had completed its line to the south near the town of Pickering (at the time the village was also called Duffins Creek) and consequently became the main business focus for the township.

Audley. The village of Audley is centered at the modern day intersection of Audley Road and Taunton Road East in Ajax. This would have been the road allowance between Lots 2 and 3 in Concessions 3 and 4. The original name for this community was Brown's Corners, where a post office was established on April 1, 1853. The name Brown's Corners continued to be used until November 1856, and the post office and village was re-named Audley on January 1, 1857. The community was noted in the 1873 Lovell's Gazetteer of British North America. The post office, with the exception of a few brief closings, remained operational until it closed permanently

[17] Pickering 1871 census division 3 schedule 6 (reel C9973.) Richard Squire died in 1894 and the land passed to William Squire who retained ownership until his death in 1945 at which time it was purchased by James William Mitchell. Hydro and Trans Northern Pipe Lines purchased rights-of-way over the land in 1948 and 1952 respectively.

on October 31, 1914.[18] The 1878 atlas map shows many of the buildings in the village on the south side of Taunton Road, with the others on the north-east side of the Audley Road intersection. Major land holders immediately outside the village at the time were Orvis, Edwards, Irving, Carpenter, McBrady and Puckrin. School Section 5 was established at Audley where a log school house stood on Lot 2, Concession 3 between 1840 and 1850. This building was replaced by another log structure to the north-west (on Lot 11, Concession 4) which was in use between 1850 and 1856. A frame school was constructed (1856-1865) and the present brick school was completed in 1866. Today the SL&H railway passes south of the crossroads, while Carruthers Creek passes directly through the Deer Creek and Fawn Brook Golf Courses on what would have been the O'Leary and Puckrin farms. The Jolly Huntsman Equestrian Centre is located on the north-east corner of the crossroads.

Kinsale. Two miles directly north of Audley, this village is located at the intersection of Kinsale Road and Highway 7 in Pickering. This was originally the road allowance between Lots 2 and 3 in Concessions 5 and 6. In 1873 Lovell's Gazetteer of British North America notes the village population was 90 inhabitants. The 1878 atlas map shows all the buildings in the village situated on the west side of Kinsale Road, with a branch of the Lynde Creek flowing through the intersection. The major land holders immediately outside the village were D.L. Reed (sometimes spelled "Reid") and J.W. Clark. The post office at Kinsale was established on May 1, 1856 and closed on October 30, 1915.[19] **Union School** Section 2 was established here in 1852.

Salem. Located about ¾ miles directly west of Kinsale, this village is located at the intersection of Salem Road and Highway 7. This was originally the road allowance between Lots 6 and 7 in Concessions 5 and 6. The original name of the community was Hyfield before it became Salem's Corners. Although the land in this area had been patented to Jacob Farrand in 1798 and sold to John Elmsley in 1799 with no further registered conveyances until the 1830s, it would appear that "squatters" had settled on this land at a very early date. We are told that the first Pickering Township Meeting was held on June 4, 1801 at Samuel Munger's farm "near Salem" on Lot 7, Concession 6. This farm was bought by the Munger family from the Elmsley estate in 1835 and bought by the Gibsons (it was later known as the Judson Gibson farm) in 1838. John Hyfield (1783-1866) was another early settler who arrived from Limerick, Ireland in 1836 and purchased a farm on the north-east corner of the crossroads.[20] The Adamson family, settlers from Yorkshire, settled on the south-west side of the crossroads where they established a brick and drain tile kiln sometime in the 1850s.

[18] The known postmasters for Audley have been: A.W. Brown (1853-6), Thomas Palmer (1856), Benjamin Medill (1857-1862), Robert Graham (1862-1865), Daniel McBrady (1871-1878), Emmanuel Maddaford (1879-1882), Francis M. Harvey (1884-1886), Charles A. Lynde (1889- 1898), Miss Margaret Orvis (1899-1900), Thomas Puckrin (1900-1905), C. Henry Pilkey (1906- 1910) and James P. Dalby (1911-1912).

[19] The postmasters for Kinsale have been: John Fairles (1856-1869), Levi Mackey (1869-1879), Bailey Wetherhall (1879-1896) and John W. Rodd (1897-1915).

[20] Lot 6, Concession 6 is another instance of unregistered land conveyances being found among the "Township papers" which resulted in three late patents being issued to clear the title to the land (Pickering Township papers, RG1 C-IV, MS 658 reel 394 pages 1175-1201). This lot was held as a clergy reserve and in 1828-29 John Elmsley, Ezekiel Crain and James Munger expressed a desire to purchase the lot. In September 1830 one Israel Gibbs paid the patent fee and the patent was issued to him in January 1834. Gibbs conveyed the N½ of the lot to Wing Rogers in April 1834 and the S½ to Charles Jains (or Janes) in December of the same year. Janes sold his part of the lot to John Campbell in January 1838, and Campbell sold 50 acres to James Gibson in October 1845 and the other 50 acres to John Hyfield in September 1847. In January 1846 at Gibson's request the land was surveyed by John Farquharson (PLS) to confirm the limits of his purchase. New patents were issued to Wing Rogers (June 1846), James Gibson (September 1858) and John Hyfield (December 1861) to confirm title to their land.

Salem Cemetery was established in 1831 at Salem on Lot 7, Concession 5.

The first **school** was built at Salem on ¼ acre of land on Lot 7, Concession 6, purchased in August 1844 from James Huntington. By 1855 this land had been sold to Samuel Snell, a carpenter, although the school building still appears to have been in existence in 1878 when it is found marked on the atlas map. The first teacher was John Peacock, who was succeeded in that position by a Miss Thompson, daughter of a hotel keeper.[21]

A **cemetery** was established in 1831 at Salem on Lot 7, Concession 5. This cemetery was enlarged to the south in 1888 when land was purchased from the Adamson family and again in 1914, and to the east in 1939. The Ontario Genealogical Society has transcribed at least 232 tombstones from the "older" sections of this cemetery (film MS 451 reel 4.)[22]

On May 19, 1849 Elizabeth Gibson sold ¾ acres to John Sadler and other trustees for the erection of a Wesleyan Methodist church. The congregation had been founded prior to the sale of the land, perhaps as early as the time of the establishment of the cemetery (1831) and so it was an appropriate location for the church. By 1848 the congregation had planned for the construction of their own church. The building was initially constructed out of wood, with John Adamson supervising the work. The building was erected quickly since it was ready for services at the end of May 1849. The interior of the church is described as being plain with straight-backed pine pews which were uncomfortable to sit in. In 1880 the church was remodelled and bricked. A local historian writes:

> *An old Kinsale lady used to tell how they went to Kinsale church in the morning, walked to Audley church in the afternoon, and walked to Salem at night. They thought this was grand, walking many miles meant nothing to them in those days as they were accustomed to it... Salem church never had an organ or any musical instrument when regular services were held. Alexander Brown used to lead the singing. He had a fine tenor voice (McLean and McLean, 1960:15).*

"Class meetings" were held at Salem church for which a record book survives from the period 1861-1871. Originally Salem formed the "Hyfield Branch" of the Markham Circuit of the Wesleyan Methodist Church. Between 1847 and 1855 it was included within the Oshawa Circuit, then it formed part of the Whitby Circuit (1855-1862), and the Pickering Circuit (1863-1893). In 1893 the Greenwood Circuit was established.[23]

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[21] The school may have been erected prior to the land purchase on Hyfield's land since local histories record that the first school at Hyfield or Salem was on the north east corner. See McLean and McLean, *Greenwood through the Years* (1960) p. 4.

[22] The earliest marked grave in the cemetery appears to be that of Hugh McBrien, died Feb. 6, 1836 aged 22 years. At the time the cemetery was transcribed, in October 1974, the cemetery was still being used for burials. There are also some surprises found here such as the grave of John Austan who died in 1854 aged 77 "a native of the Kingdom of Sweden."

[23] The Pickering Circuit in 1865 embraced the communities of Duffin's Creek, Kinsale, Salem, Greenwood, Claremont, Mount Pleasant, Brougham, Jackson's and Glen Sharrard now called Glen Major. The circuit riders at the time were recorded as "Messrs. Lake, Morrow, Low, Darlington, Gamble, Eldon, Bunting, Lock, Switzer and Blow." In 1893 the Greenwood Circuit was established which covered Audley, Kinsale, Brougham, Glen Major, Mt. Zion and Greenwood. At a later period Audley was joined to Pickering village and Glen Major was dropped from the Greenwood circuit.

The church was closed in 1890 because there were other larger congregations nearby. Yet the church was not immediately abandoned, since one old man continued to come to Salem "regularly for some time after it was closed, and sat in his old pew on Sundays and worshiped his God alone and in silence" (McLean and McLean, 1960:15). Memorial services were annually conducted in the last Sunday in June, and an historical plaque was erected in 1967 by the Kinsale Women's Institute.

North of Salem, on Lot 8, Concession 7, ¼ acre of land was conveyed by William Paxton to school trustees in February 1854. Whether a school was erected on the north-west part of the lot is uncertain, and the land was sold by the school trustees to Christopher McAvoy, owner of the adjoining land, in May 1877. The McAvoy family retained ownership of the northerly 72 acres of the lot until at least 1927. On the south part of the lot John Little sold 20 perches (approximately ½ acre) to the trustees of the Methodist Episcopal church in October 1857. The 1878 atlas map indicates the existence of a church structure at that time.

The history of Carruthers Creek is long, extending from the Aboriginal pre-contact period and French regime through to the coming of the Loyalists and other settlers from the United Kingdom down to the present day. The creek was not exploited as a trade route or for hydraulic power for industries since it is not as large and hence cannot produce a steady supply of water such as is the case with Duffins Creek or Lynde Creek. After being surveyed in 1791, and despite construction of the Kingston Road in 1798, settlement was slow due to the fact that not only was the township geographically isolated from the markets and larger population centers such as York or Niagara, but also because in the early 19th century much of the land was held by the governing elite at York in large blocks or as Crown and Clergy Reserves. It was the reluctance of families like the Smiths and Elmsleys to dispose of their land that settlement of this part of the township was impeded.

A few early families had settled upon their Crown patents in the pre-1812 period but they generally sold out very quickly to what may be considered the first bona fide settlers of the watershed such as the Mungers, Powells, Posts and Browns. There was little action seen in Pickering during the War of 1812 with the exception of troop movements and the forwarding of dispatches. After the close of the War of 1812 a gradual increase in settlement took place, but it was not until the late 1820s and early 1830s when the area witnessed a large influx of Anglo-Irish-Scotch settlers and Quakers who began clearing the land in earnest. Many of these families had extensive farms where they practiced mixed agriculture, growing a variety of crops and livestock with an increase in fruit growing seen towards the end of the 19th century. Some of these families also ran small businesses, such as brick making or lime burning, in addition to their agrarian pursuits and had large assessed value on their estates by the mid-19th century.

Nearly all the families within the watershed retained farm ownership for half a century or more, and in several instances well into the 20th century. Houses were typically constructed of log or frame, but some were brick or stone construction. Three small communities, Audley, Kinsale and Salem sprang up at various crossroads in the watershed by the 1850s. Audley and Kinsale each had their own post office which stayed in operation until the 1914-15 period. Log schools were constructed in the area, and the spiritual needs of the community were met by several churches.

The first major settlement in the area was by a number of Quaker families, so it is not surprising that the first church was built by the Society of Friends in 1819-1820 on the Kingston Road on land donated by Nicholas Brown. Many of the later settlers were Methodist, so the other churches were of that denomination and formed part of various Methodist circuits through the years. A large Methodist burial ground was established at Salem in 1831 and remained in use until at least the 1970s. The Irish Catholics in the area do not appear to have had a church of their own, presumably they would have been visited by the clergy or would have made the trip into Pickering Village where there was a larger Catholic congregation.[24] These small villages in Pickering Township did not grow in any importance due to their geographic location. Steadier supplies of water power to the west and east attracted milling enterprises towards the larger creeks and communities such as Claremont, Brougham, Greenwood and Whitevale. Eventually these communities were also by-passed when the Grand Trunk Railway opened in the southern part of the township in 1856 bringing greater prosperity and more settlement to towns like Pickering and Whitby.

[24] The Parish of Oshawa was visited by a Catholic clergyman as early as 1825, and mass was held in parishioners homes or McGregor's school once a month for several years. The parish was visited by clergy from Toronto, Cobourg and Peterborough until the appointment of a regular priest in 1843. Pickering's first Catholic church was St. Winefrid's, erected in 1849, and Pickering was erected into a separate parish in 1860. St. Joseph's was built nearby at Highland Creek in Scarborough in 1854. The Catholic population of Pickering was said to be about 350 in 1892. For a history of the parish see J.R. Teefy, *Jubilee Volume of the Archdiocese of Toronto 1842- 1892* (Toronto: Geo. T. Dixon, 1892, pp. 316-319).

Summary

Two main issues have limited the 1999-2000 study of human heritage features in the Carruthers watershed. The first concern deals with the level and quantity of data which is available for each site. Individual LACAC Heritage Inventories vary considerably in terms of the level of data provided. Without conducting an exhaustive research program to examine primary documentation for each heritage property, it was impossible to be consistent in providing specific data (i.e. date of construction for historic structures) across the watershed.

Secondly, the quality and reliability of spatial data varies depending upon the source. As an example, it would take a considerable amount of effort to locate any mill sites which may have existed temporarily along this creek. For this reason, mills have not been included in the present mapping inventory.

The communities within the Carruthers Creek watershed have a rich and varied history, which we have just begun to understand. From the time of the retreat of the most recent glacier to the present, the environmental conditions in this watershed welcomed human inhabitants. Currently, 59 archaeological and built heritage features are known, but vast areas of the watershed are yet to be explored.

References Cited

Ellis, Chris J., Ian T. Kenyon and Michael W. Spence, 1990. The Archaic. In *The Archaeology of Southern Ontario to A.D. 1650*, edited by Chris J. Ellis and Neal Ferris. Pp 321-359. Occasional Publication of the London Chapter of the Ontario Archaeological Society, Number 5. London: Ontario Archaeological Society.

Farewell, J.E., 1907. *County of Ontario: Short Notes as to the Early Settlement and Progress of the County and Brief References to the Pioneers and some Ontario County Men*. Whitby: Gazette-Chronicle Press.

Government of Ontario, 1887-1928. *Annual Archaeological Reports for Ontario*, (AARO), reports to the Minister of Education.

Government of Ontario, 1992. *Guidelines for Preparing the Cultural Heritage Resource Component of Environmental Assessments*.

Konrad, V.A., 1973. The Archaeological Resources of the Metropolitan Toronto Planning Area: Inventory and Prospect. *York University, Department of Geography, Discussion Paper No. 10*.

McLean, Irven and Beatrice R. McLean, 1960. *Greenwood Through the Years*. Greenwood Farm Forum.

Ontario Archaeological Society
Arch Notes, Newsletter of the Ontario Archaeological Society.
Ontario Archaeology, Journal of the Ontario Archaeological Society.

Spence, Michael W., Robert H. Phil and Carl Murphy, 1990. Cultural Complexes of the Early and Middle Woodland Periods. In *The Archaeology of Southern Ontario to A.D. 1650*, edited by Chris J. Ellis and Neal Ferris. Pp 125-169. Occasional Publication of the London Chapter of the Ontario Archaeological Society, Number 5. London: Ontario Archaeological Society.

Wood, William R., 1911. *Past Years in Pickering: Sketches of the History of the Community*. Toronto: William Briggs.

Historical Maps Consulted:

- 1860 Tremaine's Map of the County York. Toronto: George C. Tremaine.
- 1877 Illustrated Historical Atlas of the County of Ontario. Toronto: J.H. Beers & Co.
- 1878 Illustrated Historical Atlas of the County of York. Toronto: Miles & Co.

APPENDIX A

CARRUTHERS CREEK WATERSHED 1999-2000 HUMAN HERITAGE STUDY METHODOLOGY

Specific Tasks

- Document numbers and locations of archaeological sites, historic sites, and cemeteries and other burial sites in the Carruthers Creek watershed.
- Document, in both written and photographic form, numbers and locations of built heritage structures, cemeteries and plaques in the Carruthers Creek watershed.
- Prepare a GIS model (map) of the above information for the Carruthers Creek watershed.
- Provide a generalized summary of the above resources.

Products

- An open-ended inventory of the archaeological sites in the watershed.
- An open-ended inventory of the built heritage and historic sites in the watershed.
- A background report summarizing the cultural heritage character of the watershed.

Operational Structure

- Define individual human heritage resources which fall within the study area.
- Locate individual resources on the relevant 1:10,000 Ontario Base Maps and determine spatial coordinates.
- Enter information pertaining to each resource into the database.
- Photograph the available built structures and develop a CD-ROM version of the images.
- Examine relevant documentation for each resource.

Resource Definition

Two separate approaches were employed in the definition of individual human heritage resources. These approaches included:

- An examination of individual compilations of built heritage resources as defined by municipal Local Architectural Conservation Advisory Committees (LACACs).
- An examination of individual compilations of archaeological sites as defined by the Ontario Ministry of Culture (formerly Tourism, Culture and Recreation).

LACAC Heritage Inventories

The two municipalities found within the Carruthers Creek watershed, through their Local Architectural Conservation Advisory Committee (LACAC), has prepared an inventory of buildings of architectural and historic importance.

Examination of these inventories located a total of 59 extant cultural heritage sites, three of which are Designated, which fall within the study area. It should be noted that this list is not definitive. If an individual structure is not classified as Designated or Listed by a municipality, it is not included in the local inventory and consequently is not included in the present study, with the exception of cemeteries, cenotaphs and plaques.

Archaeological Sites

A total of 32 archaeological sites have been located within the watershed. It is important to note that mills were fundamental to the development of communities in Upper Canada, and while in most instances these mills are represented now as archaeological sites (although most have yet to be surveyed and registered with the province), they must be included in any inventory of an historic landscape. However, in the present study information detailing the precise locations of mills was not available and, therefore, mill sites are not included on the project mapping.

Secondary Sources

Archaeological Sites

The principal source of data examined in respect to the study area was the Archaeological Database of the Heritage Branch of the Ontario Ministry of Culture. The database is a summary of the archaeological investigations conducted in and around the study area during the past century. Both newly found sites and resources rediscovered due to archival research (primarily by Konrad, 1973) are documented in Ontario Ministry of Culture records.

Archival research of historic documents was also conducted to ensure that all previously located archaeological sites were recorded with the Ministry. These archival sources included the A.J. Clark Papers (n.d.), the *Annual Archaeological Reports for Ontario* (1887-1928), research notes on file with the Department of Anthropology at the Royal Ontario Museum, and *Arch Notes* and *Ontario Archaeology* published by the Ontario Archaeological Society.

Historical Resources

Many volumes describing the history of the Carruthers Creek watershed have been written and consulted for this project.

Spatial Definition

A total of 59 individual heritage features were defined during the Resource Definition phase of the project. Each heritage site is considered a positive landscape feature. In order to integrate known heritage resources with other features (biotic) of the watersheds, spatial coordinates for each of the 59 data points were determined. This process was facilitated through use of 1:10,000 Ontario Base Maps (OBMs).

The full extent of the Carruthers Creek watershed is defined on Ontario Base Maps. After individual drainage systems, municipal boundaries were defined on these maps, and each site was graphically represented in its proper position. Individual Universal Transverse Mercator (UTM) coordinates were derived for each feature or landscape centroid. These coordinates define each site in space in respect to number of metres north of the equator and east of the false transect positioned in relation to the prime meridian. The spatial data collected was then entered onto the database for GIS purposes.

Site Data

The individual content of the heritage inventories used to prepare this report varied considerably in terms of information defined for each feature. Consequently, it was difficult to collect a common set of data for each site. The information that was commonly available was recorded onto the Carruthers Creek Watershed Heritage Study Database. The format of the database was loosely modelled on the Heritage Record Form For Environmental Assessments, contained within the Ontario Ministry of the Environment's *Guidelines for Preparing the Cultural Heritage Resource Component of Environmental Assessments*, 1992.

Carruthers Creek Watershed Heritage Study Database

To expedite immediate access to information on individual human heritage features and landscapes, a Carruthers Creek Watershed Heritage Study Database was developed. This data file is written with SPSS software and is accessed with an IBM-compatible computer. The specific 'record' format used was patterned after the **Heritage Record Form For Environmental Assessments**, defined by the Ontario Ministry of the Environment. The database was designed to be used in conjunction with this report, the individual Ontario Base maps which describe the location of each site and the GIS maps produced for the study. All OBMs and GIS mapping are on file with the TRCA's Archaeological Resource Management Unit's map library. Each of the 59 individual sites identified were defined within this database. Table 1 illustrates an example of the 'fields' employed in this data file.

Table 1: Carruthers Creek Watershed Heritage Study Database

Field	Description	Data
DATABASE ID	unique database identifier	44
NAME	name of feature	Post Tavern
ADDRESS	street address or Lot/Concession	367 Kingston Rd East
ORIGNLUSE	original use	Inn/Staging Post
DATECONSTR	date of construction, if applicable	1815
ARCHITSTYL	architectural style, if applicable	Georgian
CULTAFFIL	cultural affiliation, for archaeological sites	
REFERENCE	reference	Ajax LACAC
DESIGNATED	designation (Designated, Listed or not applicable)	Designated
EXTENT	number of structures (single or multiple), if applicable	Multi
OBM	Ontario Base Map number	78
NORTHING	OBM north coordinate	4858580
EASTING	OBM east coordinate	660100
MUNICIPAL	municipality	Ajax
SUBWTRSHED	watershed or subwatershed	Carruthers Creek
OBMID	OBM sheet identifier	#1
COMMENTS	additional comments	LACAC plaque

APPENDIX B

CARRUTHERS CREEK WATERSHED HERITAGE DEFINITIONS

Archaeological Resources

Archaeological Resources are defined as: The remains of any building, structure, event, activity, place or cultural feature or object which because of the passage of time is on or below the surface of the land or the water and which is associated with Aboriginal history (pre AD 1608) or the post-contact (historic) period (post AD 1608) in Ontario.

Architectural Resources

Architectural Resources are defined as: buildings, structures, or remains built by people which reveal some of the broad architectural, cultural, social, political, economic or military patterns of Ontario's Euro-Canadian history or are associated with specific events or people that have shaped Euro-Canadian history. These would include resources such as: individual buildings; groups of buildings; historic settlements; foundations; cemeteries; barns and other outbuildings; fences; bridges etc. Architectural Resources of outstanding historical or architectural character can be protected under the Ontario Heritage Act by being Designated. This procedure requires the passing of a By-Law by the local municipal government. Architectural Resources considered as potential or candidates for this protective measure are defined as Listed.

Cultural Heritage Landscapes

Cultural Heritage landscapes are defined as: any discrete aggregation of features made by people where the arrangement of the features that exist in conjunction with one another is representative of distinct cultural processes in the present, and historical development and use of the land within the watershed. Cultural landscapes include any scenic/heritage or contemporary area perceived as an ensemble of culturally derived landscape features such as a neighbourhood, a townscape, landscape or waterscape that illustrates noteworthy relationships between people and their surrounding environment.

For practical purposes Historic Landscapes may be considered as part of, or a subset of, the cultural landscape but are differentiated by their historical merit. They can be remnant or existing landscapes but have a specific association to historical events, people, heritage building(s)/structures or archaeological sites. They can be clearly identified as providing an important contextual and spatial relationship necessary to preserve, interpret or reinforce the understanding of important historical resources, settings and past patterns of land use.

Heritage Conservation Districts/Heritage Area

Heritage Conservation Districts are defined as: any aggregate of buildings, structures and open spaces that as a group is a collective asset to the community and which may have architectural, historical, archaeological or scenic value. Districts may be found in urban and rural environments and may comprise residential, commercial or industrial areas landscapes or entire villages. Heritage Conservation Districts are designated by municipal by-law, under Part V of the Ontario Heritage Act.

APPENDIX C

CARRUTHERS CREEK WATERSHED ARCHITECTURAL STYLES

Style	Description
Boomtown	A style commonly used for commercial structures during the mid-1800s. The Boomtown style is characterized by a front gable roof hidden by a false facade to make the structure appear a full storey taller. The top of the 'crown' was typically rectangular or stepped.
Bridge	A structure linking two sections of road or pathway over an obstacle such as a river.
Burial Place	A cemetery, family burial ground, or other location where deceased individuals have been interred.
Cenotaph	A monument erected in memory of members of a community, generally in military service, who died in war.
Classical Revival	Also called Neo-Classical, this style is characterized by its balanced composition (often symmetrical), low pitch gabled roofs (often with returned eaves) or square hipped roofs, and the use of columns, pediments, and elliptical transoms with sidelights around the doors. The architectural details are reminiscent of Roman or Greek architecture.
Edwardian/ Foursquare	Edwardian houses are built on a square or rectangular plan. They generally have medium to high pitch hipped roofs, usually with one or more dormers, and are two to three stories high. The front entrance often has a porch or stoop, and windows are rectangular. Foursquare houses are essentially Edwardian houses built on a square plan. Most Edwardian or Foursquare houses were built between 1900 and 1925.
Georgian	A house of this style is built on a rectangular plan and will generally have a medium pitch gable roof with returned eaves, a symmetrical facade with the door at the centre, and paired chimneys on each side. Other common elements include a frieze under the eaves, a transom and sidelights around the door, and in larger structures, a second floor hall light in the centre of the front facade. Larger Georgian houses often have a Palladian window on the front facade over the entrance. Most surviving Georgian houses in Ontario were built between 1830 and 1850.

Georgian Revival

These houses are almost identical in design to Georgian houses. The primary difference is the date of construction, which is generally after 1850 but before the turn of the century.

Gothic Revival

These houses are irregular in plan and have multiple-gabled, steeply pitched roofs, often over "Gothic" (pointed) windows. Other elements of traditional Gothic architecture that sometimes occur (especially on Churches) include buttresses and high pointed steeples or belfries. Some Gothic Revival houses have decorative bargeboard in the gables and may resemble Picturesque houses. They were commonly built between 1860 and 1880.

Italianate

Italianate houses in Ontario vary greatly in plan, but are recognized by their elongated, arched windows, often with elaborate moulded hoods or surrounds. Some houses had towers incorporated into the construction, or lantern openings on the roof. Other common features include hipped roofs, overhanging bracketed eaves, arched porches, and balustraded balconies.

Ontario House

These commonly occurring houses are built to a rectangular or "T" plan, and are symmetrical in design. They usually have medium to high pitched gable roofs with a centre or cross gable over a decorative window on the front facade. These gable windows are often Gothic or Arched. In older structures there may be a "suicide door" in place of the gable window, and the end gables may feature returned eaves. Many Ontario Houses have been embellished with decorative wood trim under the eaves and in the gables. These houses were generally built between 1875 to 1900, though earlier examples exist. Some Ontario Houses may be modified Georgian or Georgian Revival houses.

Picturesque

This style of house is generally built on an "L" plan, with a medium or high pitch gabled roof, and an entrance and verandah in the enclave. The projecting section of the front facade contains a single or double storey bay window. Other windows usually have segmental heads. Elaborate bargeboards, pendils, and other decorative elements are common on gables, under the eaves, and around the verandah roof, if any. These houses were built between 1880 and 1900, with some earlier examples.

Romanesque Revival	These structures are generally rectangular in plan, with a projecting portico and an elaborate entrance. Doors are often surrounded by a transom and sidelights. Windows are generally long and often round headed. The use of columns and other monumental ornamentation characterizes this style. Townhouses and public buildings built in this style often have carved stone ornamentation. This style was most popular between 1880 and 1910.
Saltbox	A 1 to 1.5 storey residential structure topped by a shed roof, which is formed by a high-pitched plane covering the entire structure, with the peak at the front and the slope towards the rear.
Vernacular	A structure not designed by an architect in a recognized style. The building reflects locally available materials, environmental factors and prevailing tastes. Form often follows function in these structures.
War-time Bungalow	A narrow, rectangular residence with a low-pitched gable or, less frequently, a hipped roof, and often containing small front porches. Often, entire subdivisions built during the Second World War contained variations of this style.

APPENDIX D

EARLY SETTLERS ALONG CARRUTHERS CREEK

Much appreciation is extended to Mr. Brian Narhi, who compiled the Euro-Canadian/Historic Period occupation of these lands for this report.

The following historical descriptions of individuals and families often include their property locations, specifically lots and concessions. These areas are shown on the **Illustrated Historical Atlas of the County of Ontario** ***(which later became Durham Region). Copies of the*** **Atlas** ***are available for viewing at the Pickering Central Library and the Uxbridge-Scott Museum.***

John Bell (-1908) purchased part of Lot 5, Concession 3 from Patrick Larkin in November 1874. This land was passed onto his son, John, before being sold to Frank Puckrin in March 1919 for $8,000.

Ebenezer Birrell (1801-1887) was born in Scotland and came to Canada in 1834. In October of the same year he was able to purchase farm land from both Elmsley and Macaulay, and eventually he had acquired and farmed on 502 acres being Lots 9, 10 and part of Lot 11 in Concession 7. Here "Squire Birrell" built his home, "Maple Hall" which remained in the family as late as 1957. He was said to be a man of "superior education" who took an interest in the life of the community, and for many years he was one of Pickering's most prominent citizens. He was president of the Pickering Agricultural Society (1853-1859), local Superintendent of Education (1856-1865), elder and session clerk in the Claremont Presbyterian Church, and was Lieutenant-Colonel of the 4th Battalion of Ontario Militia. A story is told about one episode in particular when Squires Frederick Green and Birrell were holding court in Greenwood:

> *A big, blustering fellow was before them charged with assault. He was marched in and out of the court at his pleasure, using much profane and very disrespectful language to, of and about the court. Squire Green asked his brother justice Birrell if there was not some way of stopping this. Squire Birrell said he might call out the posse comitatus, whereupon Squire Green said "The posse comitatus be damned! This court is adjourned for 5 minutes until I whip the scoundrel!" The court in due time resumed its sitting with a well whipped prisoner present and submissive, ready to do and receive what the court should award in the premises (Farewell, 1907:15).*

Birrell died February 27, 1888 aged 87 years and 10 months. His wife, Janet Mackey, died in October 1846. They are buried in Claremont Union churchyard along with some of their children and grandchildren.

Carpenter. The Carpenter family settled near Audley on part Lots 3 and 4, Concession 3 in 1825 when James Carpenter, a blacksmith from Vermont, settled here. Carpenter purchased 200 acres from Anne Smith in July 1826 of which he sold 112 acres to Abraham Brown in February 1841 and the remainder to his son, Ira B. Carpenter, in February 1852. In 1875 Ira mortgaged the lands for $8,500 in favour of Joshua Richardson. The case was tried in the plaintiffs favour, and Carpenter executed a quit-claim deed in 1898 to Susan Richardson. The land was conveyed to Fannie E. Richardson in November, 1898.

Richard Carruthers. It is remarkable that this creek bears the name "Carruthers" since this family, even though they owned 202 acres along its banks, were by no means the wealthiest or most prominent land owning family in the watershed. Carruthers was born in Cumberland, England in 1819. He settled on part of Lots 4 and 5, Concession 1, having purchased these lands in January 1856 and September 1862, as well as purchasing part of the road allowance from the township in June 1875. The land remained in the Carruthers family until at least the 1940s when Bell easements were registered on title. Two "town lots" also formed part of the family estate. His family consisted of his wife, Elizabeth (b. 1831) and at least four children: William A. (1849), Levina (1850), Richard (1854) and Wesley David (1857). A niece, Cordelia Mason, came out to live with the family and is named on the 1871 census. Carruthers was listed as a farmer in the 1871 census and the family was Wesleyan Methodist. In 1871 the family owned three houses and seven barns/sheds, five carriages/sleighs, five wagons, five ploughs, one reaper, one horse rake, one threshing machine and three fanning mills. The farm produce included wheat, barley, oats, peas, beans, 'Indian corn,' potatoes, turnip, carrots, mangel-wurzel, hay, apples and other fruit. Livestock included horses, colts, milch cows, horned cattle, sheep, pigs and one beehive. The farm produce included barrels of cured beef and pork, butter, wool, cloth, two muskrat pelts, 100 cords of firewood and 120 cubic feet of square white pine. This is not much different from 1861 when the farm products included cheese. In 1861 the assessed value of the farm was $3,000 with an additional $400 in farm machinery.

Richard Carruthers died on August 8, 1887 from neurasthenia. His will with a codicil was made probate in September 1887. His wife Elizabeth was to have half the house and furniture, use of the orchard and $300 yearly, as well as a milch cow, horse with harness and conveyance, and a supply of firewood or coal. His daughter Lavina was to receive the interest from $1,200 to be invested by the executors of the estate, and his niece Cordelia Mason was to receive $300. His eldest son William was to inherit a 100 acre farm in Markham with all stock and personal effects. The youngest sons, Richard and Wesley David, were to have 100 acres each in Pickering subject to the legacies to their mother. They were each able to use "the creek in the north field to water horses and cattle" as well as the right to cut, carry and sell whatever timber they agreed upon. A remaining farm in Whitby was to be sold outright for profit in order to pay any debts or legacies contained in the will (will #1955 [1887] film GS1-1161).

Clark. The Clark (or Clerke) family were from County Cork, Ireland. John Clark (1803-1862) farmed part Lot 8, Concession 6 which he bought from Thomas McMurray in April 1843. His wife was Phoebe Shaw, who was born in New Brunswick in 1813 and died in 1894. The farm remained in the family until 1924 when it was sold to Barbara and William H. Carson.

James Coffin was probably a scion of the loyalist Coffin family. Residents of Boston, Massachusetts since the early 18th century, the family had established themselves as wealthy merchants, distillers and ship owners. At the time of the Revolutionary War some of the family took up arms in the Royal Regiment of New York while others fled to the safety of Québec in 1775-76. Here they were awarded with civil and military offices as compensation for their personal losses. Each of the Coffin family members (there were 11) were granted 1,200 acres of land. James petitioned for his lands in Upper Canada in 1797, as well as for a town lot in Niagara in 1798. James and his brother Nathaniel (who settled at Kingston and died in Toronto) played conspicuous roles in the War of 1812 in the Commissariat's Department. James retired to Québec and still later to Bath, England. William Coffin later wrote and published (in 1860) *A History of the War of 1812*.

Jacob Farrand was a Loyalist from New York State, and had served as Lieutenant in the Royal Regiment of New York during the Revolutionary War. He came to Upper Canada with his uncle, John Gray, and settled near Cornwall in the Eastern District in 1783. Farrand was connected to the Bethune family through his sons' marriage. He was granted 2,000 acres as his "military lands" in 1798 and a town lot in Cornwall in 1802; by 1798 had purchased an additional 10,050 acres from other Loyalists through 48 different conveyances. Farrand was a practicing lawyer whose name appears in the rolls on the very first meeting of the Law Society of Upper Canada in July, 1797. He had been appointed a clerk in the Court of Common Pleas for the Luneburg District (later the Eastern District) in July, 1788 and his name is found as legal council in various cases between 1790 and 1798 as well as for submitting expense accounts related to his court duties. He was responsible for compiling and maintaining the UEL list for his district, and for preparing and submitting land petitions on behalf of his fellow Loyalists. As a further reward for his services, Farrand was appointed first Land Registrar in Glengarry and Stormont (1795-1803) and for Dundas County (1801-1803). He was succeeded by his son, John Low Farrand, in these posts. Farrand may have had some trading interests as well, since his name is found in 1802 as paying duties on shipments of rum, brandy, wine, sugar, coffee and salt. An early murder near Lake Scugog, that of John Sharp (a trading associate of the Farewell's in Pickering) by an Ojibwa named Ogetonicut has connections with Farrand. The case was to be tried in the Newcastle District by Farrand's cousin, Robert Isaac Dey Gray, with the assistance of John Anderson who had articled under Farrand. In October of 1804, while en route to Newcastle, the ship "Speedy" was lost in a storm on Lake Ontario taking Dey Gray, Anderson and Ogetonicut to the bottom.

William Gee. The Gee family came from Northamptonshire, England. They farmed Lots 6 and 7, Concession 5. The family burial place is at Salem.

Gibson. The Gibson family came to Canada from Ebberston, Yorkshire in 1837, which included William and Sarah (nee Yeoman) Gibson and sons Judson (1832-1910) and Yeoman (b. 1828). On the voyage over the family contracted small pox. They settled in Toronto for a year where William worked as a butcher. Their land, part Lot 7, Concession 6, was bought in April 1838 from James Munger, an earlier settler. Two more children, a son who died in infancy and another daughter, were born on the farm. William himself died in 1847 "suddenly from apoplexy" while his widow lived until 1887. Judson continued to farm this land until his death in 1910. Judson married an Irish girl, Carrie Graham from Mt. Rath, Queens County, while Yeoman married Belinda Hyfield, daughter of their neighbour from across the road and moved to Whitby. The Gibsons are buried at Salem.

John Jones farmed part of Lot 9, Concession 6 and part of Lot 8, Concession 7. These lands were purchased in 1863 from the McMurray estate and in 1878 from the John Little estate.

Patrick Larkin (-1908) came to Canada from Ireland in 1843. He farmed 100 acres, being part of Lot 9, Concession 6 which he sold before his death in 1908. He was an honest and respected figure in the community, and was township tax collector for over 20 years. His wife was Mary O'Leary.

John Little (1789-1854) was born in Ireland and came to Canada in 1826. He was a farmer on 200 acres, part of Lots 6 and 7, Concession 7. He had purchased this land from the Elmsley estate in 1838. He is buried at Salem.

Madill. There was a large family named Madill in Pickering. Benjamin Madill was a native of Ireland who came to Markham in the early 1830s and then settled in Pickering, where he bought 112 acres, part Lot 4, Concession 3 from Abraham Brown in February 1842. This was sold to James McGown in March 1847. James Madill owned 100 acres part Lot 5, Concession 3, which he bought from John McQuay in December 1860 and sold to Isaac Puckrin in April 1887. William Madill lived further north on part Lot 3, Concession 4, and Henry W. Madill bought 31 acres of Lot 4, Concession 4 from John McDonald in 1855. There was a large extended family, Henry having married Phoebe Sharrard the daughter of Elder James Sharrard (1782-1862) and his wife Phoebe (1784-1869). James Sharrard was son of William who came to Manhattan from England around 1760. At the outbreak of the Revolutionary War he joined the Loyal American Regiment; he was in the West Indies before coming to the Eastern Townships and eventually settled in Hastings County where he died in 1823. James Sharrard settled in Markham and Stouffville before coming to Pickering in 1812. "He was a man of considerable prominence in the municipal and religious life of the community...being not only a public spirited citizen but widely known as an effective preacher of the gospel." Sharrard was a member of the "Christian Church." They are buried in the Sharrard Burial Ground in Pickering.

Christopher McAvoy and his wife, Mary Kerr, were married in Carrick-a-duff, County Armagh, Ireland, in 1830 and set out for Canada the same year. They settled in Whitby and then Pickering where they worked for a Quaker family for three years. They eventually purchased part Lot 8, Concession 7 from John Brander, and their son continued to work the farm long after the death of his parents. Christopher McAvoy's parents also came over from Ireland to live with their son. McAvoy and his wife both died in 1888 and are buried at Salem.

Thomas McCann. Thomas McCann Sr. (1801-1878) was born in Ireland. He took up farming on Lot 7, Concession 4 which he bought in December 1856. His son, Thomas Jr. (b. 1841), was a wheel-wright. He sold the farm to Francis J. McCarthy in February 1906.

William McCausland. He was an early settler in Pickering, and had purchased Lot 7 in the Broken Front Range in 1815. It is said that on this farm "there is an old graveyard, the graves being marked by large stones, but no one knows who sleeps beneath" (Wood 1911:266). McCausland owned part of Lot 5 in Broken Front Range 3 through which a part of Carruthers Creek flows, which continued in family ownership until Charles McCausland sold the land to the Crown (for post-war housing purposes?) in October 1946.

Robert McLaren (-1873) settled as a farmer in Pickering on Lot 5, Concession 4. He bought his land in August 1843 from David Palmer. After his death, the land passed to his son, who sold it to Isaac Puckrin in 1878. The land remained in the Puckrin family until 1952.

Thomas McMurray (1806-1884) was a native of Ireland. He was a farmer and purchased part of Lot 9, Concession 6 from the Canada Company in June 1836. The McMurray plot is in Salem.

McQuay. This family were originally from County Fermanagh, Ireland, and came to Upper Canada in 1829 with a widowed mother, four brothers and one sister having endured a 14 week voyage. Their farm, part of Lots 3 and 4, Concession 6, was patented to them in 1856 and remained in the family until 1933. The McQuay family are buried in the cemetery at Erskine.

Ralph Mowbray. Mowbray's father, John, was originally from Ayrshire, Scotland but settled in County Donegal where Ralph was born in 1789. The family first went to live in Brooklyn, New York, but had settled in Pickering by 1833. By 1838 they had saved enough money to be able to purchase their farm from the Elmsley estate, being part of Lot 7, Concession 6. Their nearest neighbour for several years was Samuel Munger. It is said that "the first logging chain and axes, as well as the first supplies, were carried on his back from Little York." This land remained in the family until it was sold in 1907 to Christopher Weatherilt. Mowbray's wife was Catherine Walker. Their son, Ralph Mowbray, was a reeve and warden for Pickering, and was nominated as a Liberal candidate for parliament. The family is buried in Salem.

George O'Leary (1796-1881) was a native of Ireland who came to Upper Canada in 1831. His wife, Mary O'Connor (1808-1879) arrived in 1835. O'Leary farmed until 1874 when he sold his land to Richard Squire and "retired" to Pickering Village. They had a family of eight children. Both were buried at Salem.

Powell. The Powell family settled in Pickering on Lot 6 in the Broken Front Concession Ranges 2 and 3 which James Powell, a settler from New Brunswick, purchased in October 1808. His sons, Caleb and Henry (1785-1870) continued to farm on this lot in addition to making purchases of adjoining lands from the 1830s through the 1860s. Part of their land in Broken Front Range 3 was sold in March 1858 to the trustees of School Section #1. A portion of their farm was sold in 1911, and the remainder was conveyed away in 1923.

Isaac Puckrin (1825-1902) and his wife, Ann Brignall (1825-1895), were natives of Winteringham, Yorkshire, and settled initially in Scarborough. They came to Pickering in 1843 where they settled on Lot 7, Concession 4. Puckrin purchased other farms (part of Lot 6, Concession 4) between March 1863 and April 1887. These lands remained in the family until 1931 and one parcel even as late as 1952. The family consisted of seven children. The family is buried in the Salem churchyard.

Thomas Redman. Redman was born in Yorkshire, England. He took up farming on Lot 5, Concession 5 which he bought from the Sadler family in 1888. Redman died in 1888 and was buried at Salem.

David L. Reed. Reed purchased 75 acres, part Lot 6, Broken Front Concession Range 3, from Henry Powell in November 1865 as well as an additional 24½ acres in September 1867 which he sold to William S. Gold in September 1885. Reed was the principle land owner around the village of Kinsale, having acquired over 450 acres in Concessions 5 and 6, as well as other scattered holdings in the township.

J. Remmer. Remmer farmed approximately 120 acres on Lots 4 & 5 in the Broken Front Concession Range 3, as well as part Lot 5, Concession 1 which he acquired in 1854 and 1862.

Joshua Richardson. Richardson was a Quaker from Queen's County, Ireland, who settled on Lot 3 in the Broken Front Range Concession 3 around 1820. The family acquired extensive land holdings (over 1,000 acres) during the 1840s and 1850s in the Broken Front Concessions 2 and 3 as well as in Concession 1. This area is now known as Richardson Point, part of the land has been subdivided (Pickering Beach) while east of Shoal Point Road and south of Ashbury Boulevard is Conservation Authority lands. Small parks also dot the former Richardson lands such as Paradise Park, Ajax Waterfront Park, Kinsmen Park, Clover Ridge Park and Southwood Park. Joshua Richardson served in a number of municipal offices including pathmaster and as commissioner of the Court of Requests. In October 1847 Richardson took in an Irish boy, Michael Kelly, from the Widow's and Orphans' Asylum in Toronto, perhaps as a farm hand. Due to circumstances not recorded, Kelly ran away and, by the closing of the Asylum in 1848, was left unaccounted for. Richardson left a large number of descendants.

Sadler. The Sadler family, consisting of two brothers and two sisters, came to Canada in 1833 from Stockton-on-Tees, Yorkshire. They bought part Lot 5, Concession 5 from the Canada Company in August 1833 which remained in the family until 1932 when it was sold to Fred Draper. One of the sisters, Elizabeth, married John Adamson. The family is buried at Salem.

Richard Squire. Squire was born in England in 1829 and came to Canada where he took up farming. He purchased part Lot 6, Concession 4 from George O'Leary in 1874. This land remained in the Squire family until 1945 when it was sold to James Mitchell.

Vail. The Vail (or Vale) family were early settlers on part of Lot 4, Concession 1. Two unusual land transactions took place on this land. In April 1821 David William Smith sold the lot to Elizabeth Hulett for £462.11.0. In July 1833 she conveyed 50 acres of this land to Phoebe Vail for £80. Such conveyances could not take place (i.e. a woman could not hold land in her own right) unless she was an unmarried woman or a widow. Phoebe continued to farm this land until her death in June 1879. Under the terms of her will, her eldest son Ira Vail inherited the farm and a second son, Elansing Vail, received $300. An unmarried daughter, Charity Vail, was well provided for. She was allowed the household goods, effects and furniture as well as a cow. She was to have the use of the front room in the house, the south bedroom, part of the cellar and chamber, and provided with cut firewood, 12 bushels of potatoes, one fat hog, flour, ¼ acre of garden, the privilege to pick her choice of fruit and $60 cash (will #1297 [1880], film GS 2-132). The land remained in the Vail family until it was sold by Canada Life in 1917 to Edward Shirley. Thereafter it passed through a number of subsequent owners: William Kemp (1917), Ernest and Alice Crocker (1917), His Majesty the King (1920), and Charles, Marja Theresa and Sigmund Ziejewski (1932-1952).

Duffins and Carruthers Watersheds

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TORONTO AND REGION Conservation for The Living City

Carruthers Creek

State of the Watershed Report

Greenspace, Trails and Recreation

Greenspace, Trails and Recreation

June 2002

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Introduction to Greenspace, Trails and Recreation

In 1999, Environment Canada released The Importance of Nature to Canadians: Survey Highlights. This summary of a 1996 survey of 87,000 people tells us that Canadians commit large amounts of their leisure time to activities that depend on natural areas and wildlife. As stewards of these valuable natural assets, Canadians are responsible for managing them to allow sustainable use. This "management" requires an understanding of the state of the natural environment, the threats to its sustainability, and an appreciation of the ways in which people make use of these natural assets.

This chapter will explore the greenspace and recreational lands within the watershed and the ways in which people currently make use of these lands.

Carruthers Marsh

The Toronto and Region Conservation Authority (TRCA) Land Holdings

Since 1957, TRCA programs have provided the basis of an interregional greenspace system and have conserved and enhanced the renewable natural resources of the Conservation Authority's watersheds in the Greater Toronto Area.

Lands owned by the TRCA within the Carruthers Creek watershed (totalling to 25 hectares) are located around the Carruthers Marsh at the mouth of Carruthers Creek and are predominantly for conservation and recreation purposes. The following sections briefly describe TRCA owned or managed lands, other publicly-owned greenspaces, and privately-owned lands within the Carruthers Creek watershed and their current uses.

Ajax Waterfront

In 1970, the TRCA was designated as the implementing agency for the Waterfront Plan for all sectors in which it had jurisdiction, except for the central harbour area, including the Town of Ajax waterfront. TRCA, in conjunction with the Town of Ajax and the Region of Durham, prepared a Master Plan for the lands from Duffins Creek to, and including, Carruthers Creek. This plan provides for the protection of the two marsh areas, trail development, habitat regeneration, parking and washroom facilities, and an interpretive centre and marina.

In May of 1995, the Town of Ajax released the strategic Waterfront Management Plan that identified long term goals, objectives and a vision for the waterfront including Rotary Park. The primary goal of this plan is to ensure that the

Carruthers Marsh

waterfront lands are appropriately used in ways that reflect the values of the community, while preserving and protecting the waterfront from overuse or over-development. The plan is based on ecosystem principles that assume the waterfront and its surroundings are a complex system of many interrelated elements. The Ajax Waterfront Management Plan also provides specific direction for modifying the Master Plan and its implementation through subsequent multi-year projects.

Municipal Lands

Local municipalities provide parks, recreation, and cultural facilities and programs through the mandates of their Departments of Parks and Recreation and/or Culture. Each municipality develops a parks and recreation master plan which guides development for parks, open space, recreation and culture. These documents also provide inventory information and coordinate recreation service delivery.

Deer Creek Golf Course

Other Lands that Provide Outdoor Recreation

In addition to lands traditionally considered as public greenspace, public golf courses, schools, utility corridors and other lands may be used by the public for passive recreational activities.

Golf Courses

Two golf courses are currently located within the Carruthers Creek watershed, Deer Creek in the Town of Ajax, and Hawthorne Valley Golf Course in the City of Pickering.

Recreational Fishing

Recreational fisheries are intrinsic to what Canada offers its citizens and visitors. Protecting these fisheries and their habitat, promoting responsible use of the resource, and maintaining and developing angling opportunities makes sense for us and for future generations. This statement provides a starting point for governments and the private sector to work together to conserve and develop these fisheries.

From: Recreational Fisheries Conference, 1986, Federal Fisheries and Oceans as cited in the Durham Region Sports Fishing Study, 1989.

In 1999, Environment Canada released The Importance of Nature to Canadians: Survey Highlights. This summary of a 1996 survey of 87,000 people tells us that in 1996 an estimated 4.2 million Canadians fished for recreation in Canada. In comparison with the population in

Kids Fishing

general, recreational fishing was more popular among men than women. Fishing was also more popular among rural Canadians than among urban Canadians. Participation was more concentrated among those younger than 45 years of age than among the older age groups. The survey also revealed that Ontario residents spent an estimated $4,283 million on various nature related activities in Ontario including wildlife viewing and recreational fishing.

A variety of lake fish, including white and yellow perch, bass and carp, can be found at different times of the year in Carruthers Creek, although fishing opportunities are mainly restricted to the lower portions of the watershed, in and near the Carruthers Marsh. See the Aquatic Habitat and Species chapter for a complete summary of recreational fish found in the Carruthers Creek watershed.

The Ministry of Natural Resources (MNR) publishes a summary of the regulations that govern fishing in Ontario, called the Ontario Sport Fishing Regulations, which can be obtained free of charge at any office of the MNR. Vital information regarding size, catch and possession limits, licences, fish sanctuaries and open seasons are found in this booklet. For consumption purposes, refer to the Ministry of the Environment's Guide to Eating Freshwater Fish.

Trails

There are a number of existing and proposed trail systems that connect the natural, cultural, heritage, recreational, and educational features in the Carruthers Creek watershed with one another and with other destinations outside of the watershed. This comprehensive trail system has been outlined in the Town of Ajax's A Bicycle and Leisure Trail System Plan (2001), and complements the Town's Vision 2020 planning for the developed and urbanizing areas. The plan calls for a hierarchy of trails in varying sizes in order for cyclists and pedestrians to have a diverse system of trails, which can also be used as pathways to reach destinations around the Ajax area, such as conservation areas, the waterfront and other points of interest. Linked to this is a suggested program of education and stewardship along with building strength in trail user groups and fundraising to realize the goals of the trail system.

The Ajax trails will also connect with other municipal trails as alternate commuting routes and are intended to link with regional and provincial trail systems. The cornerstone of this plan will be the waterfront trail that follows the Lake Ontario shoreline. While the focus is on developing and maintaining trails in natural areas, some will be linked with sections in urban areas. The study also recommends that Ajax roads should be made as user friendly to cyclists as possible.

The Vision 2020 – A Bicycle and Leisure Trail System Plan for the Town of Ajax described the Carruthers Creek Trail as follows:

The lower portion of the Carruthers Creek valley with its provincially significant wetland areas, comprised of Warblers Swamp and Carruthers Creek Forest and Marsh is one area where public

Great Blue Heron

accessibility is an issue. The wetland complex is noted for its lakeshore marsh, mixed deciduous forest swamps, and significance for waterfowl staging and breeding and migratory bird stopover. Concern has been expressed by local residents and in environmental studies over the introduction of trails through the area, due to disruption to wildlife habitat. The heronry, located on the north side of Warblers Swamp, has been identified as a particularly sensitive area. The A3 Environmental Study undertaken in 1997 identified several alignments for the Carruthers Creek Trail, without incursions into the significant wetland. These include the use of buffers and Shoal Point Road.

The regional sewer easement that runs within the valley provides an opportunity to cross from the east to the west side, in the vicinity of the pumping station.

Buffers have been designated between the provincially significant wetland and new residential areas of a sufficient width to support trails development. Experience in other municipalities has shown that when residential areas back directly onto natural environment areas or open space buffers, there are frequent encroachments, such as extension of mown lawns, vegetable gardens, private gates, dumping of yard waste and litter, and random trail development. With no formal access, the municipality lacks the ability to easily monitor these zones, and degradation of the adjacent natural areas may occur.

Trails development within the open space setbacks should be combined with revegetation and naturalization programs to create barrier plantings, augment the ecology of the natural areas, and buffer neighbouring residential properties. Trail development and buffer planting should take place at the same time as the residential development, or be clearly identified as future initiatives to forestall future complaints over privacy issues.

North of the 401, the Carruthers Creek system has fewer environmentally significant areas, and could more readily support a continuous valley trail system. However, safe crossing of the 401 and several arterial roads will require major retrofitting of existing structures and would be tied to road reconstruction activities. Interim rerouting to new collector road intersections will be necessary. Trails development should focus on the sectors where residential areas are proposed adjacent to the valley system, and be tied to community development.

Summary

Publicly-owned lands are distributed throughout the Carruthers Creek watershed, and have the potential for becoming connected greenspaces. These future connections, or linkages, will improve the health of the environment for wildlife, as well as provide much needed recreational opportunities for residents.

Due to the rural nature of the northern two-thirds of this watershed, perhaps the most enjoyable recreational activities involve cycling or driving to scenic vistas and catching glimpses of domesticated and wild animals, birds, and plants. The natural environs take on special character, from the headwaters, to the Lake Iroquois shoreline, and downstream to the marsh. The creek and its aquatic life also show differing characteristics through these landforms. Pockets of human habitation are also scattered throughout, which contain beautiful historic buildings and cemeteries, reminding us of an earlier time. There are many opportunities for both passive and active recreation within the Carruthers Creek watershed.

References

Environment Canada, 1999. *The Importance of Nature to Canadians: Survey Highlights.*

Regional Municipality of Durham, 1989. *Durham Region Sports Fishing Study.*

Town of Ajax, 2001. *A Bicycle and Leisure Trail System Plan for The Town of Ajax: Final Report*. Prepared by SRM Associates, February 2001.

Waterfront Regeneration Trust, 1995. *Lake Ontario Greenway Strategy: Next Steps*. Toronto: Hambly and Woolley, Inc.

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Carruthers Creek

State of the Watershed Report

Land Use and Policy Framework

Land Use and Policy Frameworks

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Introduction to Land Use and Policy Framework

Watershed planning has been recognized by all levels of government as an "effective means of evaluating and developing water-related resource management strategies and practices" (MOEE, 1993). The development of watershed management strategies provides context and recommendations for natural systems protection, restoration, environmental education, recreation, and cultural and heritage planning activities. Yet a large part of implementing watershed management plans and strategies depends on how well the vision and goals can be reflected in the existing land use planning process. To do this, adequate linkages must be established between the direction provided by watershed strategies and the development of land use planning policies and practices. For this reason, it is important to understand what land use patterns exist in the Carruthers Creek watershed and how current land use planning policies and practices can be expected to affect conditions in the watershed. This chapter briefly describes the land use planning process and the tools available to effect change in the watershed. It also describes the predominant land use conditions in the Carruthers Creek watershed and the expected changes in land use.

Land Use Planning in Ontario

In the Province of Ontario, the federal, provincial and municipal governments are all involved in land use planning. The federal government generally has limited involvement with municipal land use planning, their main role being the highest level of government and having legislative authority. The province's direction for land use planning is expressed in the *Planning Act* and in the "Provincial Policy Statements." Under the *Planning Act*, the province sets out a land use planning process providing a distinct framework for the development of environmental, social and economic goals and objectives for municipalities. The key planning documents in the municipal land use planning process are the Official Plan, zoning and special by-laws, plans of subdivision, site plans and associated studies and agreements (Figure 1). Through the planning process, unresolved issues can be appealed to the Ontario Municipal Board (OMB) or Divisional Courts.

The public can become involved in many aspects of the planning process in Ontario. When the province is revising policies (like the Provincial Policy Statement Review in 2001) or introducing new planning policies (like Smart Growth), the public is often asked to give input, so that public opinion can be taken into account. Likewise, at the regional and local level, municipalities often ask for public input on major policy initiatives, like Official Plan reviews. Public meetings may also be held during the approvals process for planning applications; this gives the public an opportunity to review planning proposals and provide comments.

Federal Government

The federal role in municipal land use planning is generally indirect, however, as the highest level of government in Canada, federal legislation supercedes all other levels of government. Additionally, the federal government is not bound by the policies in provincial and municipal plans. At the federal level, ownership of land and control of transportation and telecommunications may have the greatest impact on municipal land use planning. Furthermore, federal legislation may impact land use planning decisions, such as development proposals involving fish habitat that will have to satisfy regulations under the Fisheries Act.

Provincial Government

The provincial role in land use planning is governed indirectly through various pieces of provincial legislation, and directly through the *Planning Act*, the establishment of municipal governments, ownership of land, and control over utility corridors and public highways. The *Planning Act* is the primary piece of legislation governing land use planning in Ontario. The Planning Act sets out the policies by which a municipality must implement land use planning decisions. The Provincial Policy Statement (PPS) articulates provincial policies set out under the *Planning Act* which impacts land use planning. In Ontario, other legislation reflecting environmental considerations (e.g., *Environmental Assessment Act*, *Lakes and Rivers Improvement Act*, *Conservation Authorities Act*, *Drainage Act*, *Public Lands Act*, *Aggregate Resources Act*, and *Environmental Protection Act*) may be applicable for specific land use planning situations.

The Provincial Policy Statement provides policy direction for land use planning and development on matters of provincial interest. Section 3 of the Planning Act requires that land use planning decisions "shall have regard to" policy statements issued under the Act. The Provincial Policy Statement also recognizes the need for planning decisions to integrate environmental, social and economic factors. A healthy economy and managed growth of communities, wise use and protection of resources, and the long-term health and safety of Ontario's population are the key components of the Provincial Policy

Official Plan

The Official Plan is one of a series of policies, guidelines and regulations that directs the actions of a municipality and shapes growth and development. The central activity in land use planning is the development of an Official Plan to guide future development. The plan is prepared by municipal planning staff through consultation with citizens and other public agencies, and then approved by the local council, planning board or municipal planning authority. Once an Official Plan is in effect, it guides all of the municipality's planning decisions ranging from when and how the community will grow, to the location of new housing, industry, offices and shops, and the provision of services like roads, watermains, sewers, parks and schools. An approved Official Plan must be reviewed every five years to determine whether the plan needs to be changed in accordance with the provisions of the Planning Act. Official Plan amendment applications may be initiated by the municipality to accommodate recent changes in the community or at the request of a property owner. Official Plans can also include policies setting out what types of consultation is required with residents or agencies for different types of planning applications.

In the Carruthers Creek watershed (as with most of southern Ontario), Official Plans are developed by both the upper tier municipalities (county or regional municipality) and lower tier (or local) municipalities. The upper tier Official Plan establishes a regional framework for growth and development. The regional plan allows for the coordination and management of resources on a broader scale while outlining provincial interests and allocating resources among member municipalities. Lower tier Official Plans must conform to the broad strategic framework of the regional plan, these local plans are able to address community needs at a more detailed level.

Official Plan policies can specify when studies are required in the case where there may be potential for harm to the natural environment. These studies are often circulated to relevant public and private agencies for review and comment.

Zoning By-law

A zoning by-law implements the objectives and policies of an Official Plan by specifying land use zones and standards that are legally enforceable. Within each zone, the by-law states the permitted uses (e.g. residential or commercial) and the required performance standards (e.g. building heights, coverage and setbacks). A development proposal must comply with the zoning by-law and other regulatory requirements before it can obtain a municipal building permit.

Special By-law

A number of specialized by-laws may be used to control land use under unique and often temporary circumstances (e.g. holding by-laws, interim control by-laws, temporary use by-laws and increased height and density by-laws). There are also regulatory by-laws that deal with the protection and management of specific natural heritage features and resources in the community (e.g. tree by-laws, ravine by-laws, topsoil preservation by-laws, sediment and erosion control by-laws, fill and grading by-laws, etc.).

Figure 1

Tools Involved in the Planning Process in Ontario.
Continues on page 5.

Land Severance and Plan of Subdivision

A subdivision refers to a piece of land divided (land severance) into two or more parcels for the purpose of selling each distinct parcel as an individual lot. To subdivide land, approval of a plan of subdivision is required from the Minister of Municipal Affairs and Housing or a municipality that has been delegated approval powers. The plan of subdivision is a legal document that shows the surveyed boundaries and dimensions of lots to be developed, the location and dimensions of streets, and sites for future schools, parks, and other amenities. A proposed subdivision must conform to the Official Plan and local zoning by-laws of the regional and local municipalities, as well as applicable federal and provincial legislation. Municipalities can also set conditions on development to ensure significant environmental features are protected.

Site Plan

If a property is covered by a local site plan control by-law, a site plan must be submitted to the municipality for review and approval before any building permits can be issued. A municipality will establish areas where site plan control will be applied to complement and refine local zoning. Site plan control enables planners to ensure adequate provision on the property (e.g. access, drainage, landscaping, etc.) and to ensure the quality and appearance of new developments.

Note: Any of the above mentioned planning tools can be appealed by landowners and concerned agencies to the Ontario Municipal Board where technical evidence and policies are reviewed by the Board members. The Ontario Municipal Board is the final authority on planning matters in Ontario.

Figure 1: ***Continued from Page 4***
Tools Involved in the Planning Process in Ontario.

Statement. Three main policy areas cover these key components: 1) Efficient, Cost-effective Development and Land Use Patterns (including developing strong communities, housing, and infrastructure); 2) Resources (including agriculture, mineral resources, natural heritage, water quality and quantity, and cultural heritage and archaeological resources); and 3) Public Health and Safety (including natural hazards and human-made hazards).

Key provincial interests under natural heritage policies included designation of Areas of Natural and Scientific Interest (ANSI) and Provincially Significant Wetlands (PSW). ANSIs are areas identified by the Ontario Ministry of Natural Resources that have significant natural heritage, scientific study or educational values requiring protection. There are two types of ANSIs: Life Science (for the protection of provincially or regionally significant ecological features) and Earth Science (for the protection of significant geological features). Provincially Significant Wetlands are wetlands that have been evaluated by the Ontario Ministry of Natural Resources and protected for their biological, hydrological, social and/or special features.

Regional Municipalities

The provincial government established Regional Municipalities as upper tier municipal corporations. Regional Municipalities generally set out a regional level of strategic land use policies to guide economic, environmental and community-building decisions for a larger context. This allows for the implementation of planning and servicing initiatives on a regional scale, based on directions given in the Provincial Policy Statement. Regional Municipalities are the Approval Authority for some types of planning approvals for lower tier municipalities. Accordingly, local municipal

Official Plans must conform to regional Official Plans. Regional Official Plans set the stage for the more detailed land use policies found in local municipal Official Plans. The Durham Region Official Plan (1993, Office Consolidation 2001) is referenced in this chapter.

Local or Area Municipalities

Local municipal Official Plans contain policies for the specified area relating to land use planning and development control. The Official Plan examines growth management within the municipality while having regard for the larger context. Many municipal Official Plans include Secondary Plans or Neighbourhood Plans, which are detailed policy documents governing specific areas within a municipality. Municipal Official Plans also identify, in detail, natural areas such as valley and stream corridors, and set policies for the protection of significant natural features from development. Zoning by-laws implement Official Plan policies and are used to establish land use permissions and restrictions and development standards. Local and regional municipalities may also implement special municipal by-laws, such as interim control by-laws or tree by-laws to address land use under unique conditions or local environmental concerns (Table 1). Such by-laws are important to watershed management for a number of reasons: 1) they prohibit and regulate activities that might have a detrimental effect on natural resources; 2) they increase public awareness and education; 3) they impose legally enforceable standards by which to manage natural resources and provide the potential to be a strong deterrent; and 4) they provide a localized base from which to address specific environmental and/or risk management issues. Local municipal Official Plans referenced in this chapter include the Town of Ajax (2000), and the City of Pickering (2000).

Municipal Planning Process

Municipalities are able to direct land use planning to minimize the impact of development and improve the natural heritage system through policies in their Official Plans. As a commenting agency under the Planning Act, the Toronto and Region Conservation Authority (TRCA) provides technical comments on Official Plans as they pertain to the TRCA's Valley and Stream Corridor Management Program. The goal of this program is to identify valley and stream corridors, and then protect these corridors under appropriate designations, such as open space. The TRCA will also comment on the types of land uses that will be allowed in valley and stream corridors.

Applications for development are generally submitted to either the regional or area municipalities for approval. Official Plan policies often detail what types of environmental and other studies may be required to support an application, such as an Environmental Impact Statement, stormwater management or hydrogeological studies, etc., and what agencies should be prorated with the studies and application. Conservation Authorities, including the TRCA, review the various applications and their associated studies to ensure that certain interests are adequately addressed and then provide their comments and conditions to the approval authority. Some of these concerns include hazard issues such as slope stability, erosion of valley systems and flooding and environmental protection issues such as fish and fish habitat, environmentally sensitive areas and wetlands. Development proposals may be subject to conditions of approval or agreements may be required by the various commenting agencies in order for the municipality to approve a development proposal. These conditions may require further studies, continued monitoring or changes to the proposed development to ensure that any environmental impacts are mitigated, and in some cases, that a net environmental benefit is realized.

Table 1: Special Municipal By-Laws

TYPE OF SPECIAL MUNICIPAL BY-LAW	MUNICIPALITIES THAT HAVE ENACTED THE BY-LAW
Tree By-laws - To protect or conserve trees and/or woodlots in a municipality by restricting and regulating the injuring or destruction of trees by cutting, burning or other means.	Regional Municipality of Durham Town of Ajax
Erosion & Sediment Control By-law - Similar to the above, though emphasis is placed on controlling detrimental effects by employing suitable methods of erosion and sediment control.	Town of Ajax City of Pickering *

* The City of Pickering will be enacting Special Municipal By-laws early in 2002.

Every five years, municipal governments in Ontario are required to hold a public meeting to consider whether a review of Official Plan policies is needed; a review is intended to guide future growth over time. During this process, amendments made since the last approval of the Official Plan are incorporated and opportunities for the public to identify issues and suggest changes are provided. Some area municipalities also develop Secondary Plans to develop policies to guide growth on a more localized basis. Secondary Plans enable a municipality to plan and coordinate land use, transportation and servicing for specific communities within their jurisdiction. The more detailed Secondary Plans are implemented through Official Plan amendments and are also included in Official Plans. Since most Official Plans and Secondary Plans now address environmental concerns, these two processes provide an ideal opportunity for watershed strategy recommendations to be incorporated into municipal policies and regulations. The Region of Durham is currently undergoing an Official Plan review, while the City of Pickering and the Town of Ajax recently completed revisions to their Official Plans.

Watershed Planning

Watershed planning applies the ecosystem approach to land use planning within the boundaries of a watershed. This approach is appropriate for many reasons: water continuously moves through watersheds and influences biotic and abiotic features; change in one section of the watershed may impact other areas of the watershed; and the movement of water does not stop at political boundaries. Watershed planning involves the identification of natural features and functions, the assessment of interactions of natural processes within broader boundaries, and of the interactions between those natural processes and man-made social and economic demands. A watershed plan usually contains targets, goals and objectives for the protection of natural system core areas, linkages and functions, water resource management, enhancement or rehabilitation of natural features, determining areas suitable for development, establishing Best Management Practices (BMP) for subdivision design, and management practices for open space areas and green space corridors. Watershed plans may also outline directions for stormwater management plans (or other detailed plans) for specific areas within a watershed. Additionally, watershed plans can promote the environmental benefits of limiting urban sprawl by focusing development in specific areas of the watershed. Planning recommendations contained in watershed plans should be incorporated into municipal Official Plans through an Official Plan amendment.

Current Regional Planning Framework

Regional Municipality of Durham

The Durham Region Official Plan (DROP, 1993) provides a framework for growth and development within Durham Region. Land use structure within the regional Official Plan consists of the following main areas: Urban Areas, Rural Settlement Areas, Agricultural Areas, and an Open Space System. Also included in the regional structure are Regional Nodes, a Transportation System and Resource Extraction Areas. Durham Region is currently undergoing its first comprehensive Official Plan review since 1991. This review is focusing on six policy areas: population and employment growth, urban land requirements, commercial structure, environment/open space, rural/agriculture, and transportation.

Although present land use within the Carruthers Creek watershed is primarily rural, the Durham Region Official Plan designates approximately 1/3 of the land as urban areas. Urban areas have been designated as the primary areas for future growth, and are generally comprised of residential, commercial/office and industrial uses. Lands south of Taunton Road and West of Audley Road are designated for urban use. Rural settlement areas in the Durham Official Plan consist of hamlets, country residential subdivisions, residential clusters and rural employment areas. The hamlet of Kinsale is located within the Carruthers Creek watershed. In the Durham Region Official Plan, large areas in the northern portion of the Carruthers Creek watershed are designated Permanent Agricultural Reserve. Agriculture and farm-related uses dominate these areas. This designation protects large tracks of land for food production.

A major Open Space System in Durham Region has been established to provide a continuous system of open space throughout the region, protecting environmental areas, such as watercourses. In Durham Region, the main natural features located in the Carruthers Creek watershed are environmentally sensitive areas (ESA), valley systems, and the Lake Ontario waterfront. Permitted uses under the major open space designation include agriculture and recreation. Golf courses are permitted through an Official Plan Amendment subject to certain criteria. The open space system provides north-south linkages towards Lake Ontario, as well as east-west linkages. Significant forests and woodlots are identified as part of Durham Region's environment and open space system and are present in the northern portion of the Carruthers Creek watershed. It is the intent of the Official Plan to direct new settlement areas or intensive land use changes away from these features and to work with area municipalities, Conservation Authorities and other agencies to manage the forests and woodlots. For the most part, woodlands in the Carruthers Creek watershed are managed for multi-use purposes. This means that various activities, such as conservation, passive recreation, and reasonable levels of wood production, may occur in the same woodlot.

Under the Durham Region Official Plan, no aggregate extraction sites are located within this watershed. However, small areas in the central portion of the Carruthers Creek watershed are shown as having high potential for aggregate resources and are protected for long term possible use. The Durham Region Official Plan supports a transportation network that promotes efficient movement of people, goods and services, while balancing the need between the private automobile and alternative modes of transportation (e.g., public transit, cycling, walking, etc.). The Transportation System consists mainly of public transit and a road system. The regional and local municipalities require servicing plans to be prepared and approved for all major developments. These plans help ensure that smaller, individual applications are consistent with the region/town/city's overall servicing strategies. For example, long-term improvements, expansions and additions to water supply and sanitary sewage systems must meet the area's population and employment targets. In turn, councils may limit the type and intensity of proposed development if the provision of municipal services and utilities would result in undue financial and/or environmental hardship.

Durham Region supports a servicing plan which gives priority to the provision of municipal services within urban areas and for developments that support a compact form of development; the design and construction of municipal services will be provided in a cost-efficient manner; and negative impacts on the natural, built and cultural environments will be minimized.

Current Land Use

The Carruthers Creek watershed is located within the Regional Municipality of Durham, and two local Area Municipalities, the City of Pickering and the Town of Ajax. Land use in the Carruthers Creek watershed is largely divided between urban and rural uses, with agricultural practices dominating the northern landscape, and urban uses located to the south. An increasing population in this area has led towards expanding residential development, especially in rural areas adjacent to the Town of Ajax. Figure 2 illustrates the existing/approved land uses in the Carruthers Creek watershed as it is outlined in the Durham Region Official Plan. The following is a detailed description of land use in the Carruthers Creek watershed.

The Carruthers Creek watershed can be separated into three physiographic units: the south slope section of the watershed, Lake Iroquois shoreline and the Lake Iroquois plain. The till plain (south slope) in the north has undulating terrain where agricultural practices dominate the landscape (Chapman and Putnam, 1984). Many drumlins are found further south, in the central portion of Durham. These drumlins are long and thin, and point upslope (Chapman and Putnam, 1984).

The Carruthers Creek watershed has experienced some urban growth in recent years. Still a predominately rural landscape, farming practices have declined, giving way to urban uses. The northern portion of the watershed remains rural and agricultural, while the southern portion is urbanizing. Until 1940, general farming practices were common in the southern portion of the watershed. These lands are considered to be some of the best farming lands in Ontario, in part due to the moderation of the climate by Lake Ontario. However, since the 1940s, agricultural practices in this area have decreased, and much of the land has been urbanized. Portions of the land in this area are within the urban boundaries of the Town of Ajax. Additionally, many rural subdivisions and rural non-farm residences are located in this area.

Headwaters

The headwater streams of the Carruthers Creek are protected under Pickering's Natural Areas designation as part of the Open Space System. The Natural Areas designation permits uses such as conservation, environmental protection, restoration, education, and passive recreation. Agricultural uses are also allowed outside of valley and stream corridors, wetlands, environmentally significant areas and Areas of Natural and Scientific Interest (ANSI). Surrounding these natural areas, land use is almost entirely designated for agricultural practices. Agricultural policies in the area municipal Official Plans further support agricultural objectives stated in the regional Official Plan, by generally recognizing lands containing classes 1-4 soils (as defined by the Canada Land Inventory Soil Capability for Agriculture) for long-term protection, and/or only permitting agricultural uses in accordance with the Agricultural Code of Practice. Additionally, the most northern lands in this area are contained within a larger area that is under a Provincial Order to restrict development adjacent to the Pickering Airport Lands to the west. Although lands within this portion of the watershed are not currently slated for development, there have been a number of Regional Official

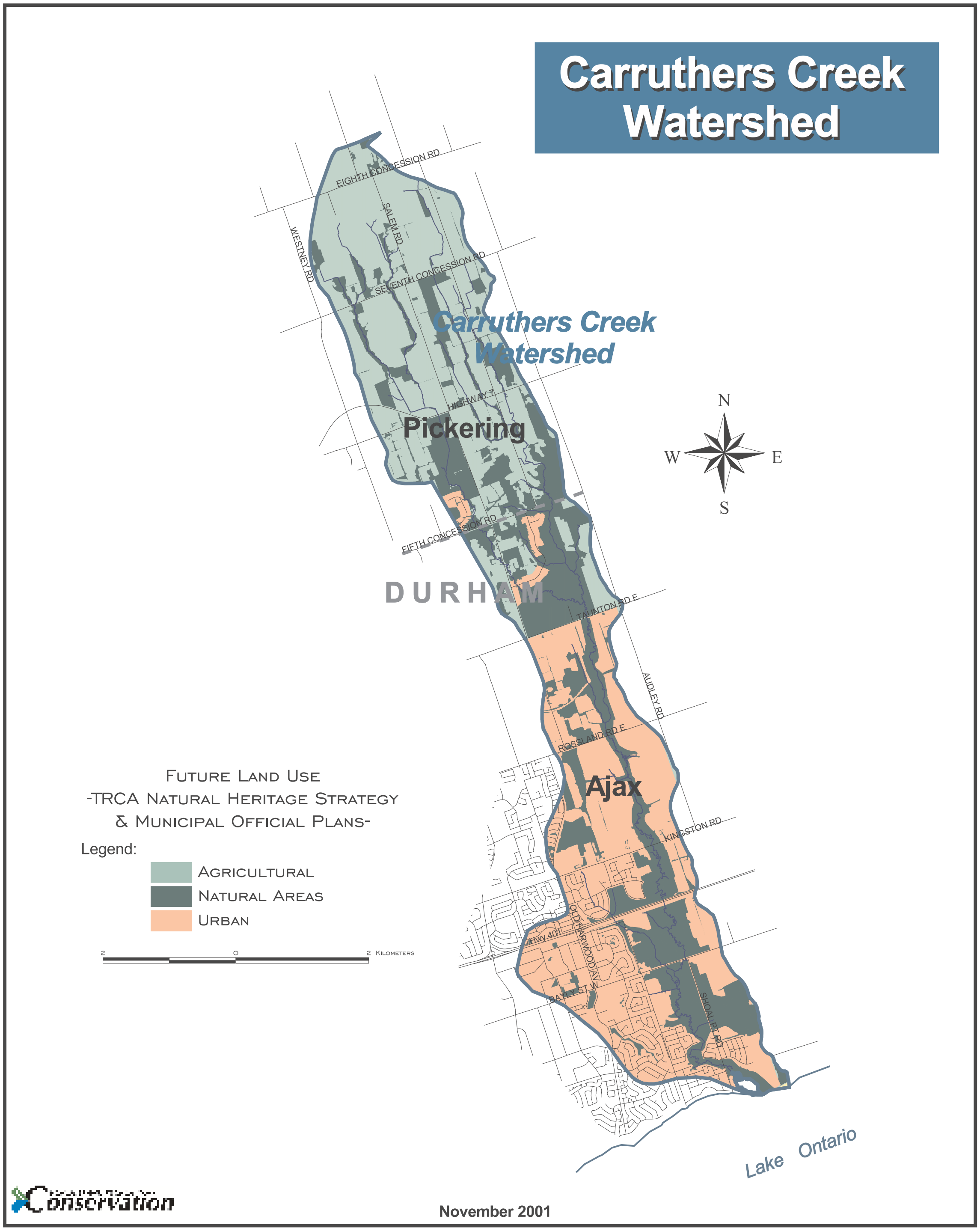

Figure 2:

Future Land Uses in the Carruthers Creek Watershed as Designated in Municipal Official Plans.

Plan Amendments to allow some development close to the northern boundaries of the watershed. Although other uses such as golf courses or community facilities may be permitted on agricultural lands, the Official Plan policies generally protect agricultural operations from conflicting land uses by directing residential, commercial and industrial growth to designated urban areas.

Middle Reaches

Land use in the middle reaches of the watershed (north of Taunton Road) is primarily rural, with agricultural practices being the dominant land use. Here, tributaries of the Carruthers Creek are surrounded by large natural areas including a wetland, agricultural areas, and the former Lake Iroquois shoreline. Under the Pickering Official Plan, stream and valley lands are protected by the Natural Areas designation; to the south in the Town of Ajax, these areas are protected under the Environmental Protection designation (EPA), and contain Environmentally Sensitive Areas (ESA), as identified by the TRCA, that are to be preserved and maintained. These lands are protected under an EPA designation to preserve those areas that are environmentally significant or are sensitive to some forms of development for biological and ecological reasons. Also this designation is used to protect human life and reduce the potential for property damage by controlling development on lands that are physically unsuitable or hazardous for development.

Several country residential developments (e.g., Birchwood Estates and Forest Creek Estates) and hamlets (e.g., Kinsale) are found in this portion of the watershed. Land use in these areas allows for small settlements of less than 500 people while maintaining the rural character of the landscape. The rural area between Taunton Road and 5th Concession was set aside by the Town of Ajax in order to establish a permanent countryside dominated by open fields, forests, and a functional natural system. However, there is a large block of subdivision applications proposed adjacent to the south side of 5th Concession; the boundary of these proposals appears to encompass several tributary branches of Carruthers Creek. Additionally, an active recreational area, the Ajax Sportsplex, is located in the central portion of the watershed.

From Taunton Road, south to Kingston Road, most of the land is either vacant and/or used for agricultural purposes. To the east, lands are designated for rural uses. While these lands will remain rural, further west and north to Taunton Road, lands are designated for residential and employment uses to accommodate future urban expansion. Future urban development is planned for these lands in the form of a large mixed commercial corridor, prestige and general employment areas and mostly low density residential areas. Additionally, small areas for high and medium density residential use have been set aside along the arterial roadways and by the CPR tracks; these areas also happen to be directly adjacent to the valley and stream corridor. In addition to the valleyland system, there are a few Provincially Significant Wetlands in this portion of the watershed either directly adjacent to the valley or connected through a linkage with other supporting natural areas and woodlands.

The Carruthers Creek continues to be protected under an environmental protection designation, and is surrounded by protected wetlands, woodlands and other supporting natural areas. Immediately adjacent to these natural features are residential developments (low, medium and high), as well as areas set aside for future urban growth. Commercial developments, employment areas and residential developments will be part of the future urban growth designated for this part of the watershed. Major transportation routes, such as Highway 401 and the CNR tracks, cross this portion of the watershed halfway between Bayly Street and Kingston Road. The Town of Ajax, in consultation with the region and province, is currently widening Highway 401, with new interchanges at Carruthers Creek Parkway and Lake Ridge Road. North of the highway and rail tracks, the wetland system ends and the valley corridor begins to narrow.

Lower Reaches and River Mouth

Towards the mouth of the Carruthers Creek at Lake Ontario, almost the entire valley system surrounding the creek incorporates Provincially Significant Wetlands (the Carruthers Creek Wetland Complex) and other significant natural features. Portions of these areas have been designated as Areas of Natural and Scientific Interest and Environmentally Significant Areas (ESA) by the province and Conservation Authority, respectively. ESAs are defined as land or water areas that contain distinctive or unusual features, perform a key ecological function and/or provide habitat for significant plant and/or animal species.

Located on the shore of Lake Ontario is the Carruthers Creek Marsh ESA. This marsh is approximately 38 hectares in size and is home to diverse biological communities, including mammals, fish, migratory birds, and rare bird and plant species. Environmental features in this section are classified under the open space and environmental protection designations, both of which are considered part of the Regional Greenlands Framework. Adjacent to the valley system, land use is almost exclusively designated low density residential with small tracts of medium and high density residential zones north of the shoreline. Lands closest to the waterfront have already been developed, with several new proposals underway for the remaining lands.

Table 2: Municipal Population Projections

	1996	2021
Pickering	81,400	145,000*
Ajax	66,500	120,000*

* refers to targets for urban areas only.

Proposed/Future Development

Anticipated Growth

It is expected that municipalities within the Carruthers Creek watershed will experience increasing pressure to urbanize within the designated urban boundaries in coming years (Table 2). Population growth is expected to continue for the next 25 years as indicated by population projections in Durham. Durham Region's population increased by more than 40 per cent between 1986 and 1996 to nearly 460,000 people and is anticipated to reach 1 million by the year 2021. The Durham Region Official Plan states that an overall target will be to accommodate approximately 20 per cent of all new population growth through intensification within existing urban areas. Another significant target set by Durham is to match population growth with an adequate increase in employment opportunities. As a result, the region is requesting the federal and provincial government improve accessibility to employment areas and increase employment opportunities by providing additional interchanges along freeways, widening and extending 400-series highways, supporting the expansion of transit, and locating higher education facilities and government offices in the region.

Transportation

The Region of Durham is preparing a Transportation Master Plan to guide the future transportation programs and investments in the region. Results of the plan will include the identification of new and improved facilities needed to serve future growth, strategies to encourage the use of non-auto modes of travel and ways to make the best use of existing transportation services. Several future transportation projects that affect the Carruthers Creek Watershed are contained within the Durham Region Official Plan, including highway improvements (Highway 401 widening and new 401 interchanges at Carruthers Creek Drive and Lake Ridge Road, and the expansion of Highway 407 eastward); arterial road improvements (5th Concession/14th Avenue connection, Taunton Road expansion, Clements Road extension and other arterial road improvements); and transit improvements (existing GO Train service along the Lakeshore East line and future services along the CP Belleville line, public transit right-of-ways on major arterial roads and freeways including Highway 407, and improved inter-municipal and inter-regional transit services).

Pressure on Resource Use

The landscape of the Ajax portion of the Carruthers Creek watershed is changing from predominantly rural and agricultural to a more urbanized area, thus increasing residential, commercial and industrial land uses. Pressures on the watershed are expected to increase with the increasing pressure for urban development and growth. As more urban areas are established, groundwater resources may be affected. These effects may be related to providing adequate water supply to urban areas, and/or changes to groundwater recharge and discharge capabilities. Relatively small potential sites for aggregate extraction have been identified in the middle reaches of the Carruthers Creek watershed. These areas, currently designated as open space, are protected and may be considered for future aggregate extraction to provide the necessary materials for urban development. Additionally, many of the lands zoned for future urban development are currently being used for agricultural purposes. The development of these lands not only means a loss of agricultural production, but a potential loss of environmental functions that these lands serve. For example, there may be a decrease in stormwater infiltration and an increase in runoff, leading to less recharge of groundwater aquifers and increased erosion and sedimentation of streams.

Conclusion: A Comprehensive Watershed Strategy

Land use in the Carruthers Creek watershed is changing rapidly in many areas, from a predominantly rural landscape to suburban or country residential communities with pockets of commercial and employment nodes. Based on current development activity and population and employment projections, effects on the environment, infrastructure/servicing, and resources are expected to continue with the increasing pressure for growth and development. These pressures brought together the regional and two municipal governments in the Carruthers Creek watershed in support of developing a watershed strategy. Various levels of government with interests in the Carruthers Creek watershed, must work together to ensure that their land use planning policies and practices are consistent with one another and that they are working towards the same goals.

As outlined in this chapter, there are tools available in the land use planning process which can be used to improve and/or maintain present conditions in the watershed. The key will be to recognize where these growth pressures are what natural features and functions should be protected, and to develop a consistent and balanced approach to controlling future development and its impacts. A healthy, functioning natural system contributes so much to the quality of life in neighbourhoods and communities. Developing a feasible watershed management strategy that can be implemented through the land use planning process will provide further opportunity for governments, agencies, and citizens of the Carruthers Creek watershed to protect and rehabilitate their environmental heritage for generations to come.

Acknowledgements

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References

Chapman, L.J. and Putnum, D.F., 1984. *The Physiography of Southern Ontario*. Third Edition. Ontario Geological Survey, Special Volume 2. Ministry of Natural Resources. Toronto, Canada.

City of Pickering, 2000. *Official Plan*. Office Consolidation. www.city.pickering.on.ca

Ontario Ministry of Environment and Energy (MOEE), 1993. *Subwatershed Planning*. Queen's Printer for Ontario. Ontario, Canada.

Regional Municipality of Durham (DROP), 2001. *Official Plan*. Office Consolidation. www.region.durham.on.ca

Town of Ajax, 2000. *Official Plan*. Office Consolidation. www.town.ajax.on.ca

Duffins and Carruthers Watersheds

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Duffins Creek and Carruthers Creek

State of the Watershed Reports

Air Quality

Air Quality

June 2002

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Tables and Figures

Introduction to Air Quality

Air quality is affected by local, regional and global factors. It represents the cumulative effect of contaminants in the atmosphere from both human and natural activity, and from their atmospheric interactions. The state of ambient air quality in the Duffins and Carruthers watersheds can be understood by examining the following:

- What are the current air quality conditions? Is air quality getting better or worse? What effect do the conditions have on life in the watershed?

- What are the factors that influence air quality?

Air quality data from Ontario's Ministry of the Environment's (MOE) air monitoring stations in and around the Duffins Creek and Carruthers Creek watersheds provide a basis for this assessment. The Stouffville station (No. 48002) is located on Highway 47 just east of Highway 48. The Scarborough (No. 33003) and Oshawa (No. 45025) stations are to the east and west of the watershed. Although this assessment focuses on these local stations, the atmospheric region of influence or "airshed" for the area extends far beyond the watersheds. High levels of pollutants are known to originate from neighbouring US states southwest of the Duffins and Carruthers watersheds.

Data from the ministry's air quality monitoring network in 1997 and 1998 were considered to represent "current conditions"(MOE, 2001). The contaminants evaluated include ground-level ozone (O_3), suspended particles (SP), nitrogen oxides (NOx), sulphur dioxide (SO_2), carbon monoxide (CO) and volatile organic compounds (VOC). The sources and effects of these pollutants are summarized in Table 1. This assessment of air quality also includes information on the Air Quality Index (AQI) which is based on groups of pollutants that have adverse effects on human health and the environment. Trends over time were evaluated using data for the most recent 10-year period (1988 - 1997).

Current Conditions

The Duffins Creek and Carruthers Creek watersheds have good air quality conditions the majority of the time, as illustrated by the distribution of Air Quality Index (AQI) scores for the Oshawa and Scarborough monitoring sites (Figure 1). In 1998, air quality was good to very good (AQI 0-31) 94 per cent of the time. Less than one per cent of the time air quality was in the poor or very poor range. A full description of the pollutants used in the calculation of the AQI and their impact for various index scores is provided in Table 2.

The distribution of AQI scores in the good to very good range for Oshawa and Scarborough is similar to those throughout Ontario. For example, in 1998 downtown Hamilton also had good to very good air quality 94 per cent of the time, while a site in downtown Toronto (York) had good to very good air quality 93 per cent of the time. In London, Ontario, this dropped slightly to 90 per cent of the time. An examination of the number of days the AQI was in the poor range (50-99) for various sites across Ontario in 1998 reveals that Oshawa and Scarborough are in approximately the middle ranges of the distribution, with 9 and 15 days, respectively. This was due exclusively to high levels of ground-level ozone, about half of which was attributed to local sources and half to long range transport from upwind sources in neighbouring US states. In comparison, sites in Windsor, London, the Hamilton escarpment, downtown Hamilton, downtown Toronto and Ottawa had 31, 26, 14, 7, 6, and 1 days in the poor range, respectively. No sites in Ontario had any hours with an AQI in the very poor range (100+) in 1998.

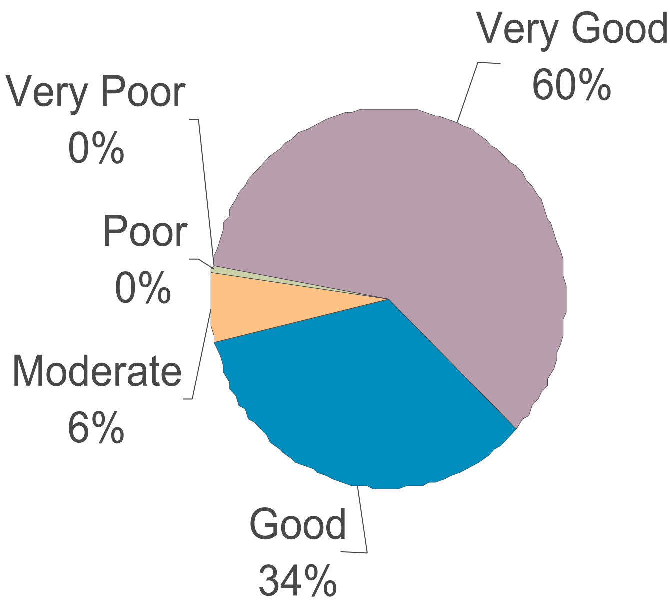

Figure 1

Duffins Creek and Carruthers Creek Watersheds, 1998 Air Quality Index

Note: Percentages represent an average of the Oshawa and Scarborough monitoring stations.

Ozone (O_3)

In all instances across the province, elevated ground-level ozone levels are by far the primary cause of air quality advisories. For instance, ground-level ozone was responsible 100 and 99 per cent of the time in 1998 and 1997, respectively, when AQI scores exceeded 31 in Oshawa. Across the GTA, 99 per cent of AQI above 31 were due to ground-level ozone in 1998. Across Ontario, this relationship was 97 per cent. Ground-level ozone is the main ingredient in smog, and together with suspended particulates form the yellowish-brown cloud hanging over cities on summer days. Ground-level ozone is different from the ozone layer above the earth that protects us from the sun's harmful UV rays.

Unlike other air pollutants, ground-level ozone is not emitted directly to the atmosphere. It is a secondary pollutant formed when nitrogen oxides react with volatile organic compounds (a class of volatile compounds containing at least one carbon atom, such as hydrocarbons) in the presence of sunlight. The sources of these pollutants, discussed in detail in subsequent sections, are derived both from local sources, in particular the transportation sector, as well as

Table 1: Principal Air Quality Contaminants – Sources and Effects

Pollutant	Characteristics	Sources	Ontario Criteria	General Health Effects	General Ecological Effects
Ozone (O3)	A colourless gas with a strong smell. Major component of summer smog.	Ozone is not emitted directly into the atmosphere. It is produced by photochemical action on nitrogen oxides and volatile organic compounds.	1 h average 80 ppb	Irritation of the lungs and difficulty in breathing. Exposure to high concentrations can result in chest tightness, coughing and wheezing.	Damage to agricultural crops, ornamentals, forest and natural vegetation.
Volatile Organic Compounds (VOC)	A chemically diverse group of volatile compounds with at least one carbon atom. Major source of ground level ozone.	Iron and steel production, vehicles, household paints, lawnmowers, solvents and motor fuels.	n/a	Some VOCs are known carcinogens and several others are strongly suspected of being carcinogenic.	Some VOCs contribute to the destruction of stratospheric ozone.
Total Suspended Particles (TSP)	Particles of solid or liquid matter suspended in air in the form of dust, mist, aerosols, smoke, fume, soot, etc. Size range 0.1-100 microns.	Industrial processes including combustion, incineration, construction, metal smelting, etc. Also motor vehicle exhaust and road dust. Natural sources such as forest fires, ocean spray and volcanic activity.	24 h average 120 pg/m3 1 y average 60 pg/m3	The smaller the particle the greater the effect on health. Significant effects for people with lung disease, asthma and bronchitis. See PM10 below.	Damage to vegetation, deterioration in visibility and contamination of soil.
Inhalable Particles (PM 10)	Same as TSP except size range of particles is less than 10 microns.	Same as TSP.	24 h average 50 pg/m3	Increased hospital admissions and premature deaths.	Same as Total Suspended Particulate
Total Reduced Sulphur (TRS)	Offensive odours similar to rotten eggs or cabbage.	Industrial sources include steel industry, pulp and paper mills and refineries. Natural sources.	1 h average 27 ppb (kraft pulp mill)	Not normally considered a health hazard. They are the primary cause of odours.	
Sulphur Dioxide (SO2)	Colourless gas with a strong odour similar to burnt matches.	Electric utilities and nonferrous smelters. Also, primary metal processing, iron ore smelters, pulp and paper, petroleum refineries, etc.	1 h average 250 ppb 24 h average 100 ppb 1 y average 20 ppb	Breathing discomfort, respiratory illness, aggravation of existing respiratory and cardiovascular disease. People with asthma, chronic lung or heart disease are most sensitive to SO2.	Leads to acid deposition, which causes lake acidification, corrosion and haze. Damage to tree leaves and crops.
Nitrogen Dioxide (NO2)	Gas with a pungent and irritating odour.	Automobiles, thermal power plants, incineration, etc. Natural sources include lightning and soil bacteria.	1 h average 200 ppb	Increasing sensitivity for people with asthma and bronchitis.	Leads to acid deposition; adverse effect on vegetation.
Carbon Monoxide (CO)	Colourless, odourless, tasteless and poisonous gas.	Major source is transportation sector (ie. road vehicles, aircraft and railways).	1 h average 30 ppm 8 h average 13 ppm	Impairment of visual perception, work capacity, learning ability and performance of complex tasks.	

Adapted from "Air Quality in Ontario, 1998", Ministry of the Environment.
ppb = parts per billion • n/a = not available • pg/m3 = picogram per cubic metre • h = hour
ppm = parts per million • API = Air Pollution Index • y = yearly

distant sources in the US. Approximately half of the ozone in Ontario is estimated to come from US sources through long-range transport.

Ground-level ozone affects the body's respiratory system and causes inflammation of the airways that can persist for up to 18 hours after exposure ends. Breathing difficulties can result, particularly for people with asthma or other respiratory difficulties. Although the provincial criteria for ozone suggests health effects are not evident unless levels exceed the 1 hour average of 80 parts per billion, a recent Canadian study has concluded that there is no safe level of human exposure to ground-level ozone (Environment Canada, 2001).

Ozone levels tend to be lower in urban areas when compared to rural areas. Urban areas generate pollutants which chemically react with ozone, thus initially destroying some of it. An examination of smog days across 37 Ontario monitoring sites illustrates this point. Seven of the top ten sites across Ontario with the highest number of smog days in 1998 are rural. The rural Stouffville site ranks 9th, while the urban sites of Scarborough, Oshawa and downtown Toronto rank 14, 25, and 29 out of 37, respectively.

Suspended Particulate

Another critical air pollutant is suspended particulate. Particulate matter or suspended particles is the general term used for a mixture of solid particles and liquid droplets found in air which come in a wide range of sizes and originate from many different stationary and mobile sources, as well as from natural sources. They may be emitted directly from a source or formed in the atmosphere by the transformation of gaseous emissions.

Suspended particles are considered a critical air pollutant due to its human health effects. Along with ground-level ozone, it is the second main component of smog and can cause serious breathing difficulties. Suspended particles of

Table 2: Air Quality Index Pollutants and Their Impact

Index	Category	Carbon Monoxide (CO)	Nitrogen Dioxide (NO_2)	Ozone (O_3)	Sulphur Dioxide (SO_2)	Suspended Particles (SP)	SO_2 + SP (As measured by the API)	Total Reduced Sulphur (TRS)
0 - 15	Very Good	No known harmful effects	No odour; no known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects
16 - 31	Good	No known harmful effects	Slight odour	No known harmful effects	Damages some vegetation in combination with ozone	No known harmful effects	No known harmful effects	Slight odour
32 - 49	Moderate	Blood chemistry changes, but no noticeable impairment	Odour	Respiratory irritation in sensitive people during vigorous exercise; people with heart/lung disorders at some risk; damages very sensitive plants	Damages some vegetation	Some decrease in visibility	Damages vegetation; (ie. tomatoes, white beans due to sulphur dioxide)	Odour
50 - 99	Poor	Increased symptoms in smokers with heart disease	Air smells and looks brown; some increase in bronchial reactivity in people with asthma	Sensitive people may experience irritation when breathing and possible lung damage when physically active; people with heart/ lung disorders at greater risk; damage to some plants	Odorous; increasing vegetation damage	Decreased visibility; soiling evident	Increased symptoms for people with chronic lung disease	Strong odour
100 or over	Very Poor	Increasing symptoms in non-smokers with heart disease; blurred vision; some clumsiness	Increasing sensitivity for people with asthma and bronchitis	Serious respiratory effects, even during light physical activity; people with heart/ lung disorders at high risk; more vegetation damage	Increasing sensitivity for people with asthma and bronchitis	Severe odour; some people may experience nausea and headaches	Significant effects for people with asthma and bronchitis	Severe odour; some people may experience nausea and headaches

critical significance for human health are those which are inhalable (diameter <10 microns) and respirable (diameter < 2.5 microns). All respirable and inhalable particles can penetrate into the lung. The smaller the particle, the further it can penetrate, causing a more serious effect on people's health. In 1998, suspended particulate levels in Oshawa and Scarborough were such that they were not the cause of any Air Quality Index scores above 31. About half of Ontario air monitoring stations had a small fraction (1-3 per cent) of AQI scores above 31 due to high suspended particulate levels.

The major sources of fine particles are combustion processes, with diesel combustion being very significant. Inhalable particulates originate in part as direct emissions from industrial stacks, vehicles, wood-burning fireplaces and wind-blown dust from roads, construction sites and agricultural areas. Another significant fraction is generated by chemical reactions in the atmosphere which result in the formation of sulphates, nitrates or organic compounds. Respirable particulates are emitted directly into the air by combustion sources such as vehicle engines, boilers, power plants and industrial combustion processes. These particles are also formed in the atmosphere by the reaction of gaseous pollutants such as sulphur dioxide to form sulphates, nitrogen oxides to form nitrates, volatile organic compounds to form secondary organic aerosols and ammonia to form ammonium compounds.

Sulphur Dioxide (SO_2)

Sulphur dioxide is a colourless gas that is generated when sulphur-containing fossil fuels or ores are burned or processed. At elevated levels it irritates the human respiratory system. It can be oxidized into sulphate particles, which can lead to further lung irritation (see suspended particulate above) as well as acid rain. Levels of sulphur dioxide in the Duffins Creek and Carruthers Creek watersheds are not a problem and there were no AQI scores above 31 in 1998 where sulphur dioxide was responsible. The iron and steel sector is the major source of SO_2; carbon black manufacturing, and marine and vehicle emissions also contribute to a lesser extent. Major non-industrial area sources of emissions include transportation and residential heating.

Carbon Monoxide (CO)

Carbon monoxide is a colourless, odourless, toxic gas that is primarily a product of the incomplete combustion of fossil fuels. In Ontario, the transportation sector accounts for two-thirds of the emissions. Carbon monoxide enters the blood-stream and reduces the oxygen carrying capacity of the blood. The highest annual average CO levels in Ontario were recorded in major urban centres, including Toronto, Hamilton, Mississauga and Ottawa. There were no AQI scores in Ontario above 31 in 1998 that were attributed to elevated levels of carbon monoxide. There were no instances when carbon monoxide levels exceeded safe outdoor air quality in the Duffins Creek and Carruthers Creek watersheds in 1998. Across Ontario, indoor sources, including cigarette smoke, gas cooking stoves and portable non-electric space heaters are responsible for the major exposure of CO to the population.

Nitrogen Oxides (NOx)

While nitrogen (N_2) makes up approximately 80 per cent of the air we breathe, it changes to the form of nitrogen oxides (NOx) during high-temperature fuel combustion to become one of the most important contributors to air pollution. This is because of the major role of NOx in producing ground-level ozone. It also contributes to acid rain and fine nitrate suspended particles. The principal source of nitrogen oxides (two-thirds) is the combustion of fuel in road traffic. The remaining third comes from power generation, primary metal production and incineration. Small natural sources include lightning and the aerobic activity of soil bacteria.

Ground-level ozone is formed when NOx react with volatile organic compounds (such as hydrocarbons) in the presence of sunlight. Ground-level ozone irritates the respiratory tract and nitrogen dioxide (NO_2) can irritate lungs and lower resistance to respiratory infection. NO_2 chemically transforms into nitric acid, which contributes to lake acidification. The natural geology of the Duffins Creek and Carruthers Creek watersheds is fortunately well buffered and thus protected from acidification effects.

Although there were no AQI above 31 in Ontario in 1998 that were attributed to NO2, the significant role of NOx in the formation of ground-level ozone and that pollutant's overwhelming responsibility for AQI above 31 make nitrogen oxides an indirect, but significant, contributor to poor air quality in Ontario. As with the other pollutants significantly affecting the air quality in the Duffins Creek and Carruthers Creek watersheds, the transportation sector is the largest local source.

Volatile Organic Compounds

Volatile organic compounds (VOCs) are volatile pollutants which exist in the atmosphere, primarily in gaseous form. In the presence of sunlight, many VOCs react with NOx and form ground-level ozone which, as described above, is the greatest cause of outdoor air quality concerns in Ontario. In addition, some VOCs are known human carcinogens (e.g., benzene), and several more are strongly suspected of being carcinogenic. VOCs are therefore both a direct concern to human health due to their role as carcinogens as well as an indirect concern through their role in the formation of ground-level ozone.

VOC levels of benzene, toluene and xylene in 1997 suggest that there are no environmental impacts at the concentrations measured; average concentrations were 1.36, 4.99, and 1.92 micrograms per cubic metre, respectively. Local major VOC sources include the transportation sector, which releases VOCs in vehicle exhaust gases. They are also emitted by the evaporation of solvents and motor fuels, as well as by the textile, steel and coal tar processing industries. Downwind concentrations are elevated compared to their upwind counterparts.

Outdoor and Indoor Air Quality

While the focus of this report is outdoor air quality, indoor air quality levels of some pollutants are responsible for the major air quality effects to human health in the population. Indoor environments with second-hand cigarette smoke, for example, tend to have greater levels of air pollutants, including carbon monoxide, and thus pose a greater risk to human health than outdoor air quality.

Air Quality Trends Over Time

An evaluation of air quality data for a recent 10-year period from stations representative of the Duffins and Carruthers watersheds suggest that levels have remained relatively constant (Figures 2-6). A slight decreasing trend is evident in carbon monoxide concentrations in Oshawa (r-squared = 0.58, p-value of 0.01) and in nitrogen oxide concentrations in Scarborough (r-squared = 58, p-value of 0.01), which is

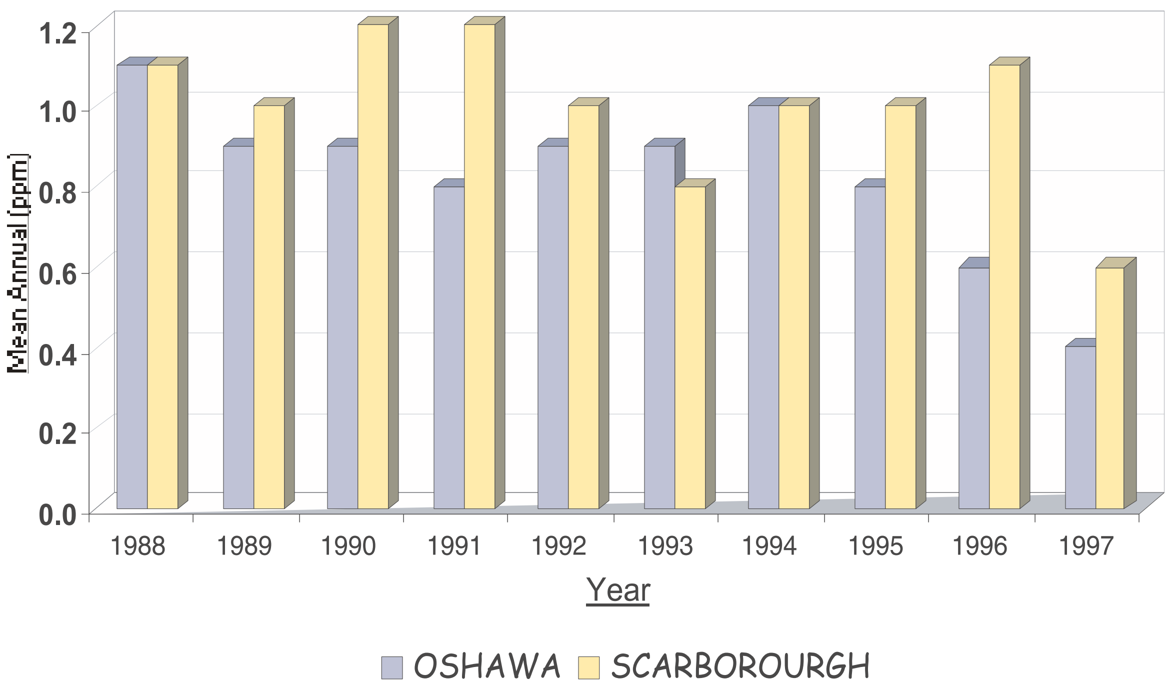

Figure 2

10-Year Trend for Carbon Monoxide in the Duffins and Carruthers Watersheds

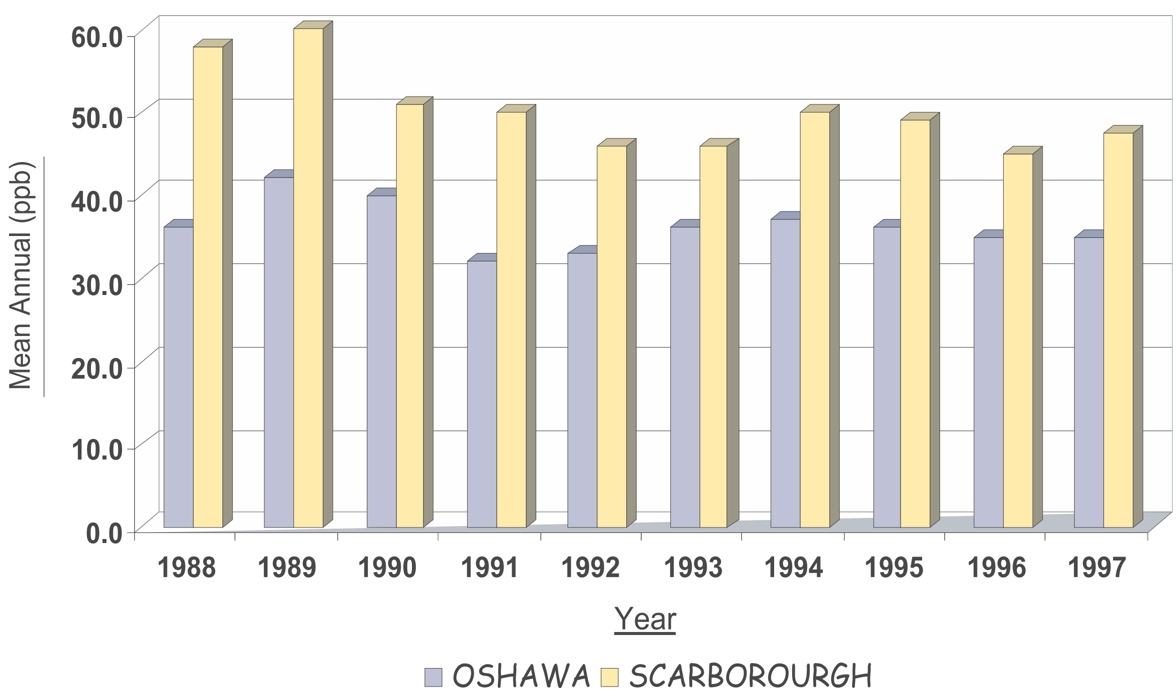

Figure 3

10-Year Trend for Nitrogen Oxide in the Duffins and Carruthers Watersheds consistent with trends observed across Ontario. This is attributed to fleet changes to newer vehicles with more stringent emission standards. Across Ontario, a decreasing trend has also been noted for sulphur dioxide and total reduced sulphur compounds, neither of which had been a problem in the Duffins or Carruthers watersheds due to the absence of their primary source (e.g., smelters and utilities powered by coal; iron and steel mills; petroleum refineries; pulp and paper mills).

No noticeable trend over time in ground-level ozone concentrations is evident in these watersheds. This is because ozone trends are complicated by meteorology and emission changes day to day. Year to year, ozone levels are strongly influenced by weather. For example, elevated ozone levels correlate with the number of "hot" days in a year (those with maximum air temperature greater than 30°C).

Across Ontario VOCs show a decreasing trend for the period 1989 to 1995, after which they have remained fairly constant. Factors affecting the decline include new vehicle emission standards, a shift in the consumption of home heating fuels from oil and wood to natural gas, and the introduction of a lower gasoline volatility in the summer months.

Stricter emission standards from long-range sources, such as industries, have also contributed to the slight decreasing trend in some pollutants over the last ten years. These improvements are expected to be lost soon because of the continuing increase in the most significant local source of many air quality pollutants: private vehicle emissions, including vehicles used within the watersheds and those in upwind regional urban centres.

Given the trend over the last decade in transportation usage on nearby major highways (Figure 7) – the opening of another major highway (Hwy 407), the widening of regional roads, and the collapse of commuter services between Uxbridge, Stouffville and downtown Toronto, air pollution can be expected to increase due to ground-level ozone, suspended particulates,

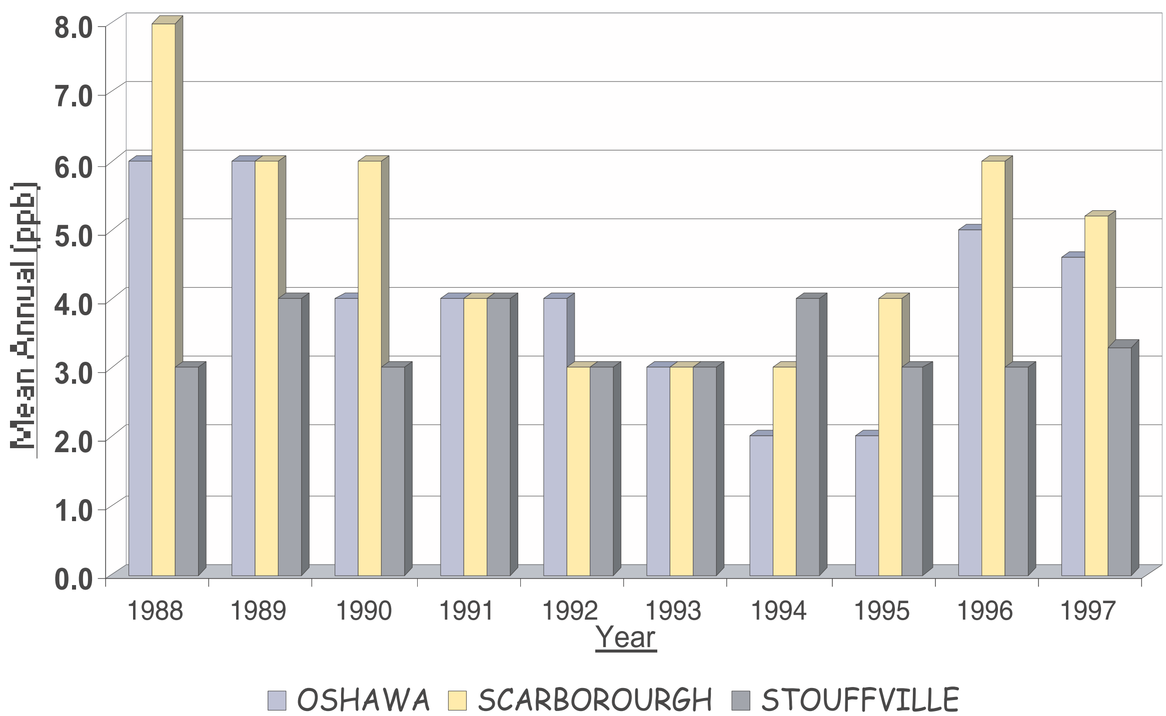

Figure 4
10-Year Trend for Sulphur Dioxide in the Duffins and Carruthers Watersheds

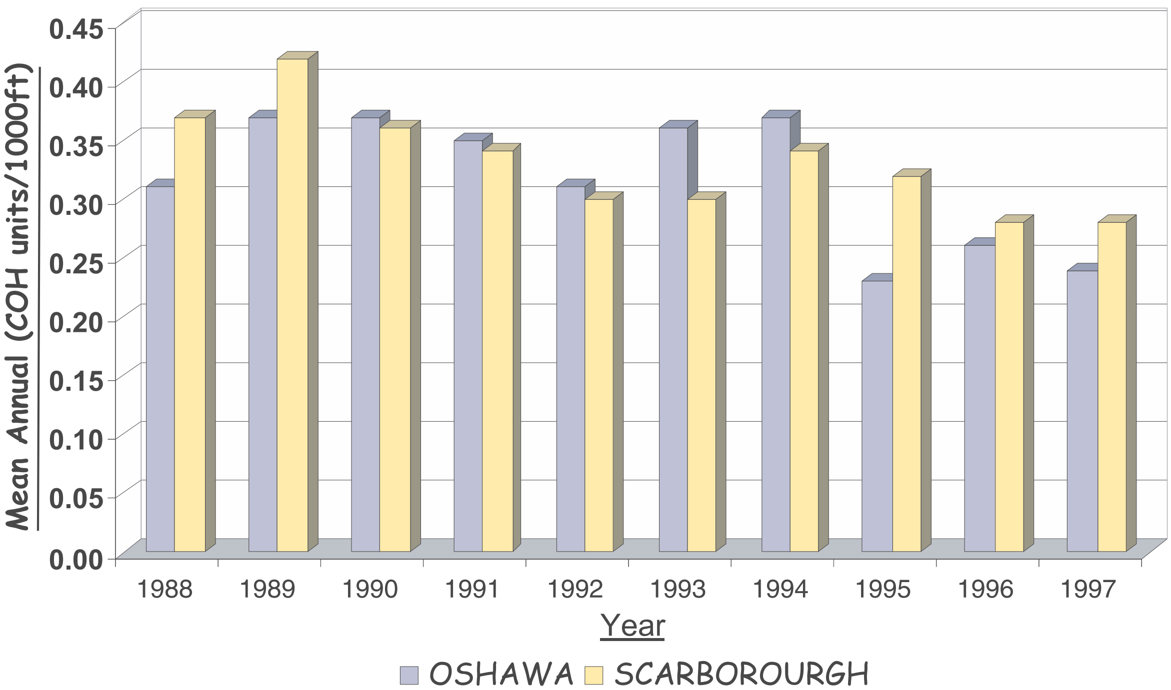

Figure 5

10-Year Trend for Suspended Particulate in the Duffins and Carruthers Watersheds

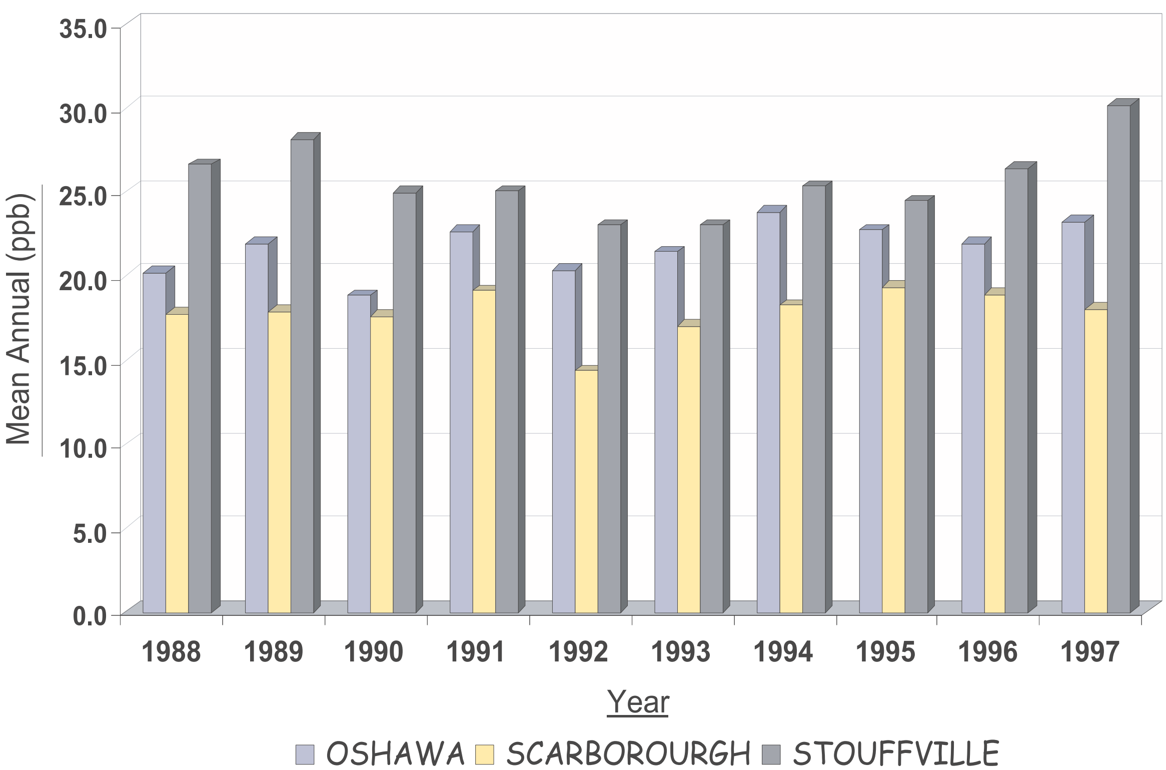

Figure 6

10-Year Trend for Ozone in the Duffins and Carruthers Watersheds nitrogen oxides and carbon monoxide unless additional offsets in vehicle use are realized.

Transport Canada recently announced plans to reopen the former VIA commuter line between Uxbridge and Toronto. Other actions, including an increase in public transportation, are essential in order to offset poor outdoor air quality episodes in the Duffins and Carruthers watersheds.

Factors Affecting Air Quality

Both local and distant sources of pollutants play a significant role in the outdoor air quality of the Duffins and Carruthers watersheds. Table 3 provides a summary of the sources of various air pollutants. Specifically for the Duffins and Carruthers watersheds, however, some sources are more relevant than others. Anthropogenic (i.e. human induced) factors are the principal cause of degraded air quality. Carbon monoxide and sulphur dioxide are exclusively derived from human activities. The most notable source influencing air quality in the Duffins and Carruthers watersheds is the transportation sector.

While source availability of critical pollutants is a key factor in overall air quality, three weather features also affect air quality: wind direction, temperature inversions and on-shore lake breezes. The prevailing winds from the southwest are critical to the long-range transport of pollutants. Distant industry sources upwind of

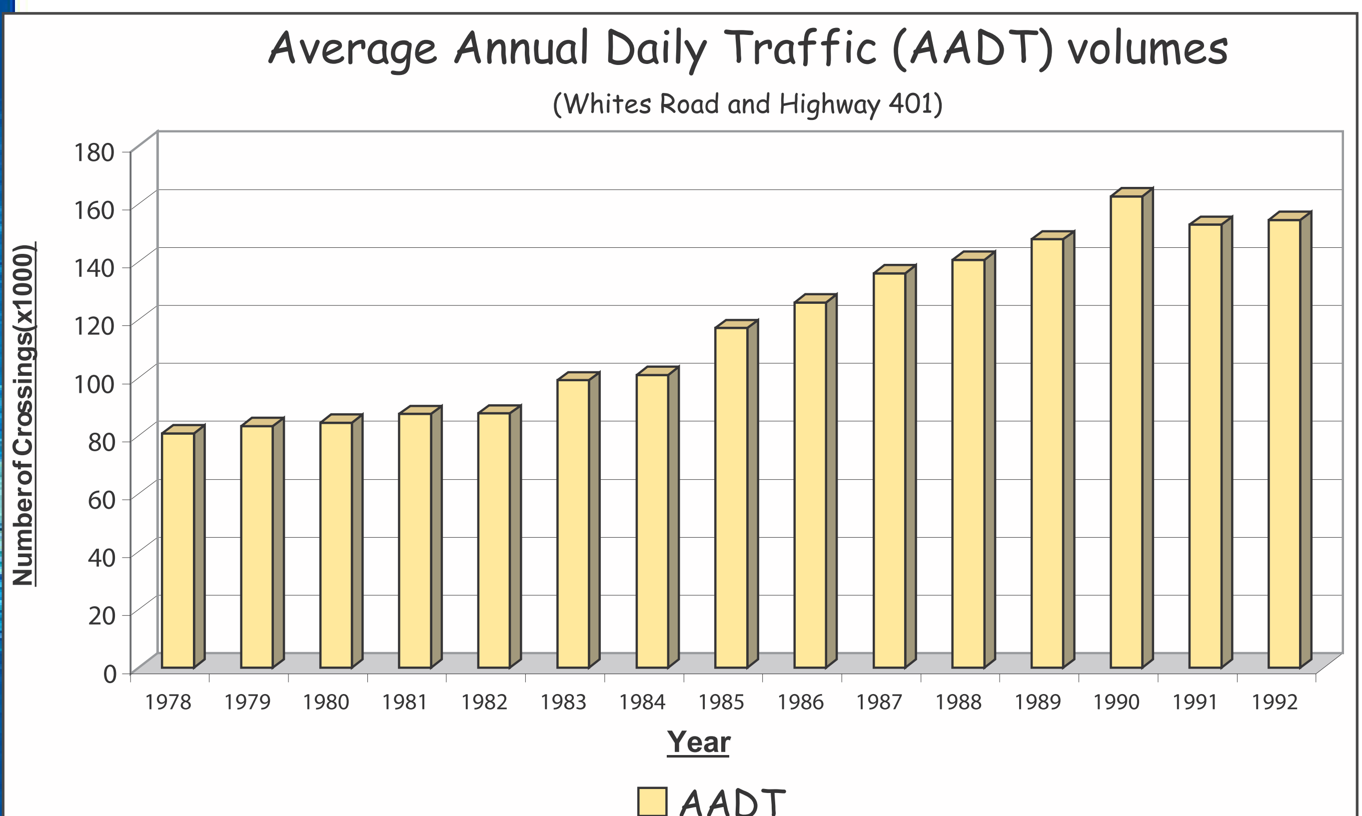

***Figure** 7*

Traffic trends over time in the Duffins Creek watershed

Table 3: Factors Affecting the Production of Air Pollutants

CARBON MONOXIDE • transportation sector (90 per cent) • primary metal production • fuel combustion in space heating and industrial processes	**NITROGEN DIOXIDE** • transportation sector (63 per cent) • power generation • primary metal production • incineration • natural sources include lightning and aerobic activity of soil bacteria	**GROUND-LEVEL OZONE** • secondary pollutant from reaction between nitrogen dioxide, hydrocarbons and sunlight **VOLATILE ORGANIC COMPOUNDS** • vehicle exhaust gases • evaporation of solvents and motor fuels
SUSPENDED PARTICULATE • motor vehicle exhaust • residential wood combustion • road dust • natural sources include windblown soil, forest fires, volcanic activity	**SULPHUR DIOXIDE** • smelters and utilities (i.e. power by coal) • iron and steel mills • petroleum refineries • pulp and paper mills • small sources include residential, commercial and industrial space heating	**TOTAL REDUCED SULPHUR** • steel industry • pulp and paper mills • refineries • sewage treatment facilities • natural sources include swamps, bogs, marshes

the Duffins and Carruthers watersheds in southwest Ontario and the US midwest contribute air quality contaminants that undergo long-range transport and transformation, especially ozone, fine particles and sulphur dioxide, as well as trace metals and toxics.

In addition to wind patterns, temperature inversions which are typical in the spring and fall cause pollutants to become more concentrated resulting in poor air quality episodes. Cool air at the ground level is trapped beneath warmer air higher in the atmosphere. High topographic features like the Oak Ridges Moraine in the north and the Niagara Escarpment to the west can contribute to inversions by trapping the pollutants between the high elevation and Lake Ontario.

On-shore lake breezes can also exacerbate the effect of air quality pollutants. Warm air from urban and industrial areas in the regional airshed rises, which in turn draws in cool air from the lake. The polluted air then moves northeast with prevailing winds to the height of the inversion layer, and then recirculates over Lake Ontario. If the lake breeze still exists, these pollutants can be recirculated over the watersheds once again.

Summary

The data examined for this report showed air quality to be good in the Duffins and Carruthers Creek watersheds, however, this data is five years old. Recent reports in the media and smog advisories issued by the government indicate that conditions are not improving. Health concerns exist particularly for young children and adults with respiratory problems. Among the critical air quality pollutants, small suspended particulates, ground-level ozone, and volatile organic compounds are the three which most severely impact human health. Ground-level ozone is the principal cause of air quality advisories in the region. The transportation sector is the major source of local pollution; distant sources, such as industry in the US midwest, is also a significent source of air pollution. Actions which focus on increasing the number of, and access to, public vehicles as well as train commuter routes to Toronto, will have the greatest impact on maintaining and improving the air quality of the Duffins Creek and Carruthers Creek watersheds.

References

Environment Canada, 2001. *Canada's Transportation Challenge #1: Maintaining a Healthy Environment: A Few Facts about Smog*. www.ec.gc.ca/ecoaction/transp/en/chal1.htm

Environment Work Group, 1997. *Hamilton-Wentworth Air Quality Initiative, Ambient Air Quality and Effects on the Environment in Hamilton-Wentworth.*

McGinlay, J., 1997. *Chemistry of Atmospheric Pollutants.* The National Environmental Technology Centre. ww.aeat.co.uk/netcen/airqual/kinetics/

Ministry of the Environment, 2001. *Air Quality in Ontario, A Concise Report on the State of Air Quality in the Province of Ontario, 1998*. www.ene.gov.on.ca/envision/airquality/1998report.htm

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Duffins Creek and Carruthers Creek

State of the Watershed Report

Climate

Climate

June 2002

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- Introduction
- Study Area
- Human Heritage
- Greenspace, Trails and Recreation
- Land Use
- Air Quality
- Surface Water Quality
- Surface Water Quantity
- Stormwater Management
- Fluvial Geomorphology
- Hydrogeology
- Aquatic Habitat and Species
- Terrestrial Natural Heritage

Cover photographs: The sun burns through the clouds after a late afternoon thunderstorm.

Photo credit: TRCA

Toronto and Region Conservation

Duffins and Carruthers Watersheds

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Introduction to Climate

Situated on the north shore of Lake Ontario, the Duffins and Carruthers watersheds experience a wide range of weather conditions through the course of an average year. Residents of the area have come to expect bitter winter cold and oppressive summer heat. Precipitation includes deep winter snow, heavy spring and summer thunderstorms, and sometimes lengthy summer dry spells. Like all of southern Ontario, the area is influenced by warm, moist air masses from the south and cold, dry air masses from the north. As well, the presence of the Great Lakes has a major influence on the climate of both watersheds.

Meandering Stouffville Creek in winter, just south (downstream) of Stouffville.

Lake Effects

As a result of their small size, there are no major variances in climate across the two watersheds. However, the presence of Lake Ontario does result in some subtle differences. Large bodies of water, such as the Great Lakes, exert a moderating influence on the temperature of the air masses that move across them.

In the summer, areas closest to the lake may experience daytime temperatures that are cooler than they would be otherwise. Although this effect may extend five to 10 kilometres northward from the lake, it is most noticeable within in the first kilometre or so (approximately the area south of Bayly Street). In this area, temperatures may be as much as 10°C lower than in the northern portions of the watershed. This often serves to provide relief from the heat on those days when the temperature is reaching into the 30s elsewhere.

By the autumn months, when colder air starts to spread southward, the lake has warmed considerably. At this time an opposite effect occurs. The water now heats the air passing over it, and as a result night-time low temperatures are not quite as cold as they would be otherwise. The advent of frost may be delayed by as much as a month because of this, allowing for the growth of plant species that could otherwise only be grown at lower latitudes. Near the shore of Lake Ontario the frost-free season is a little over 160 days, about 20 days longer than in Stouffville.

The lake also has an effect on precipitation. Winds associated with the onset of large-scale storms are generally out of the northeast, east, or southeast. When this occurs during the winter, the air flows across 80 to 200 kilometres of open water, picking up additional moisture that in turn falls on the adjacent land areas. If the wind is from the east-southeast, more snow will fall on those areas within 10 or 20 kilometres of the lake. A more southeasterly direction will result in a faster passage of the air across the lake, and thus a smaller amount of extra moisture. However, as the air moves away from the lake and into the northern half of the watershed, it encounters higher ground, where it is forced to rise and to drop its moisture. In this situation it is the northern portion of the watershed that receives the heaviest precipitation.

Temperatures

In general temperatures across the two watersheds are similar to those found elsewhere in southern Ontario. Since the area experiences a moderated continental climate, a wide variety of temperatures have been recorded *(Figure 1)*.

Summer days are characterized by daytime highs that usually reach into the mid- to upper-20s, although most summers also see several days that reach the low or mid 30s. A value of 37°C at Stouffville in 1988 is the highest temperature yet recorded in either basin. As noted previously, close proximity to the lake often results in cooler conditions in the more southerly reaches. Although overnight lows during summer nights are usually in the mid- to upper-teens, during warm spells when humidity values are at their highest the temperature may stay in the low 20s. It is at these times, when there is no night-time relief from the heat, that air conditioning use often reaches its maximum. Close to Lake Ontario an average summer has about five to 10 nights in which the temperature drops below 10°C. Farther away from the warming effects of the lake, that number doubles for the northern portion of the Duffins watershed.

In the winter, daytime highs normally fall just a few degrees short of 0°C, while overnight lows are most often around -10°C. However, winter temperatures tend to be highly variable. An incursion of warm air from the south that pushes a January day up over 10°C can easily be followed by an Arctic air mass and overnight lows below -25°C. Every few years a particularly cold Arctic air mass may even drop the

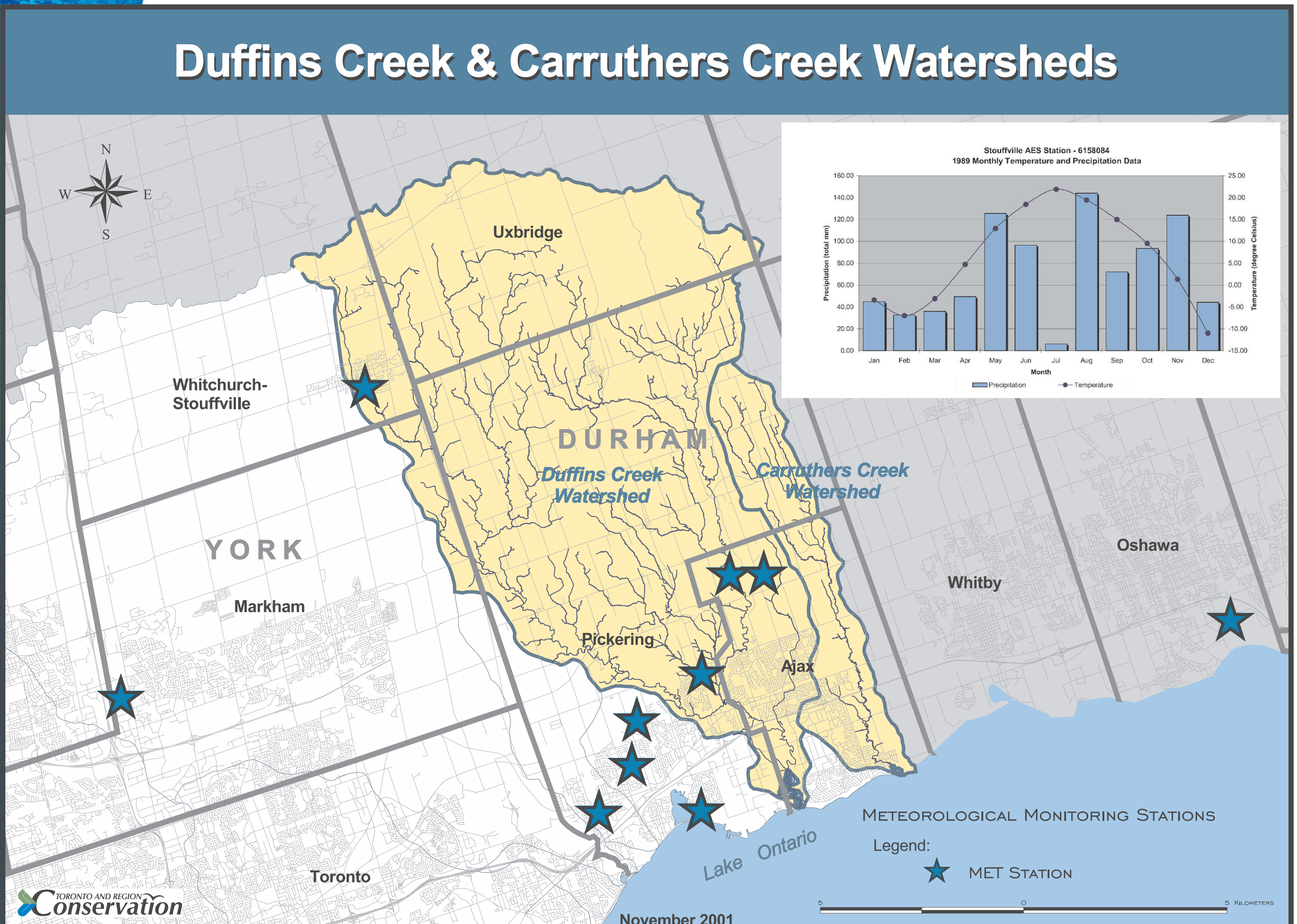

Figure 1:

Locations of Meteorological (MET) Stations in the Vicinity of the Duffins and Carruthers Watersheds. Although many are now retired, all have provided key data regarding daily temperature and precipitation for this region.

temperature below -30°C. The coldest yet recorded is -36°C, at Stouffville in January, 1981.

Precipitation

In an average year, approximately 800 to 850 mm of precipitation falls across the two watersheds. For the most part, there is little significant variation in the monthly normal. Only two months (January and February) average less than 60 mm, and only two (August and September) have more than 80 mm *(Figure 1)*.

Nonetheless, it is important to note the average annual total is not necessarily indicative of the typically expected conditions. Periods of wet or dry weather are not uncommon, and often result in years that have precipitation totals that are significantly different than the normal. Indeed, most years have a few months with precipitation totals of more than 100 mm, and one or two with 25 mm or less. At the observing site at Greenwood, open from 1960 to 1993, one month totals have ranged from a high of 209 mm (August 1986) to a low of 5 mm (March 1962). Annual totals at sites within the two basins have ranged from

640 mm in 1975 to nearly 1100 mm in 1986. At several climatological stations located within 10 kilometres of the Duffins watershed and with longer periods of record, annual amounts of only 550 mm have been recorded numerous times.

Snowfall accounts for about 15 per cent of the annual precipitation total, with the vast majority falling between December and the first half of March. Generally, snow in the two watersheds falls as the result of large-scale weather systems that also produce precipitation over much of the rest of southern Ontario or nearby New York State. Frequently however, these storms are accompanied by easterly or southeasterly winds that contain additional moisture after passing over the relatively warm waters of Lake Ontario. In these situations, the southern portions of the Duffins and Carruthers basins may have a significantly higher snowfall than in the north. At other times, when temperatures are within a degree or two of the freezing mark, the south may receive rain, while the northerly areas, with a higher elevation, record several centimetres of snow. As well, on occasion the tail end of particularly strong snow squalls originating southeast of Georgian Bay may reach into Whitchurch-Stouffville, or even the northern fringes of Pickering. However, snowfalls from these squalls rarely amount to much more than a few centimetres.

In the summer, widespread day-long rainfalls are rare. Instead, showery precipitation is the general rule. This frequently results in rainfall amounts that vary widely from place to place. It is not unusual for one part of a basin to receive 20 mm or more of rain, while locations just a few kilometres away remain dry. In addition, this kind of precipitation may come as short but intense downpours that quickly run off into drains and streams. A thunderstorm that results in 20 or 30 mm of rain in just one hour does little to relieve the moisture deficit that comes with a lengthy period of dry weather.

On occasion the area will receive the effects of the remnants of a tropical storm or hurricane moving through the eastern part of the United States. Occurring during the mid- to late summer or during the autumn, these systems may result in an all-day rainfall that at times can be quite heavy. Precipitation amounts from these systems can also be somewhat variable over relatively short distances. When Hurricane Hazel hit the area in October 1954, 96 mm of rain was recorded at Green River, somewhat less than the 150 mm that fell on areas north of Toronto, but much more than the 25 to 50 mm that fell on the Oshawa-Bowmanville area to the east.

Climate Change

One of the greatest present day environmental concerns is centred on changes to the earth's climate resulting from the addition, by human activity, of significant amounts of carbon dioxide and methane. These gases trap some of the outgoing radiation from the earth's surface, resulting in a warming of the atmosphere. Without this process (known as the "greenhouse effect" because of its similarity to the working of a glass greenhouse), the earth's atmosphere would be as much as 30°C cooler than it is. However, over the past few centuries the quantities of these gases have increased substantially as the result of the burning of carbon-based fuels. Although not universally accepted, there is general agreement within the meteorological and climatological community that this increase has enhanced the greenhouse effect, and has begun to increase the temperature of the atmosphere.

Over the past century, mean temperatures across southern Ontario have increased by approximately 0.5°C. Most of this warming has come about as the result of an increase in overnight lows rather than hotter daytime temperatures. Indeed many of the hot spells of the last decade have not been known for their scorching heat, but rather for their uncomfortably warm night-time temperatures. A commonly heard description is that "it's not getting warmer, it's getting less cold."

Conclusive evidence as to whether these changes are indeed the result of human activities or part of a natural variation is still lacking. Over the past several millennia, temperatures have been far from consistent, with numerous periods that have been either warmer or colder than the present. It is possible that the warming that took place during the twentieth century could be just another one of these periods of aberrant high temperatures. However, these changes are consistent with the effects that are expected to be felt as a result of the presence of enhanced levels of greenhouse gases. It would be an unlikely (though not impossible) coincidence if this rise in temperatures were to be taking place at the same time as the expected warming.

Various computer models have been used to give us some indication of the climate of the next century. Although there are some differences among the models, all of them agree that on a global scale temperatures will rise as the result of greenhouse warming. For southern Ontario, the expected rise is approximately two to five degrees Celsius. The greatest part of this change is expected during the winter months, possibly resulting in a shorter snow season and a longer growing season. Extremely cold winter temperatures will likely still occur, but less often and with shorter duration. In the summer, heat waves may be longer and more frequent. This may increase the usage of recreation areas close to the lake, but will probably also have a tendency to keep people indoors, where air conditioning is available.

There is less agreement about changes in precipitation as the result of greenhouse warming. Some of the models indicate a slight increase, while others show a decrease. Moreover, the wide fluctuations in precipitation amounts already experienced from year to year require a lengthy period of record in order to determine whether a change is indeed occurring. Indications are that through the past 100 years precipitation totals have been rising, but only by a barely-measurable 1 per cent per decade.

There is, however, a consensus that higher temperatures will result in increased evaporation and thus a greater need for water. Not even those models that predict higher precipitation amounts indicate that there will be enough to make up for the quantity that is lost due to evaporation. As a result, problems arising from moisture deficits are expected to become more frequent and more severe.

In addition, there are some signs that any extra precipitation that does occur may be concentrated in events that are more extreme. This could negate the effects of any increase in precipitation as heavier spring and summer thunderstorms may also result in more and faster runoff.

During the winter, because of the expected higher temperatures, it is likely that more of the precipitation that falls would come as rain. Overall, snow depths and the number of days with snow on the ground are both expected to decrease. The effect on winter recreation activities is not clear. While less snow would obviously be of concern to skiers, a reduction in the number of days with bitterly cold temperatures could be looked upon with some favour.

Finally, an increase in urbanization in the two watersheds would likely result in a change in recorded temperatures. Typically cities have the effect of decreasing the daily temperature range. Overnight low temperatures are often several degrees higher than they would be in a rural setting. During the day, maximum temperatures may be lower, largely as a result of a weakening of the solar radiation by increased air pollution.

Summary

Temperatures across the Carruthers and Duffins watersheds are similar to those found elsewhere in southern Ontario. The area experiences a moderated continental climate. In an average year, approximately 800 to 850 mm of precipitation falls across these two watersheds. Snowfall accounts for about 15 per cent of the total annual precipitation, and tends to fall between December and the first half of March.

Lake Ontario has a moderating influence on the climate of these watersheds. As wind passes over the warmer waters of Lake Ontario, it picks up additional moisture and brings climate variability throughout the watersheds. Southern portions of the Duffins and Carruthers basins may see more snow than the northern reaches of the watershed. At other times, the southern part of the watersheds may receive precipitation in the form of rain while the northern reaches see that precipitation fall in the form of snow.

Climate is not limited by watershed boundaries, but is affected by much larger regional, and even global, systems and weather patterns. During the past 12,000 years, since the end of the last ice age, the course of human habitation in these watersheds has been shaped by the changing annual cycles of temperatures and precipitation. At this point in time, it may be that atmospheric pollutants (methane and carbon dioxide) are accelerating the pace of climate change. Climate change needs to be factored into management strategies for the Duffins and Carruthers watersheds.

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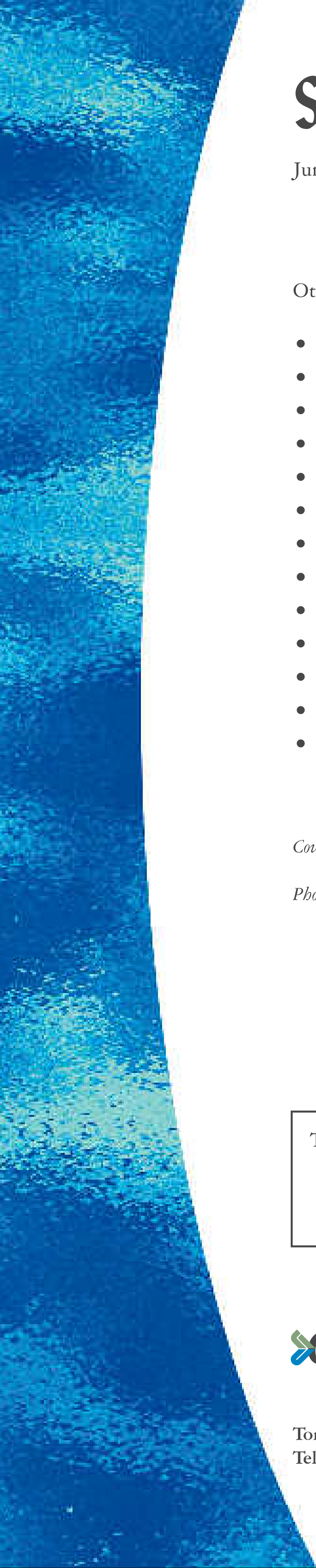
State of the Watershed Report

Surface Water Quality



Surface Water Quality

June 2002

Other topics in this series for both the Duffins Creek and the Carruthers Creek include:

- Introduction
- Study Area
- Human Heritage
- Greenspace, Trails and Recreation
- Land Use
- Air Quality
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- Stormwater Management
- Fluvial Geomorphology
- Hydrogeology
- Aquatic Habitat and Species
- Terrestrial Natural Heritage

Cover photograph: Carruthers Creek??????

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Introduction to Surface Water Quality

Water quality in Carruthers Creek is understood by addressing the following questions:

- What are the current water quality conditions? Do they vary throughout the watershed? Is water quality getting better or worse? Is the water suitable for various uses? Does it meet federal or provincial objectives?

- What are the factors that influence water quality?

Water quality data from Ontario's Provincial Water Quality Monitoring Network (PWQMN) provide a basis for this assessment. Data are available for one monitoring station for a period of about 20 years. Routine monthly data from the period of 1988 to 1993, plus a few samples from 1994, were considered to represent "current conditions," as 1994 was the last year of monitoring under the PWQMN. Unfortunately, any changes in water quality in the last six years is not quantifiable due to the lack of routine water chemistry monitoring activities. Information from the provincial data set was augmented with some limited baseflow chemistry data collected at nine sites in October, 1999.

The assessment focussed on selected water quality parameters: phosphorus, nitrogen compounds, suspended solids, chlorides, bacteria (*E. coli* and faecal coliform), biological oxygen demand, dissolved oxygen, and temperature. These parameters were selected for analysis due to their relevance to common water use concerns (Table 1). While heavy metals and persistent organic pollutants (e.g., pesticides) are also of interest, an accurate assessment of these parameters is not possible with existing data sources. The presence of these pollutants is addressed with reference to other observations in nearby, similar watersheds. Table 1 also includes provincial and federal water quality objectives or guidelines where they exist, however, some parameters are without guidelines as there is a process currently underway to standardize these across the country.

Table 1: Rationale for the Selection of Key Water Quality Parameters

Water Quality Parameter	Significance and Sources
Phosphorus	Phosphorus is a nutrient that influences eutrophication by fuelling plant and algae growth, reducing water clarity and oxygen availability. Sources of phosphorus include: lawn and garden fertilizers, eroded soil particles from construction sites, stream banks, agricultural fields and sanitary sewage. A firm Provincial Water Quality Objective (PWQO) for the protection of aquatic life does not exist at this time, however a general Provincial guideline of no more than 0.03 mg/L is recommended in the interim.
Nitrogen Compounds	Nitrogen, in the form of nitrate, is a nutrient with sources and effects similar to phosphorus. It is also potentially toxic in aquatic systems when in the form of ammonia or nitrite, the later of which is a very transient stage in the nitrification process converting ammonia to nitrate. A firm Provincial Water Quality Objective (PWQO) does not exist for nitrate at this time, however sustained high levels (e.g., 1-10 mg/L) are suspected to stress aquatic life. The PWQO for unionized ammonia (a toxic form of nitrogen) is 0.02 mg/L.
Suspended Sediment	The presence of suspended sediment in water influences water clarity and aesthetics. Water quality can also be affected because other contaminants tend to adhere to sediment particles. Suspended sediment also can impair fish habitat and spawning areas, as well as abrade fish gills. Sources include: areas of soil disturbance (such as construction sites or farm fields), eroding streambanks and streambeds and grit accumulated on urban streets. Concentrations not exceeding natural background levels +25 mg/L are recommended for the protection of aquatic life (CWQG, 1999).
Chloride	The chloride ion is a widely distributed in the environment. It is released through the natural process of weathering and is also linked to many human activities such as road salting, industrial wastes and domestic sewage discharge. It is potentially toxic at elevated levels and a study by Environment Canada has assessed the impact of chlorides on aquatic life. Its presence at elevated levels correlates well with degradation of the chemical, physical and biological features of urban streams. At this time, there is no numerical standard for chloride concentrations.

Water Quality Parameter	Significance and Sources
Bacteria	High faecal bacteria levels in a water body are indicative of loadings of faecal matter of either animal or human origin. Stormwater runoff carries bacteria from pet and wildlife faeces and bacteria in association with suspended sediment particles to the watercourse. The Provincial Water Quality Objective for Recreation limits bacteria Escherichia coli levels to a maximum of 100 counts per 100 mL. Formerly, faecal coliform and total coliform were measured as indicators of health risk with respective limits of 100 and 1000 counts per 100 mL.
Biological Oxygen Demand (BOD) and Dissolved Oxygen	The BOD of water corresponds to the amount of oxygen required for aerobic microorganisms to oxidize organic matter to a stable inorganic form. High BOD levels correspond to low dissolved oxygen concentrations, which can lead to stress responses in aquatic organisms. No official guideline for BOD exists. BOD levels above 2 mg/L (or 5 mg/L during exclusively dry weather) indicate the presence of a persistent organic load to the system. The Canadian Water Quality objective for disolved oxygen ranges from 5.0-6.0 mg/L for coldwater biota, depending on life stages.
Summer Water Temperature	Extreme water temperatures can impact fisheries and benthic communities, promote eutrophication and influence the presence of other water quality parameters (i.e. dissolved oxygen, ammonia). Water temperature is influence by groundwater inputs, streamside riparian cover and land use.

The following sections summarize the results of this water quality assessment. Detailed information is included within the Carruthers Water Quality Technical Appendix (TRCA, 2000).

Current Conditions

Provincial data for the period 1988 to 1993 show that Carruthers Creek has good water quality conditions overall relative to the other streams in the Toronto Region. As shown in Figures 1 and 2, chloride and suspended sediment levels in Carruthers Creek are among the best of all the TRCA watersheds. Carruthers Creek is slightly more impaired than the Duffins Creek, the neighbouring watershed to the west. Like other streams subject to urban and agricultural pressures, some levels of pollutants, especially nutrients like phosphorus and nitrates, are elevated. It is suspected that water quality conditions since 1993 may have changed, however, there is no other current data to support an assessment since that time.

Water quality in Carruthers Creek can best be described in terms of its implications for swimming, aquatic health and human health. For each concern: key parameters are identified; pollutant levels in the watershed are described; a comparison to objectives is provided; and trends over time are noted.

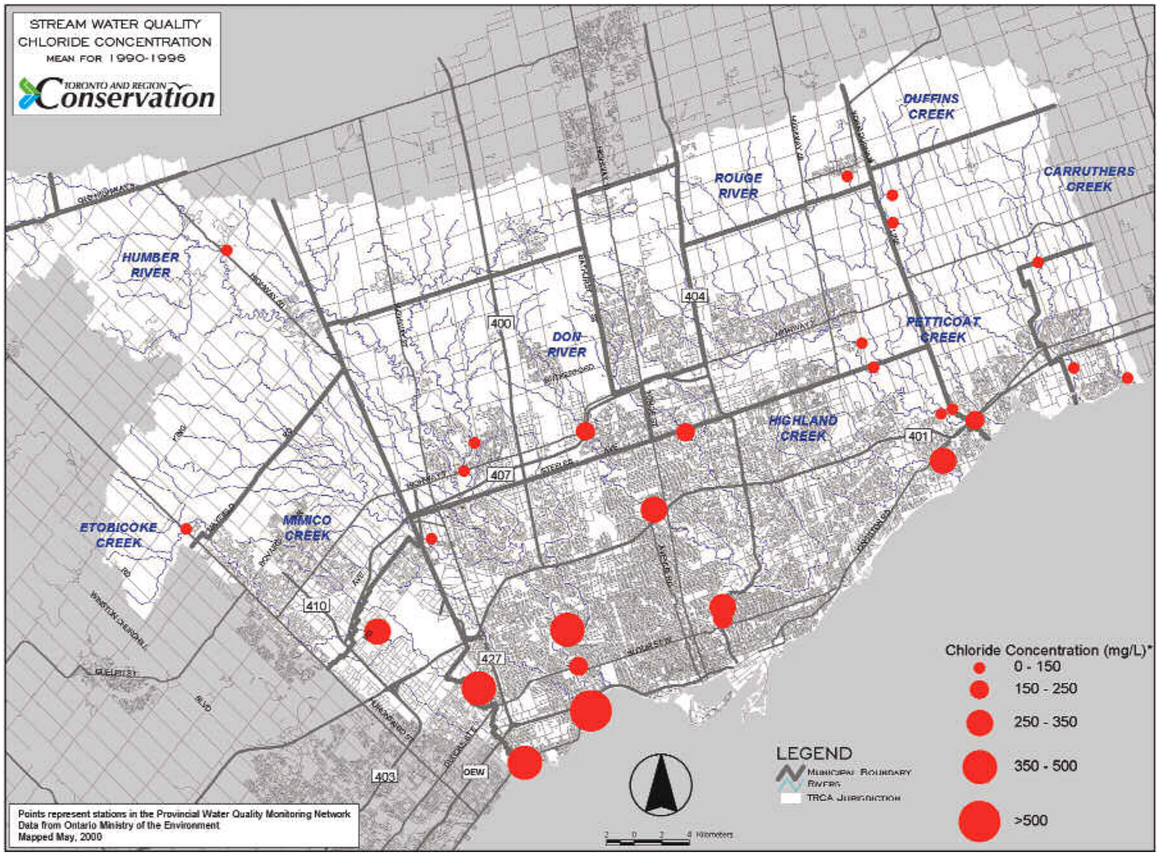

Figure 1:
Chloride Levels in Toronto Area Streams.

Implications for Swimming and Body Contact Recreation

Bacteria levels in the Carruthers watershed are such that swimming is encouraged only at public waterfront beaches. Although Carruthers Creek is generally not deep enough for swimming, it may be inviting, particularly to children, for wading or streamside play in some places. These recreational activities present risks for water-body contact and therefore pose human health concerns. Escherichia coli (E. coli) or other faecal coliform bacteria indicate the presence of faecal matter of human or animal origin and can indicate the potential presence of other bacteria, viruses or pathogens that could infect humans, pets and other warm-blooded animals. Bacteria levels monitored through the provincial water quality monitoring network in Carruthers Creek fail to meet objectives for water recreation more than half (55 per cent) of the time. This is likely an underestimate of bacteria levels in the creek because sampling for the network is biased towards dry weather, a time characterized by low bacteria levels. During and shortly after wet weather, bacteria levels can be several orders of magnitude higher.

High bacteria levels necessitate the closure of swimming beaches and create health risks associated with other forms of water-body contact recreation. Bacteria loadings from Carruthers Creek, like all watercourses draining to Lake Ontario, contribute to high bacteria levels in the nearshore zone of the lake. The one waterfront beach in the watershed, Pickering Beach, is located on Lake Ontario just west of the mouth of the creek. Due to its proximity to Carruthers Creek

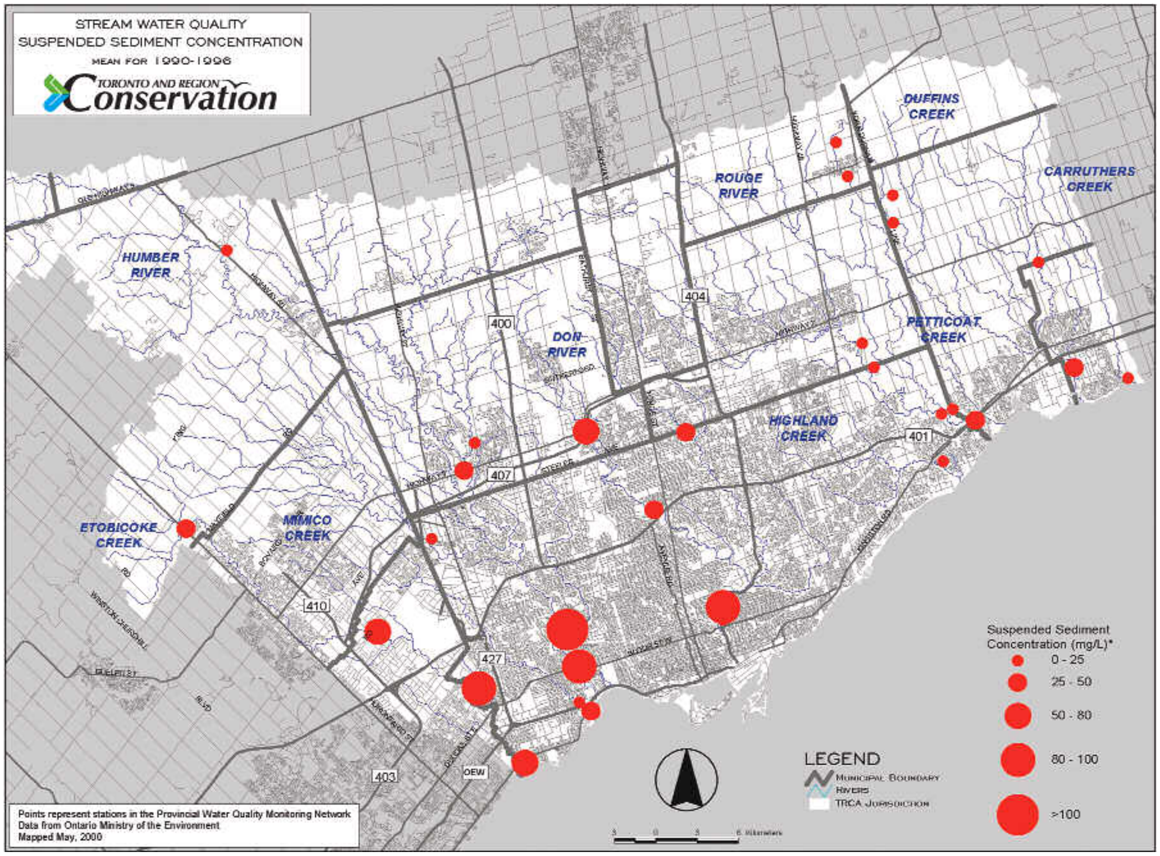

Figure 2:

Suspended Sediment Concentration in Toronto Area Streams.

and the western movement of the nearshore currents, the water quality of the beach is influenced by the water quality of the creek. In 1999, Pickering Beach was closed for 31 per cent of the swimming season (June to September) due to excessive bacteria levels (Durham Regional Health Department, 1999). This is good in comparison to some other waterfront beaches, for example Rouge and Bluffer's Park beaches, which were posted as unsafe more often (>95 per cent) in the same year.

Implications for Aquatic Health

Various land use activities generate pollutants that adversely affect aquatic habitat and species. Conventional pollutants can fuel plant growth, limit oxygen availability, reduce water clarity and be potentially toxic to aquatic life. Parameters of interest include: phosphorus, nitrogen, total suspended sediment and turbidity, biological oxygen demand, chloride and temperature (see Figures 4-7).

The nutrients phosphorus and nitrate are elevated in the Carruthers Creek watershed. Trends and effects are similar for both nutrients. Phosphorus concentrations in Carruthers Creek failed to meet the interim provincial guideline of 0.03 mg/L over two thirds of the time during the period

1988-1993, with median (defined as the middle value in an ordered data set) concentrations of 0.04 mg/L. Major sources of phosphorus and nitrogen include lawn and garden fertilizers and eroded soil particles from construction sites, stream banks and agricultural fields. Phosphorus readily binds to soil particles and ends up in the watercourse when sediment is washed or eroded away during overland flow events. Phosphorus levels during wet weather tend to be several times higher than in dry weather. Limited dry weather sampling at nine locations in the watershed in 1999 showed improved conditions, with phosphorus failing to meet the guideline in only the east branch north of Taunton Road and high levels of nitrate (5 mg/L) monitored in only the west branch at Highway 7. Isolated periods of increased levels of phosphorus in the mid to late 1980's originated from disturbed soils at construction sites associated with the expanding housing market at that time. High nitrate levels in combination with decreased stream shading can exacerbate eutrophication problems associated with elevated nutrient levels. The relationship between nitrate levels and land use is a good barometer of anthropogenic influences to the overall aquatic system.

High nitrate levels (i.e. 1 - 10 mg/L) not only fuel eutrophication, but may also have an indirect toxicity role by contributing to aquatic stress. A toxic form of nitrogen, ammonia, is a component of human and animal sewage and also forms from the microbial decomposition of organic matter. During the period 1988 to 1994, all ammonia levels in Carruthers met Provincial Water Quality Objectives (PWQO) for the protection of aquatic life.

Nutrient levels have varied over time in the watershed. Since the 1970s, concentrations of phosphorus have generally been decreasing due to the reduction in the number of agricultural operations in the watershed (Figure 3) and the adoption of modern agricultural practices. An elevation in the 1980s is attributed to expanding land development and construction activity in the watershed. Seasonally, phosphorus contributions are at their highest from late fall to spring. This is attributed to current tillage practices and limited crop cover in the watershed during these months in combination with snowmelt and rainfall.

Total suspended sediment median concentrations are around 15 mg/L and have not changed significantly over the years. Suspended sediment levels in streams are a function of particulate matter picked up during overland transport as well as instream erosion and scouring of the stream bed. Levels observed in Carruthers Creek do not pose a threat to aquatic life. Highest concentrations occur during March/April (median of 30 mg/L) and are associated with spring rains and erosion of exposed soil. Turbidity measurements in the watercourse follow a similar pattern to suspended sediment concentration. Over time, levels were generally stable, with two periods of elevation related to land use in the watershed (Figure 4). The first, in the 1970s, is related to the many farming operations in the watershed at that time, including livestock access to the watercourse, and is attributed to soil erosion from the fields. Turbidity levels, like phosphorus, were elevated in the mid-1980s when housing construction was expanding in the watershed, during which time soil is exposed and subject to erosion. Elevated suspended sediment and turbidity levels also coincide with periods of wet weather, a pattern typical of other watersheds across the Toronto area.

Biological oxygen demand (BOD) in Carruthers Creek is low, suggesting there is no persistent organic load to the watercourse. BOD was elevated until the mid-1970s, correlating to the operation of many small farming operations in the watershed prior to that time (Figure 5). Consistent with the 1970s decline in BOD, dissolved oxygen (DO) levels increased and have remained good. Similar to the pattern over time found for phosphorus and turbidity, another period of elevated BOD levels is evident in association with the housing boom in the mid-1980s.

Seasonally, BOD is relatively constant. Dissolved oxygen fluctuates throughout the year in relation to temperature, with warmer water capable of

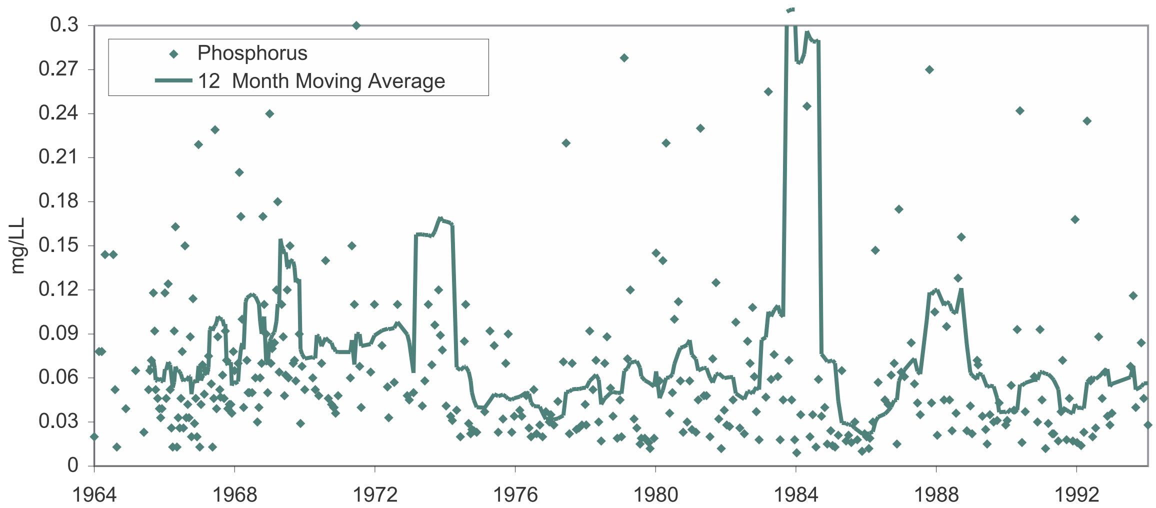

Figure 3:

Carruthers Creek Total Phosphorus.

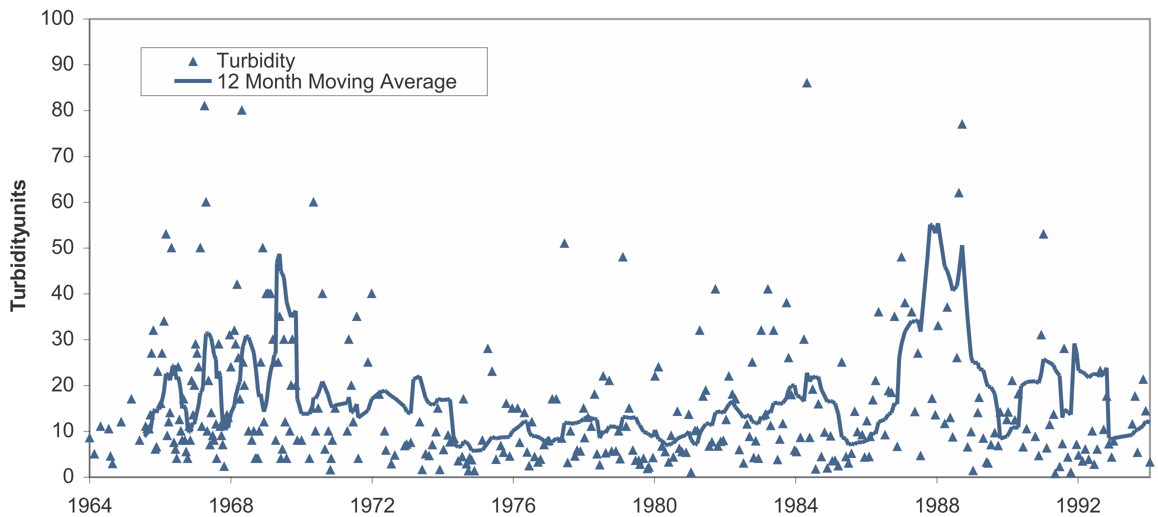

Figure 4:

Carruthers Creek Turbidity.

holding less dissolved oxygen. A diurnal cycle is evident as well with daytime production of oxygen by aquatic plants and nighttime respiration processes using up dissolved oxygen. These factors, in combination with high levels of plant productivity and decomposition in the summer months, lead to drastic swings in dissolved oxygen in the watercourse. The lowest DO levels occurring in July to August, however levels remain above the minimum level for cold and warm water fisheries. Overall, current BOD and dissolved oxygen levels in the Carruthers Creek are well within the acceptable range for aquatic life.

Chloride concentrations have gradually been increasing over time (Figure 6). The increase over time correlates to the conversion from rural land characteristics, including meadows, forest stands and agriculture to more urban uses characterized by a greater density of roadways and paved surfaces (Bowen and Hinton, 1998). Chlorides, therefore, are a general indicator of human

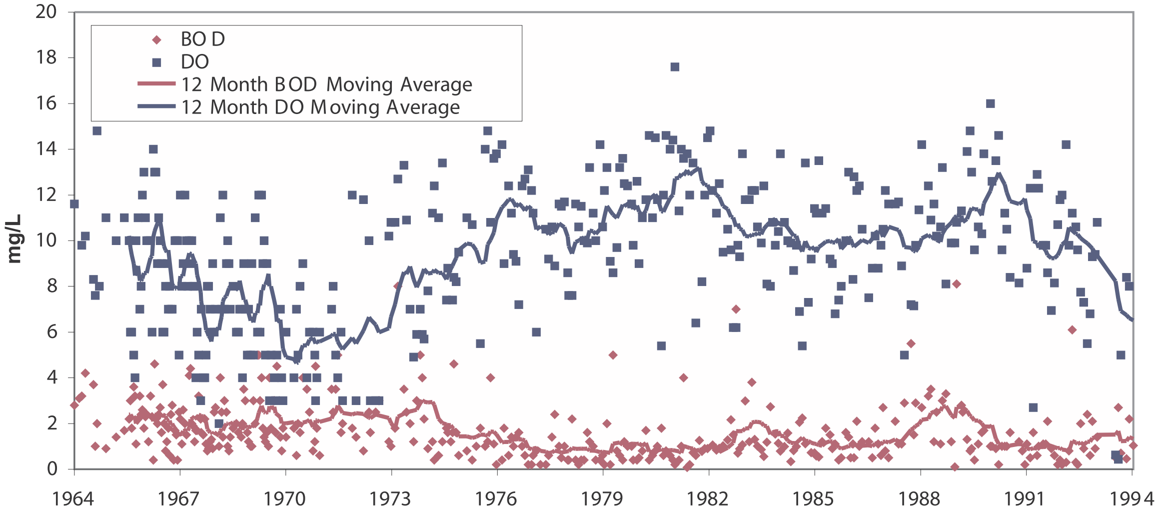

Figure 5:

Carruthers Creek Biological Oxygen Demand and Dissolved Oxygen.

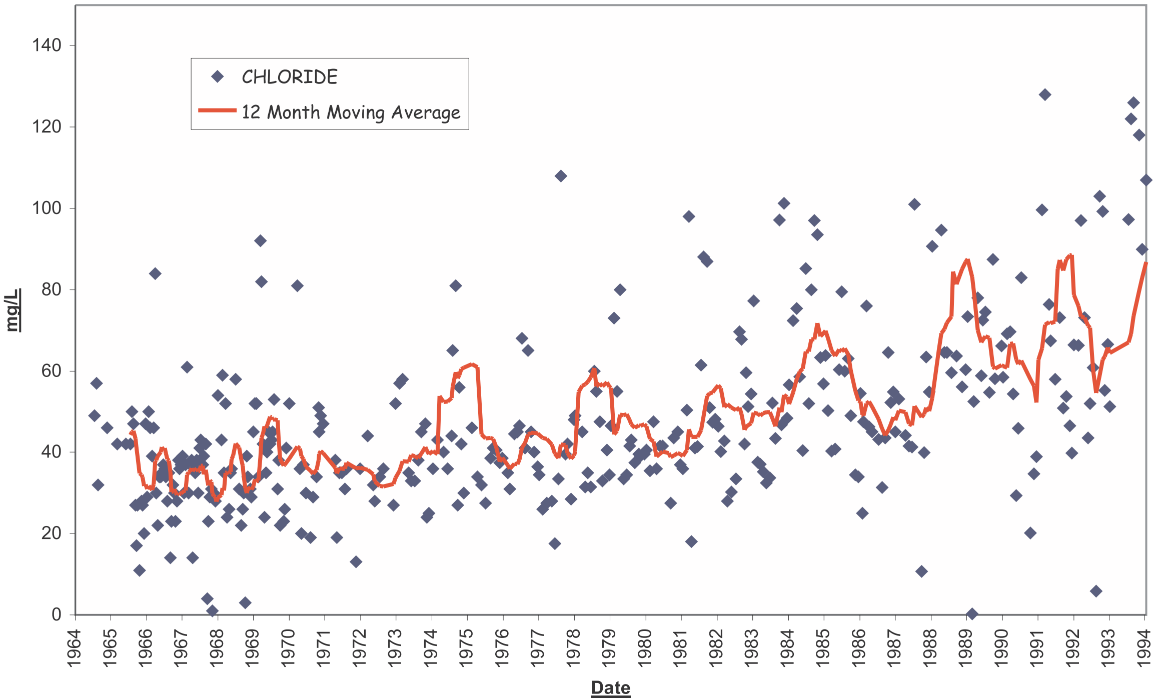

Figure 6:

Carruthers Creek Chlorides.

disturbance. Chlorides have a strong seasonal trend because a major source of chlorides is from road salt associated with urban runoff. Currently, chloride levels are around 65 mg/L, with maximum winter concentrations of 200 mg/L. A study by Environment Canada is currently underway to evaluate the potential toxicity of road salt on aquatic life. In comparison to chloride levels found in other watersheds, Carruthers Creek levels are low (Figure 1).

The average summer water temperature measured near the mouth of Carruthers Creek is 20oC. The maximum recorded temperature over the 1988-1994 period is reached in July at approximately 27oC. The current temperature regime of the creek supports predominantly warm water fisheries throughout the watershed, although historically it may have been a cold water stream. Cold water fish habitat is present in the middle portion of the watershed where groundwater inputs are higher and thus provide a cooling effect. Lack of shade from riparian vegetation and warming effects of urban runoff contribute to warm temperatures.

Implications for Human Health

Pesticides, PCBs and polynuclear aromatic hydrocarbons (PAHs) are synthetic substances, which are not found naturally in the environment. Their detection in water is therefore a cause for some concern. Metals, although naturally present in the environment, are released at excessive levels as a result of various land use activities. Certain pesticides have been banned for use due to their persistence and tendencies to bioaccumulate through the food chain.

Many of these substances have been linked to chronic health effects on aquatic organisms and humans. Environmental effects in aquatic life include physical deformities, tumours and lesions and population declines through increased embryo mortality and damage to reproductive systems. Compounds such as dieldrin and benzo(a)pyrene are believed to be carcinogenic to humans. Some researchers are concerned that exposure to toxics at the human embryo stage may affect learning capacity later in life and may disrupt the function of the endocrine (hormone) system. Endocrine disruption could result in birth defects, depressed immune systems and behavioural changes.

A thorough assessment of the presence of pesticides, PCBs, PAHs, or metals cannot directly be made for Carruthers Creek, because of limitations in water quality sampling methodologies or simply a lack of data. Alternatively, inferences can be made from a comprehensive 1991-92 study of toxic contaminants in tributary discharges along the Toronto waterfront (D'Andrea and Anderton, 1996; Boyd, 1999; Boyd et al., 1999) and from the preliminary results of a similar tributary toxics study in Duffins Creek in 2000-2001. Using an innovative sampling program, these studies are able to report reliable data for a number of parameters, including heavy metals and trace organic contaminants (e.g., organochlorine pesticides, chlorobenzene, PAHs, and volatile organic compounds).

Toxic pollutant data from the 1991-92 Toronto stream study showed that wet weather contaminant concentrations generally exceed dry weather concentrations by an order of magnitude for suspended solids, total phosphorus, *E. coli*, aluminum, iron, and most organic compounds. Neither Carruthers or Duffins creeks were included in the 1991-92 study, however results are expected to be similar to, if not better than, conditions reported for the neighbouring Rouge River watershed by D'Andrea and Anderton (1996) and Boyd (1999), where levels were lower than all other Toronto tributaries. This inference is due to similarities in the Rouge and Carruthers watersheds in that neither receive effluent from sewage treatment plants or combined sewer overflows and both have significant agricultural land use. Preliminary results from the Ministry of the Environment (MOE) 2000-2001 Duffins Creek study indicate that the majority of organic parameters were not detected, and of the few organic parameters detected, all occurred in very trace amounts (less than a few parts per billion)

(D. Boyd, Personal Communication, 2001). Metals concentrations were also within normal background levels found in nature. In comparison to other Toronto area watersheds evaluated in the study (Don and Humber rivers), fewer parameters were detected and overall concentration levels were lower, results that would be expected in a watershed with less intensive land use. A complete analysis of the 2000-2001 results will be undertaken by MOE in the near future.

The aquatic communities present in Carruthers Creek show no particular evidence of toxic contaminant problems. Physical habitat conditions, temperature and nutrient enrichment are likely to be more limiting factors for aquatic life.

Factors Affecting Water Quality Conditions

Water quality conditions in the Carruthers watershed are influenced by natural conditions and land use activities in the watershed.

Natural

Natural features and functions within a watershed influence the quality and prevalence of water resources and determine the extent to which the natural system can moderate the effects of human activities.

The shape of the land, soil types and other natural factors control the rate of overland runoff, affect ground-surface water interactions and determine the susceptibility of land to erosion. The soils of the Carruthers Creek watershed are predominantly fine-grained silt and clay. The underlying geology is primarily glacial till and fine-grained sediments from glacial Lake Iroquois. Fine-grained soils promote greater overland runoff and less infiltration, thereby providing greater opportunity for pollutants to be carried to the stream. Groundwater discharge to Carruthers Creek is limited to a small area along the Iroquois Shoreline near Fifth Concession Road and therefore, in most years, does not have a significant influence on water quality or temperature throughout the creek.

Land Use Activities

Land use activities that affect climate, landform, soils, or vegetation will impact upon the natural distribution of water within the watershed landscape and in turn have an influence on surface water quality. The most noteworthy influence from land use activities occurred when clearing and settlement began in the 1800s. Deforestation promoted even further overland runoff than occurred naturally. Agricultural practices over the years have altered the natural shape of the creek, including straightening, local ponding of tributaries and tile drainage. These alterations have changed the flow regime and allowed more pollutants to be carried to the stream. The natural filtering capacity of the riparian zone is reduced due to the removal of riparian (stream side) vegetation. Without the riparian vegetation to bind and stabilize soil, creek banks are more subject to erosion and contribute more sediment to the stream. Despite these perturbations, Carruthers Creek now has reasonably good water quality. There has also been some recovery of the watercourse over the years due to restrictions on cattle access and changes to cropping practices, both of which have allowed vegetation to recover along stream banks, which has served to reduce the volumes of sediments entering the watercourse.

Currently, the principle land use in the Carruthers Creek watershed is rural, although urban expansion has been occurring in the Town of Ajax. Present day water quality conditions are potentially influenced by: rural/agricultural activities, urbanization and stormwater runoff, golf courses, pets and wildlife, landfills, spills and atmospheric deposition.

Rural/Agricultural Activities

Agricultural areas represent a potential source of pollutants (e.g., suspended sediment, phosphorus, bacteria, pesticides) if proper practices are not employed. For example, in the neighbouring Duffins Creek, Hill (1981) found that phosphorus concentration in streams tended to be higher in catchments with a greater area in crops. Phosphorus and nitrogen compounds are derived from crop fertilizers.

Septic systems are utilized in the rural portions of the watershed. When properly located and maintained, septic systems do not impair surface water quality, although there is the potential for leaking of contaminants to ground and surface water in older systems. The prime contaminants of concern are bacteria, nitrates and chlorides.

The Rural Clean Water Program, administered by TRCA, is a remedial action program designed to improve local water quality in rural areas and may be a useful tool to improve water quality conditions in the Carruthers Creek watershed. The emphasis of the program is to educate land owners about rural water quality issues and provide technical and financial assistance to improve management practices and mitigate the levels of bacteria and nutrients entering watercourses.

Stormwater Runoff

As urbanization occurs, soil compaction and paved surfaces increase the imperviousness of the watershed which acts to generate a greater volume of stormwater runoff to the creek. The resulting increase in stream discharge can scour the creek bed and incise the channel banks. This erosive activity represents a significant source of suspended sediment loads to the creek.

Stormwater runoff picks up a variety of pollutants including: suspended sediment, nutrients, chlorides and bacteria. These pollutants arise from many sources that are described in subsequent sections. One pollutant commonly found in urban stormwater runoff, chloride, has been increasing in the watershed over time (Figure 6). Chlorides originate from de-icing chemicals like road salt and are associated with increased traffic volumes, greater density of roads and highways, population density and road salting. Chloride levels in Toronto area watersheds correlate well with observations of degraded aquatic systems, not solely in terms of pollutant levels, but also physical degradation such as channel alteration (Bowen and Hinton, 1998; Mayer *et al*., 1999).

Stormwater runoff passes through storm sewers or drainage ditches. In older urban areas, this drainage travels directly to the streams untreated. Since the 1980s, developments have incorporated stormwater management facilities designed to manage runoff volumes. Since 1990, these facilities have included a water quality control component to reduce the volume of pollutants in stormwater runoff. Presently the Carruthers Creek watershed has approximately 16 stormwater ponds built and/or in the planning stages. "At source" controls of pollutants will also help improve water quality. Chloride levels, for example, may be reduced by applying improved salting practices designed to maintain safe road conditions, while minimizing the application of salt and thus reducing the amount of chloride reaching the watercourse through stormwater runoff. In the case of chlorides, "at source" management measures are the most effective, because stormwater management facilities are not able to remove them due to their soluble nature. The Stormwater chapter of this State of the Watershed report offers a more in-depth discussion of water quality issues pertaining to stormwater.

Golf Courses

This specialized land use can contribute increased loadings of nutrients and pesticides to a watercourse if proper turf management and stormwater practices are not employed. Some golf courses rely on surface and groundwater as sources of irrigation water and therefore are particularly concerned over the protection of good water quality. Many golf courses are adopting environmental management plans, prepared specifically for their properties. By preparing these plans, the courses can become certified under the Audubon Sanctuary Program for golf courses, which aims to reduce pesticide use and negative environmental impacts of golf courses.

Pet and Wildlife Faeces

Pet and wildlife faeces can represent a significant source of bacteria to urban waters. It is estimated that there are approximately 3,000 dogs living in the City of Ajax (Koch, 2001), the most urbanized area in the Carruthers Creek watershed. These dogs generate the equivalent daily faecal output of 1,000 humans. It is interesting to note that under current regulations a community of that size would be required to have a communal sewage treatment system to manage the waste.

In urbanizing areas, pet "stoop and scoop" by-laws and "don't feed the geese" awareness programs help reduce bacteria loadings.

Landfills

There is only one known closed landfill site in the Carruthers Creek watershed and no active sites. The site was operated for the disposal of municipal domestic waste and closed in 1940 (MOEE, 1991). It is not known whether or not this site is contributing leachate to ground or surface water systems, although the likelihood of any such problem is very low given its age, its location in the lower portion of the watershed, and the predominantly clay soils that underlay the site.

Spills and Illicit Discharges

Deliberate discharges or accidental spills are especially prone to occur in densely urbanized areas, particularly in industrial areas and transportation corridors. Analyses undertaken as part of the Toronto Area Watershed Management Studies suggest that a petroleum spill of 100 litres may be as toxic to aquatic biota as combined sewer overflows or stormwater runoff and that the frequency of occurrence may be of more concern than the actual magnitude of a spill. Data on the frequency and type of spills to the Carruthers Creek cannot specifically be extracted from the Ministry of the Environment's spills database at present, however it is estimated that there could be in the order of five-six spills per year, based on total spills to water data for Ajax and Pickering.

Businesses and municipalities that adopt environmental management standards (i.e. ISO 14000) focus on pollution prevention and have a plan in place to deal with unexpected spills.

Atmospheric Deposition

Atmospheric sources of various pollutants can become relatively more significant as a watershed urbanizes. This is due to the larger areas of impervious surfaces in an urban area and the stormwater conveyance systems that collect and convey pollutants to watercourses. A local Toronto outfall monitoring study (D'Andrea *et al*., 1993) found no significant difference in stormwater quality for most parameters between drainage areas of different land use types (e.g., industrial, residential). This finding may be explained by a common atmospheric source of pollutants.

Vehicle emissions may be a relatively significant source of certain pollutants, including polycyclic aromatic hydrocarbons (PAHs) and suspended particulates. A study characterizing the sources of PAHs in street and creek sediments noted the significance of vehicle emissions relative to other industrial sources, because most of the PAHs in vehicle emissions are deposited on the street/road grid itself or within 40 metres either side of the road (Sharma *et al*., 1997). Suspended particulates, created by industrial processes and present in motor vehicle exhaust, are also of concern to water quality. Stormwater runoff conveys pollutants directly to drainage systems, without opportunity for filtration as might occur with particles deposited on vegetated surfaces. Further discussion on air quality within the Carruthers Creek watershed is provided in the Air Quality chapter.

Summary

Carruthers Creek has good water quality conditions overall. For the period 1988 to 1993, it exhibited relatively better water quality than most other Toronto Region watercourses. However, like other streams subject to urban and agricultural runoff, the creek contains elevated levels of nutrients, bacteria and chlorides. Water quality does not pose significant concerns for human health or aquatic communities, although swimming or contact recreation in the creek is recommended at public waterfront beaches only. In some aspects, water quality has improved since the 1970s due to better land use practices, although increasing chloride trends coincident with urbanization in the watershed point to the importance of managing urban development and associated stormwater runoff if water quality is to be maintained or improved. There is uncertainty about the current water quality situation due to a lack of data since 1993; it is suspected that conditions are deteriorating.

In addition to urban runoff, impacts of rural land uses, such as agricultural cropping practices, represent the primary human factors controlling water quality. The natural features of the watershed are not particularly conducive to good water quality because the fine grained soils are easily eroded and small amounts increase the turbidity of the watercourse. The geology and soils of the watershed promote increased runoff, which provides a pathway for contaminants to the creek. Furthermore, the limited extent of groundwater discharge limits baseflow in the creek, thus high summer water temperatures and contaminant concentrations are not moderated as they are in streams with larger inputs of baseflow.

References

Bowen, G.S. and M.J. Hinton, 1998. *The Temporal and Spatial Impacts of Road Salt on Streams Draining the Greater Toronto Area*. In Proceedings of the Groundwater in A Watershed Context Symposium, December 2-4, 1998. Canadian Water Resources Association.

Boyd, D., 1999. *Assessment of Six Tributary Discharges to the Toronto Area Waterfront, Volume 1: Project Synopsis and Selected Results.* Ontario Ministry of the Environment. Prepared for The Toronto and Region Remedial Action Plan.

Boyd, D., M. D'Andrea and R. Anderton, 1999. *Assessment of Six Tributary Discharges to the Toronto Area Waterfront, Volume 2: Technical Appendix and Data Summary.* Ontario Ministry of the Environment. Prepared for The Toronto and Region Remedial Action Plan.

CCREM (Canadian Council of Resource and Environment Ministers), 1999. *Canadian Water Quality Guidelines.* (CWQG) Prepared by the Task Force on Water Quality Guidelines.

CCREM (Canadian Council of Resource and Environment Ministers), 1987. *Canadian Water Quality Guidelines.* Prepared by the Task Force on Water Quality Guidelines.

D'Andrea, M., D. Maunder and W. Snodgrass, 1993. *Characterization of Stormwater and CSO in Metropolitan Toronto.*

D'Andrea M and R. Anderton, 1996. *Assessment of Tributary Discharges Along the Metropolitan Toronto Waterfront*. In Proceedings of the Watershed Management Symposium, Canadian Water Resources Association, ISBN 1-896513-06-9.

Environment Canada, 2000. *Road Salts: Assessment Report and Supporting Documentation.* Prepared for Canadian Environmental Protection Act, 1999 Priority Substances List.

Geological Survey of Canada and Ontario Ministry of the Environment. Unpublished data from the Duffins Creek Baseflow Study (1995-1996).

Hill, A.R., 1981. Stream Phosphorus Exports from Watersheds with Contrasting Land Uses in Southern Ontario. *Water Resources Bulletin* 17(4): 627-634.

Hitchin, G., 1998. *Young-of-the-Year Fish Database Update*. Ontario Ministry of the Environment and Energy.

Koch, S., 2001. Personal communication. Animal Control Services for Pickering, Ajax and Whitby.

Mayer, T., W.J. Snodgrass and D. Morin, 1999. Spatial Characterization of the Occurrence of Road Salts and Their Environmental Concentrations as Chlorides in Canadian Surface Waters and Benthic Sediments. *Water Quality Resources Journal of Canada*, 34(4): 545-574.

Neary, B., K. Cash, S. H. Bert, H. Khan, K. Saffran, L. Swain, D. Williamson and R. Wright, 2000. *The Canadian Water Quality Index 1.0: A Report to the Water Quality Guidelines Task Group of the Canadian Council of Ministers of the Environment.*

Ontario Ministry of the Environment, 1999. *Guide to Eating Ontario Sport Fish 1999-2000.* Queen's Printer for Ontario.

Ontario Ministry of the Environment and Energy, 1997. *Provincial Water Quality Monitoring Network (PWQMN) Database*, Toronto area streams, circa 1965-1996.

Ontario Ministry of the Environment, 1991. *Waste Disposal Site Inventory*. Queen's Printer for Ontario.

Petro, S., 2000. *Young-of-the-Year Fish Database Update for the Duffins Watershed.* Ontario Ministry of the Environment.

Regional Municipality of Durham Health Department, 1999. E. coli *Bacteria Data for Waterfront Beaches in Durham Region, 1997-1999*.

Sharma, M., E.A. McBean and J. Marsalek, 1997. Source Characterization of Polycyclic Aromatic Hydrocarbons in Street and Creek Sediments. *Water Quality Resources Journal* 32(1): 23-35.

Toronto and Region Conservation Authority, 2000. *Carruthers Creek Water Quality Technical Appendix.*

Duffins and
Carruthers
Watersheds

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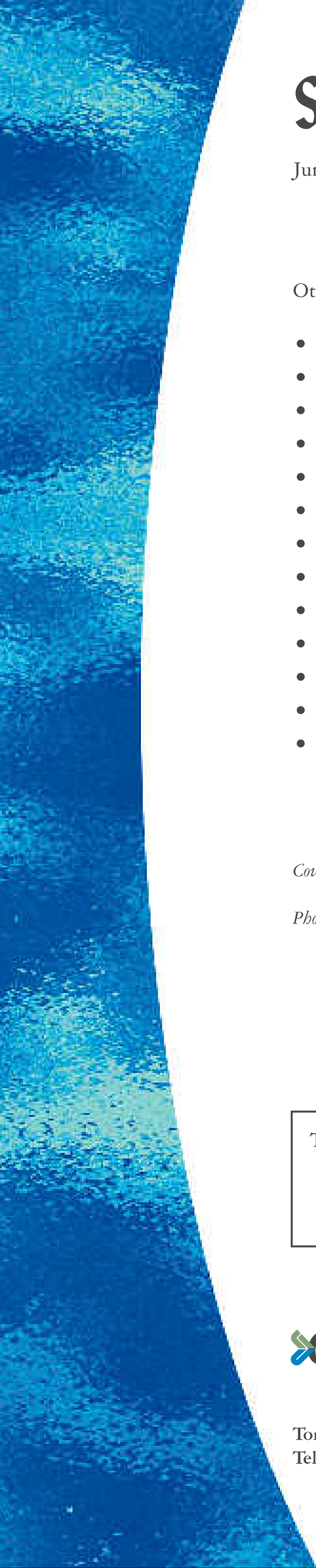
Carruthers Creek

State of the Watershed Report

Surface Water Quantity



Surface Water Quantity

June 2002

Other topics in this series for both the Duffins Creek and the Carruthers Creek include:

- Introduction
- Study Area
- Human Heritage
- Greenspace, Trails and Recreation
- Land Use
- Air Quality
- Climate
- Surface Water Quality
- Stormwater Management
- Fluvial Geomorphology
- Hydrogeology
- Aquatic Habitat and Species
- Terrestrial Natural Heritage

Cover photograph: A location on Carruthers Creek.

Photo credit: TRCA

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Introduction to Surface Water Quantity

Water quantity refers to the drainage of water through the Carruthers Creek watershed under various rainfall and snowmelt conditions. There are many complex factors at play in determining the amount of precipitation that eventually ends up flowing in Carruthers Creek. These factors include: soil types (with varying abilities to both hold and transfer water), topography, and land use. Obeying the laws of gravity, water above and below the ground surface flows down gradient eventually entering Lake Ontario at the Ajax waterfront.

Figure 1 illustrates the linkages between the major "water" components of a watershed and the factors or processes controlling this movement of water. A significant component of the precipitation falling on the watershed cycles back into the atmosphere through evaporation or transpiration (moisture released by plants). When the land surface is impermeable (e.g., urban built and paved), surplus water runs directly towards depressions (i.e. ponds, swales, swamps) and streams or evaporates back into the atmosphere. On permeable soils, however, the run-off component of precipitation is very small. Water that remains after evapotranspiration drains overland or into the ground. The subsurface movement of water begins the complex sequence of events associated with the groundwater flows system.

In managing the Carruthers Creek watershed, great care is taken to ensure a "natural balance" to the movement of water. The study of the movement of water through the hydrologic cycle is an important element of our conservation work in the watershed. In the same manner, as one manages a household or business finances, the amount of water flowing through the watershed is carefully accounted for in a water budget. As a result, the monitoring of precipitation, along with surface and groundwater levels, is an essential component of water quantity management in the Carruthers Creek.

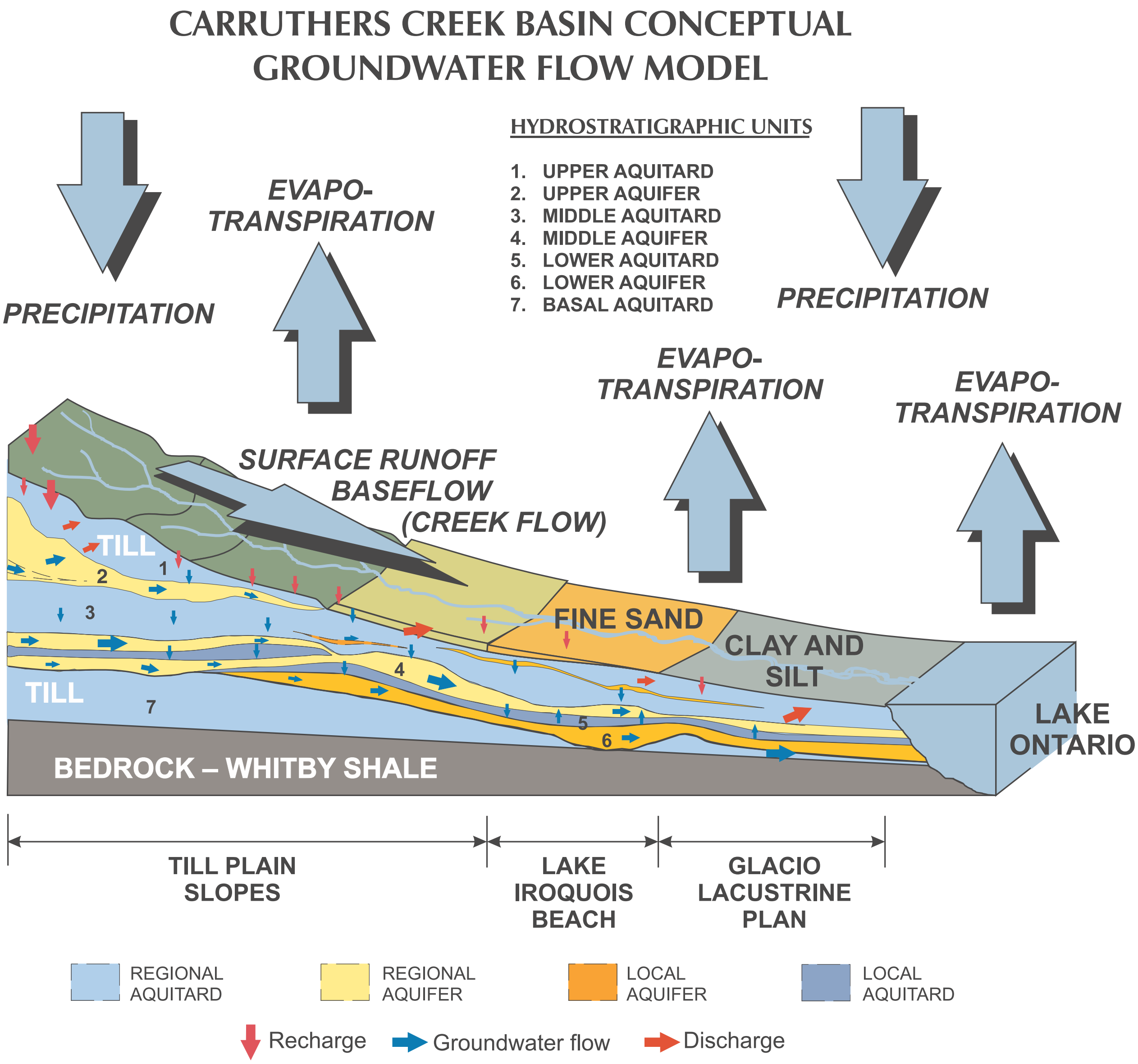

Figure 1:

The Hydrologic Cycle. Adapted from the Oshawa Creek Watershed Management Plan, Central Lake Ontario Conservation Authority (2001) and Gerber (1999).

Human uses of the watershed can have significant impacts on all of the components of the water cycle, thus altering the water budget. Changes in the volumes and pathways of surface water flowing in the Carruthers Creek can alter the size and shape of stream channels, the stability of streambanks, and dependent fish and wildlife habitats. Reductions in groundwater flow systems can have serious consequences to wetlands and aquatic communities (e.g., rainbow trout) and rural domestic groundwater supplies.

Current Watershed Conditions

The Carruthers Creek watershed, shown in Figure 2, is 38.4 km^2 in size and is located east of Toronto within the Regional Municipality of Durham. The major urban centre within the watershed is located in the lower reach of the creek in the Town of Ajax.

A hydrology study undertaken by the Toronto and Region Conservation Authority (TRCA) was completed by Totten Sims Hubicki Associates in 1991 with updates in 1995 and 1999. These studies looked at the current and future planned land uses and the hydrologic impact that they would have on the watershed. The following description of the physical characteristics of the watershed was taken from this 1991 hydrology study.

Physical Characteristics

The Carruthers Creek watershed can be separated into three physiographic regions with distinct topography, soil conditions and range of land surface elevations. These three physiographic regions include:

- the Halton Till Plain
- the Lake Iroquois Shoreline
- the Lake Iroquois Plain

The Halton Till Plain contains the headwaters of the watershed, approximately between the elevations of 140 metres and 275 metres. Topography is predominantly gently rolling, low-relief hills with the largest relief produced by drumlins. On the south slope of the Oak Ridges Moraine, the till plain contains a variety of soils, some of which have proven to be excellent through more than a century of agricultural use based upon the soil characteristics related to water retention, nutrients and acidity levels. Shale content, and therefore the acidity, of these soils increases towards the west. Soils on the till to the east of Pickering, on the other hand, are highly calcareous, or non-acidic. The southern limit of the till plain is marked by steep topographic gradients which define the former shoreline of Lake Iroquois.

The Lake Iroquois Shoreline is located near the 5th Concession Road which cuts across Pickering and serves as the northern boundary where Ajax meets Pickering. Approximately 12,800 years ago, glacial Lake Iroquois occupied the Lake Ontario basin at a time when the Wisconsinan glacier blocked the St. Lawrence outlet and water drained to the south-west. The glacial meltwaters overflowed the banks of this basin, so that the waters filled what is now the lower third of the Carruthers watershed. The Lake Iroquois Shoreline appears today as an irregular line broken by strongly developed ancient features such as embayments and river mouths; remnants of the once-coastal environment. The wave action from the waters of this glacial lake deposited boulder pavement or beach gravels along the shoreline (Chapman and Putnum, 1984).

The Lake Iroquois Plain is located in the bottom third of the watershed and consists primarily of a gently rolling till plain. Soils in this region consist of a mixture of clay, silt and sand deposits, overlaying the Halton Till. These stone-free lacustrine (lake-bottom) soils are fertile and suitable for horticulture and, combined with a diminished lake-effect frost hazard, have typically fared well for orchard crops. The largest relief is provided by drumlins.

In general, watercourse gradients range from 0.6-1.3 per cent with most of the drainage area in the 0.6 per cent. Refer to the Fluvial Geomorphology chapter for further detail.

Watershed Response

The current rural nature of the Carruthers Creek watershed is clearly demonstrated by the response of the basin. This response was specifically observed

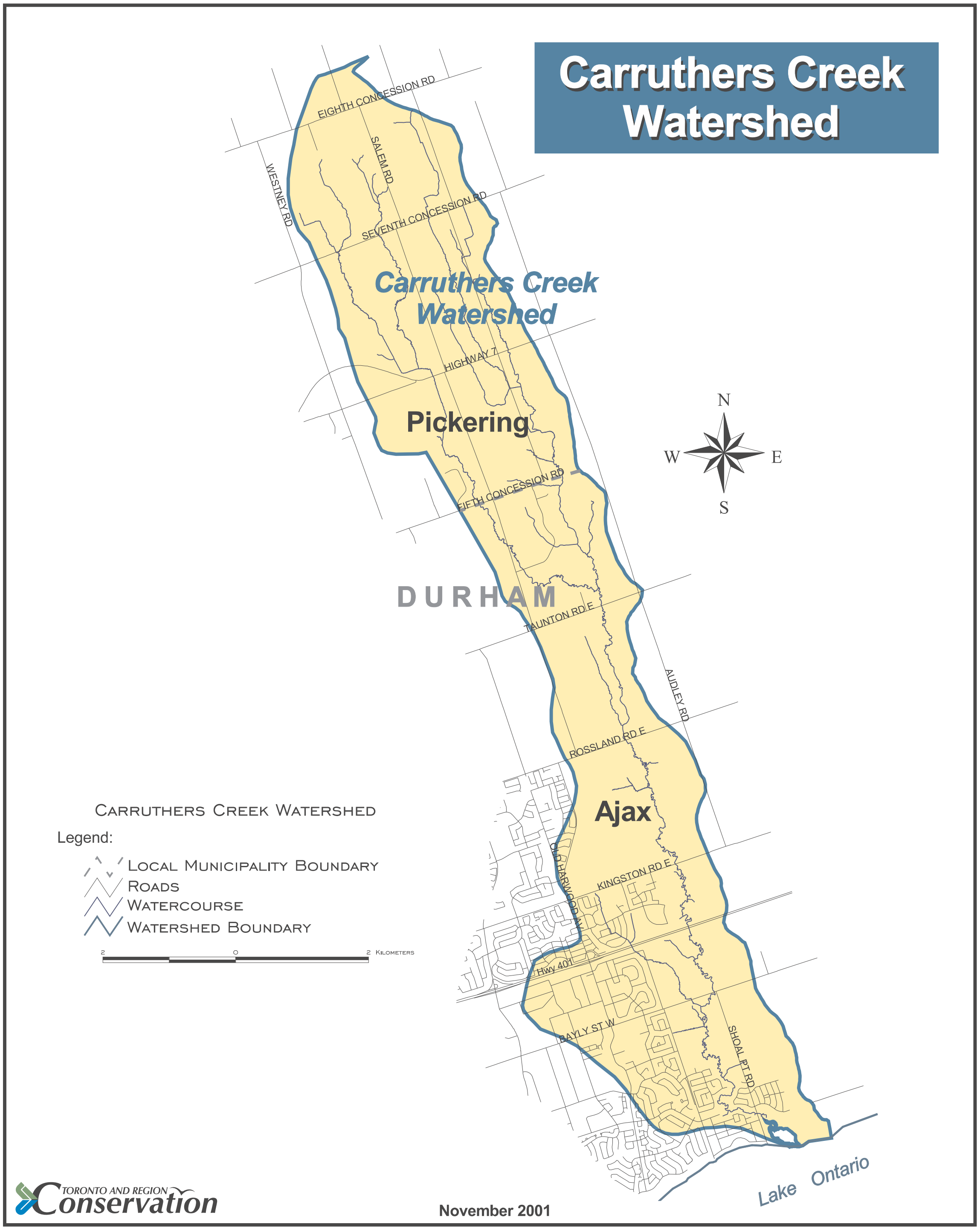

Figure 2:

Location of the Carruthers Creek Watershed Within Municipal Boundaries.

during a large rainfall event of 50-60 mm that occurred on May 13, 2000. The Carruthers Creek took approximately 11 hours to peak with water levels increasing up to 0.6 metres above their normal levels. These water level increases were observed and recorded at a stream gauge that had been recently installed at Shoal Point Road above the Carruthers Marsh (see the section below on Stream Gauges for more details).

In comparison with Duffins Creek to the west, Carruthers Creek took almost the same time to react to this large storm event. The Duffins Creek and Carruthers Creek basins are significantly different both in terms of drainage area and basin shape. The Duffins Creek has a drainage area that is almost eight times larger than the Carruthers Creek basin and the basin is almost as wide as it is long. In comparison, the Carruthers basin is much narrower. The slope of the watersheds is the principal difference that can explain similar basin responses to the same rainfall. The Carruthers Creek watershed has slopes which range from 0.6-1.3 per cent with most of the drainage area in the 0.6 per cent range, while the Duffins Creek watershed is much steeper with a range of 0.8-2.4 per cent with the majority of the basin at or above a 1.2 per cent slope.

Stream Gauges

A stream gauge was installed at Shoal Point Road, north of the Carruthers Marsh, in January of 2000. However, by that summer it was evident that the results from the gauge were not accurate, most likely due to the close proximity to Lake Ontario and the backwater effect it would have caused on the gauge. The gauge was removed from that location and was installed immediately north of Bayly Street in the autumn of 2001. A second stream gauge is planned north of Taunton Road once a suitable site is determined. Together these gauges will record and measure the streamflow which will, in turn, be used to calibrate the hydrology model so that accurate pre-development flows and water budgets can be established. Figure 3 shows the locations of these stream gauges.

Flooding

Flooding is a common and natural occurrence in all watersheds and should not be prevented from happening. Problems with flooding arise when it poses a risk to human lives or property. The best way to prevent these risks from flooding is to establish an adequate naturalized valley and stream corridor, or floodplain, and restrict any development activities within this corridor.

Significant flooding along the Carruthers Creek watershed has been a rare event over the last century, with no recorded information available on flooding within the basin. With urban development in the basin a relatively recent occurrence, information on significant flooding events prior to development would have been restricted to agricultural damages. The slope and size of the drainage basin along with low baseflows restricted the viability of historical mill developments, which were main areas of concern with regard to flooding. Recent flooding problems have principally been restricted to poor landform drainage issues in the area of the watershed that is south of Bayly Street.

Severe tropical storms, such as Hurricane Hazel in October of 1954, and heavy thunderstorms continue to be a threat to southern Ontario. Therefore, flood protection along the watercourse is a necessity to ensure that no new flood prone urban development takes place. Regulations designed to ensure flood protection along the Carruthers Creek continue to be based on these types of severe storms.

Floodplain mapping along with hydrologic and hydraulic studies for the Carruthers Creek were originally undertaken in 1979, with the watershed hydrology and hydraulics recently updated in 1999. Current development initiatives within the basin are not reflected on the base mapping south of Taunton Road, while the base mapping upstream has remained relatively unchanged. Therefore, there is a need to update the base mapping south of Taunton Road and update the floodplain mapping in the watershed at the same time. Digital mapping is required for any future updates.

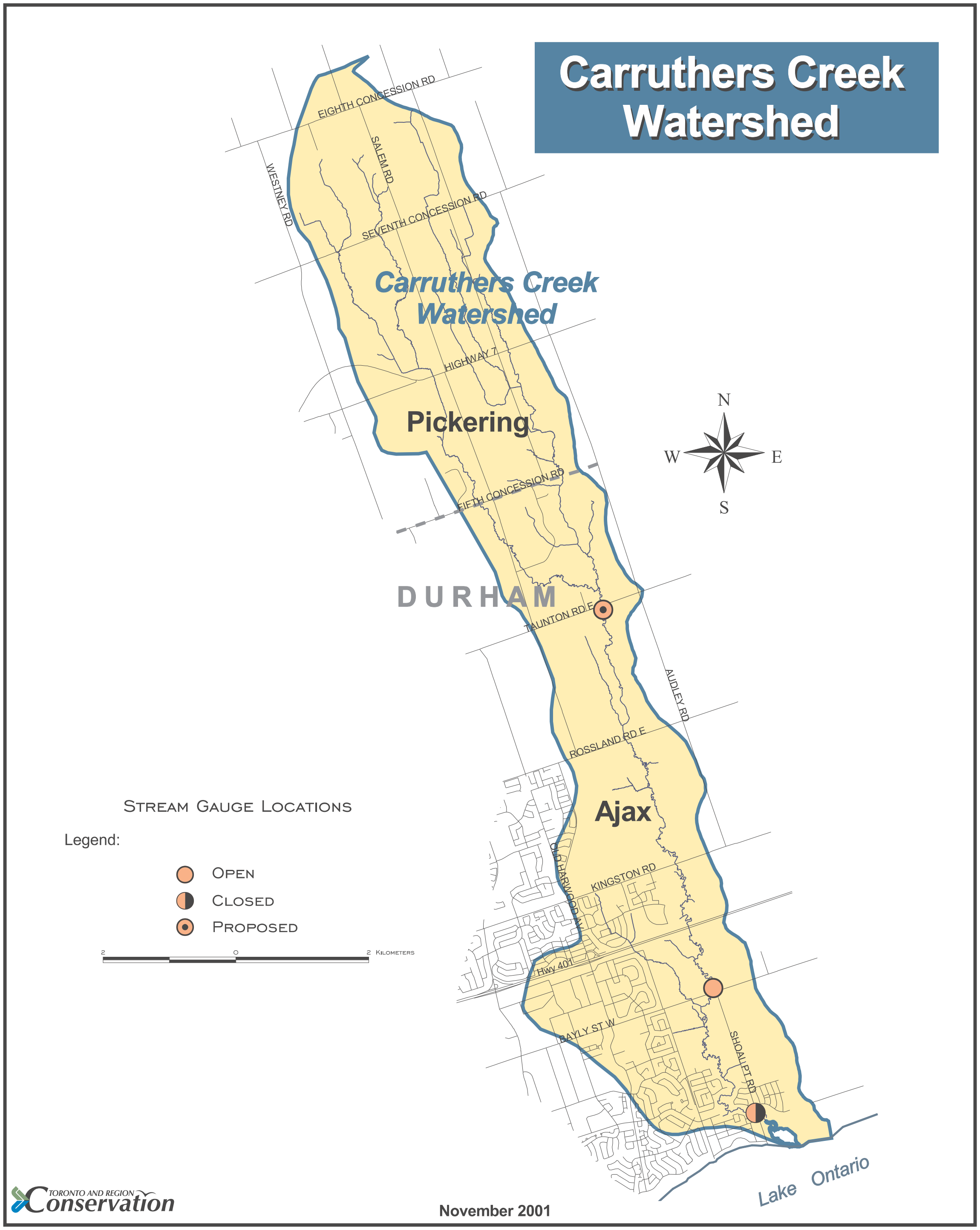

Figure 3:
Carruthers Creek Stream Gauge Locations.

The current hydrology, hydraulics and floodplain mapping identify potential locations of flood vulnerability within the watershed. Current mapping reveals approximately 12 structures and 9 roads where flooding can still be anticipated. These flood-vulnerable areas can be seen on Figure 4, however, these areas may change with the anticipated 2002 mapping update.

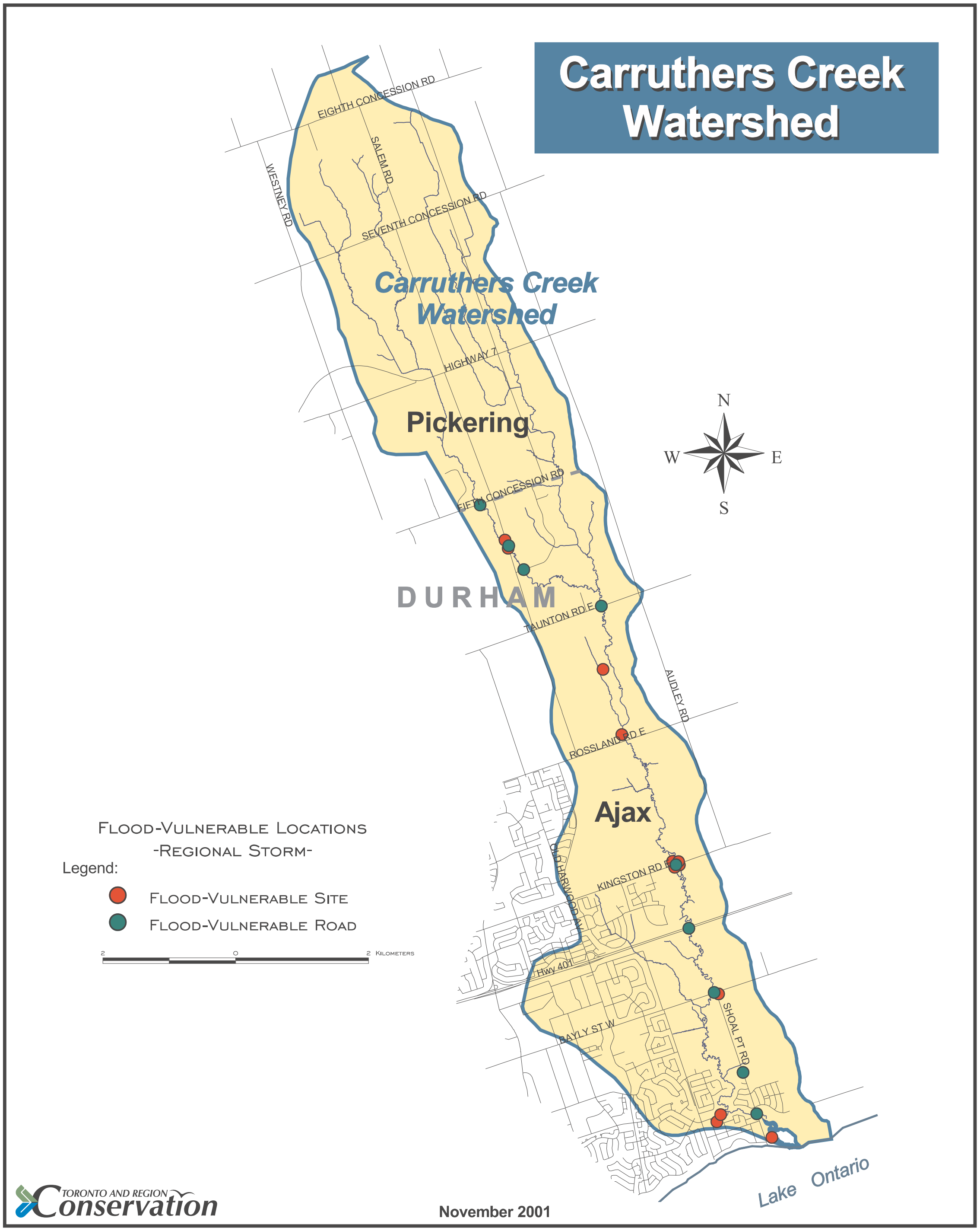

Figure 4:

Flood-Vulnerable Areas Within the Carruthers Creek Watershed.

Summary

The Carruthers Creek watershed has a healthy flow regime with respect to flooding and water quantity. It is one of the last watersheds within the Toronto and Region Conservation Authority's jurisdiction that exhibits typical rural watershed characteristics. Similar to Duffins Creek, Carruthers Creek is capable of handling large storm events, so that high runoff conditions that pose serious flooding concerns in other urban watersheds do not happen as frequently in this rural watershed. Key influences responsible for the rural watershed response include the small amount of urbanization and the large number of natural and terrain features that promote infiltration and reduce stormwater runoff.

The overall basin response for the Carruthers Creek watershed is very similar to the Duffins Creek watershed, even though the two watersheds are very different in drainage area and basin shape. Duffins Creek is more than eight times larger and is as wide as it is long. Conversely, the long, narrow shape and gentle slope of the Carruthers watershed helps to attenuate the flows. These differences in shape and slope serve to counteract one another, resulting in a similar overall basin response when comparing these two watersheds.

Significant flooding along the Carruthers Creek watershed has been a rare event over the last century, with no recorded information available on flooding within the basin. Historic flooding damages were restricted to agricultural areas, while more current flooding issues have principally been restricted to poor landform drainage issues in the south end of the watershed. Current mapping reveals that 12 structures and 9 roads are susceptible to flooding. These flood vulnerable areas will be evaluated with future growth scenarios.

Unlike Duffins Creek, streamflow in the Carruthers Creek has never been historically measured. One stream gauge has been recently installed, and a second installation is anticipated. Together, these gauges will measure the streamflow, which will in turn be used to calibrate the current hydrology model. This model, along with low flow investigations and a detailed understanding of the hydrogeology, geology and geomorphology, provides an excellent position from which to manage the water resources of Carruthers Creek.

The Toronto and Region Conservation Authority is currently undertaking the development of a water budget model for Carruthers Creek. This study, along with the calibrated hydrology model and monitoring data, will be used to establish infiltration targets, flood and erosion control criteria as well as to design stormwater management systems.

References

Central Lake Ontario Conservation Authority, 2001. *Oshawa Creek Watershed Management Plan: Existing Conditions Report.* May 2001 (draft). Oshawa, Ontario.

Chapman, L.J. and D.F. Putnam, 1984. *The Physiography of Southern Ontario.* Ontario Geological Survey, Special Volume 2.

Gerber, R.E., 1999. *Hydrogeologic Behaviour of the Northern Till Aquitard Near Toronto, Ontario.* Doctoral thesis, Department of Geology, University of Toronto, Toronto, ON, Canada. 253p.

Totten Sims Hubicki Associates, 1991. *Carruthers Creek Master Drainage Plan.* A Final Report for the Town of Ajax and the Metropolitan Toronto Region Conservation Authority.

Totten Sims Hubicki Associates, 1995. *Carruthers Creek Stormwater Management Strategy - Synopsis Report.* A Final Report for the Town of Ajax and the Metropolitan Toronto Region Conservation Authority.

Totten Sims Hubicki Associates, 1999. *Carruthers Creek Stormwater Management Strategy - Addendum No. 1 - Carruthers Creek Modelling Review.* A Final Report for the Town of Ajax and the Toronto and Region Conservation Authority.

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Carruthers Creek

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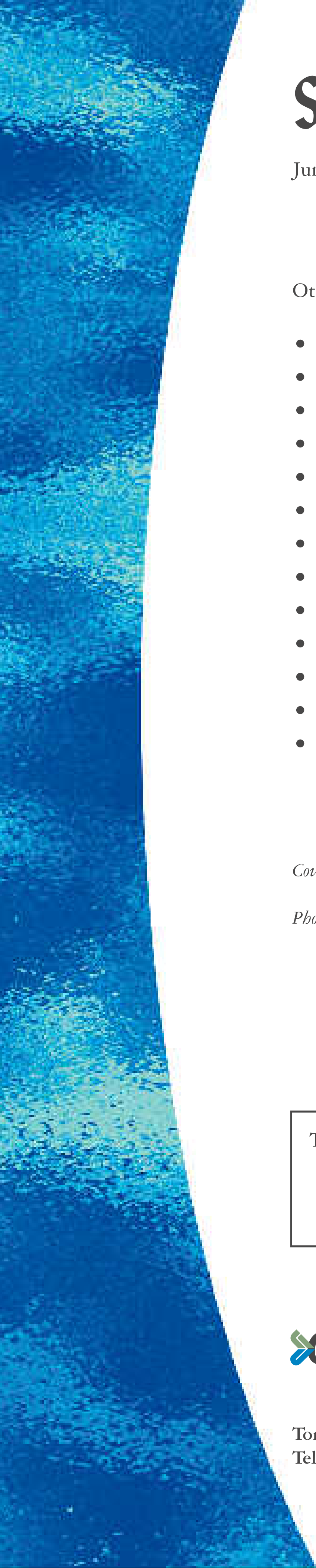
Stormwater Management



Stormwater Management

June 2002

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Cover photograph: A storm sewer inlet during a rain storm.

Photo credit: The Toronto and Region Conservation Authority

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Introduction to Stormwater Management

Stormwater management practices have evolved over the last 20 years as a result of an increased awareness and knowledge about the benefits of stormwater management and as a result of technological developments. As such, management practices used today provide a higher level of protection for the environment, property, and residents. Prior to the 1980s, stormwater management strategies focussed on the need to convey runoff to the local watercourses as quickly and efficiently as possible. The objective of stormwater controls during this time was for the provision of flood control, or quantity control. As a result, watercourses were modified through armouring, or concrete lining, to accommodate an increase in flow volume and velocity. These reactionary measures led to a decline in the health of river ecosystems through a reduction in terrestrial and aquatic habitat, a reduction in water quality levels, and increased rates of erosion where watercourses were left in their natural state.

A further decline in the health of the local and regional ecosystems was experienced as a direct result of the intensive urbanization throughout the Greater Toronto Area (GTA) since the 1980s. The realization that urban stormwater runoff was contributing to the decline of our river systems, lead to a shift in stormwater management practices. Although flood control remains one of the main objectives, stormwater management strategies now incorporate provisions for the control of water quality, protection of fish habitat, and control of in-stream erosion.

The Carruthers Creek Watershed is unique in that only 13 per cent of the watershed is currently developed. Existing development within the watershed is concentrated within the Town of Ajax and the City of Pickering. In order to mitigate the impacts of proposed, future development, it is imperative that appropriate stormwater criteria be in place to define the levels of water quantity, quality and erosion control that is required. The development of this criteria at a watershed and subwatershed scale is recommended, while recognizing that further refinement may be required at a later date to address site-specific or local concerns within the watershed.

Roles and Responsibilities

The federal government, through Environment Canada has supported research and development of new technologies and scientific advances in the treatment of urban runoff. Partnership programs like the Storm Water Assessment Monitoring and Performance Program (SWAMP) are initiated and financially supported by Environment Canada. The objective of this program is to evaluate both new and traditional stormwater management practices and to distribute the findings of their studies to relevant stakeholders.

Additional funding programs, including Great Lakes Clean Up Fund and Great Lakes Sustainability Fund, have also been made available by Environment Canada over the past few years. Projects funded through these initiatives aim to assist in the remediation of priority areas in the Great Lakes basin, including opportunities for stormwater remediation. The Toronto Area of Concern (AOC) covers a large geographical area from Etobicoke Creek in the west to the Rouge River in the east. However, given the relatively healthy state of the Carruthers Creek watershed, in relation to other GTA watersheds, Carruthers Creek is not included in the Toronto AOC and is therefore, not eligible for federal funding programs. Government funding is currently made available only to those watersheds that are already degraded and is not available to maintain or improve the health of an already healthy watershed like the Carruthers Creek. There is a need for flexibility on the part of the Federal Government so that funding resources may be distributed over a larger geographical area, benefiting a greater number of individual watersheds and optimizing the overall benefits achieved.

Environment Canada is also responsible for administering Section 36 of the Federal Fisheries Act. This section is in place to prohibit the deposit of any deleterious substance into water bodies that are inhabited or frequented by fish species. Although the existing fine structure is designed to serve as a deterrent (the fine for a first offence is $200,000), charges are rarely laid under the Act because of limited inspection and enforcement at the Federal level. In turn, these are among the development industry do not feel compelled to comply with the Act knowing that charges are seldom laid. Further effort is needed to ensure compliance and additional effort should be made to inform people, that as individual citizens they too have the legal power to press charges under Section 36 in the event that they witness a violation.

The role of the provincial government, with respect to stormwater management, has changed over the last five to ten years as a result of restructuring within various Ministries. Both the Ministry of Natural Resources (MNR) and the Ministry of the Environment (MOE) were previously involved in the day to day review of stormwater management strategies. In the mid 1990s the roles of both ministries were modified so that the MNR is no longer a part of the plan review process; however, MNR continues to issue permits under the Lakes and Rivers Improvement Act. The MOE is only involved in the review process through their approvals branch. The approvals branch is responsible for issuing Certificates of Approval under Section 53 of the Ontario Water Resources Act; however in a number of areas, the MOE has transferred this responsibility to the local municipalities. Inspection and enforcement at the provincial level is also a problem because of staffing and priority issues.

The MOE has also been involved in policy development, through the completion of the Stormwater Management Practices Planning and Design Manual (SWMP). The manual was originally published in 1994 and its intent was to be used as a guideline document for the design and review of stormwater management plans. Subsequent to this document, a draft document was produced in 1999 to update the existing information and to provide additional guidance related to erosion considerations and water balance assessment. The 1999 draft document is currently being applied on an ad hoc basis by private consultants and approval agencies. Given the evolving nature of the technology associated with stormwater management, it is possible that a number of measures and treatment options described in the 1999 document may already be outdated. Design solutions should not be limited to those recommended in the SWMP manual, but should reflect current, state of the art technology.

The local municipalities have legislative authority over the review of stormwater management strategies via the Planning Act, the Municipal Act, the Local Improvements Act and the Topsoil Preservation Act. Various municipal departments are involved in the review of stormwater management plans with each department giving concern for different aspects of the plan. The engineering department is concerned with infrastructure and municipal standards and is also interested in implications for operations and maintenance requirements. Planning staff review management plans to ensure adherence to the municipality's Official Plan and any planning amendments. Parks and Recreation staff want to ensure that the management plan does not encroach on park space and they are also interested in implications for operations and maintenance. Given these varied interests, there is a need for municipalities to adopt an integrated approach in the review of stormwater management plans to ensure the overall integrity of the plan and to guarantee the protection of valuable downstream resources.

In addition, municipalities should work towards adopting new policies which reflect commitment to good drainage practices. One example includes a policy currently being developed between certain municipalities and the Toronto and Region Conservation Authority (TRCA). The new policy will allow the TRCA, or the municipality, to collect a financial contribution, in lieu of stormwater controls, where it has been demonstrated that it is not practically or physically feasible to achieve the desired level of stormwater control. Generally this policy will be applied to small sites (less than five hectares) or for applications relating to infill development. In turn, the financial contribution is then used for rehabilitation/remediation efforts within the watershed or subwatershed. In the past, TRCA has required water quality control for these sites; however, it is felt that a financial contribution will ultimately result in a greater benefit to the watershed as a whole.

Municipal by-laws, implemented under the various acts previously mentioned, are adopted by municipalities as a means to govern specific aspects of municipal concern (i.e. erosion and sediment control by-laws, zoning by-laws, sewer-use by-laws). Adherence to the by-laws is controlled by enforcement or by-law officers working for the municipality. However, the effectiveness of enforcement is often negligible given that the majority of municipalities have very few enforcement officers. Infractions often go unnoticed because officers are not able to perform the necessary inspections to ensure compliance with municipal by-laws.

Local conservation authorities (CA) review stormwater management plans as part of their role as an approval agency under the Planning Act. CAs review management plans to ensure that the proposed development will not affect the overall integrity of the natural environment and to ensure compliance with Authority policies. Specific areas of concern include water quality, floodplain management, erosion control, fisheries management, natural heritage and ecological function.

In an effort to focus its efforts on setting policy direction at the watershed level, the TRCA is currently working with local municipalities on a number of initiatives in an effort to streamline the day-to-day review of stormwater management plans. This initiative will eliminate the current duplication of effort that exists between municipalities and the TRCA in the review of detailed stormwater management plans.

Conservation Authorities are also responsible for issuing permits under Regulation 158 of the Conservation Authorities Act. This regulation stipulates that a permit is required where a proponent proposes to construct or alter a building or structure located within the Regional Floodplain; place or dump fill material within a fill regulated area, or; straighten, divert, or modify an existing watercourse. With respect to enforcement, local CAs have limited legislative authority, having the power to enforce only those works for which a permit is granted under Regulation 158.

Other key players in the stormwater management process include the developers, consultants and home owners. Developers are bound by current policy and guidelines to provide a certain standard of stormwater protection for new development areas. Developers then rely on private consultants to undertake the design work for the site, including the stormwater management strategy. These players are often seen as the leaders in innovative design techniques and are responsible for ensuring that current stormwater management practices reflect the best available technology.

The role of home owners in the overall process is significant because they have the ability to provide valuable stormwater protection at the source. Increased effort is needed to provide incentive programs and educational outreach to ensure the highest level of source protection is implemented in both new and established communities.

Impacts of Urban Runoff

Significant documentation exists which outlines the hydrologic, physical and ecological impacts that result from the process of urban development. As natural landscapes are modified and paved to accommodate residential, industrial or commercial development, the health of the local ecosystem is seen to decline. Current stormwater management practices are designed to mitigate these impacts.

The most significant change to the natural environment during the process of urban development is the conversion of natural, pervious surfaces to impervious surfaces which then prevent water from infiltrating into the soil. Impervious surfaces include roads, sidewalks, driveways, rooftops, and parking lots. Schueler (1994) notes that channel instability and habitat degradation begin to occur when the percentage of impervious cover in a watershed reaches 10 to 15 per cent. Associated with an increase in impervious cover, is an increase in runoff volume and velocity and a decline in infiltration potential. Figure 1 illustrates the differences in the hydrograph response between an undeveloped and a developed watershed. These changes, in turn, lead to increased instream erosion and a reduction in groundwater recharge and annual baseflow within local water courses (Arnold and Gibbons, 1996).

Changes to the hydrologic regime ultimately impact the physical state of the watercourse. As the energy within the system increases, given the higher velocities and volumes of flow, the natural rates of erosion and sedimentation also increase, resulting in a loss of riparian vegetation and instream habitat, an increase in water temperature and a change in channel morphology.

In addition to the water quantity impacts, water quality is also affected as natural landscapes are modified for urban development. A number of nonpoint source pollutants exist in an urban environment including heavy metals (zinc, cadmium, copper), pesticides, nutrients (phosphorous), toxic contaminants, pathogens (escherichia coli) and debris. Vegetation plays an important role in naturally filtering sediments and removing pollutants from overland flow; however, as vegetation is removed and replaced with paved surfaces, this form of natural protection is removed. The importance of stormwater management in removing these pollutants is critical given that millions of people in the GTA rely on clean water from Lake Ontario or from private wells for drinking water supplies and other domestic uses.

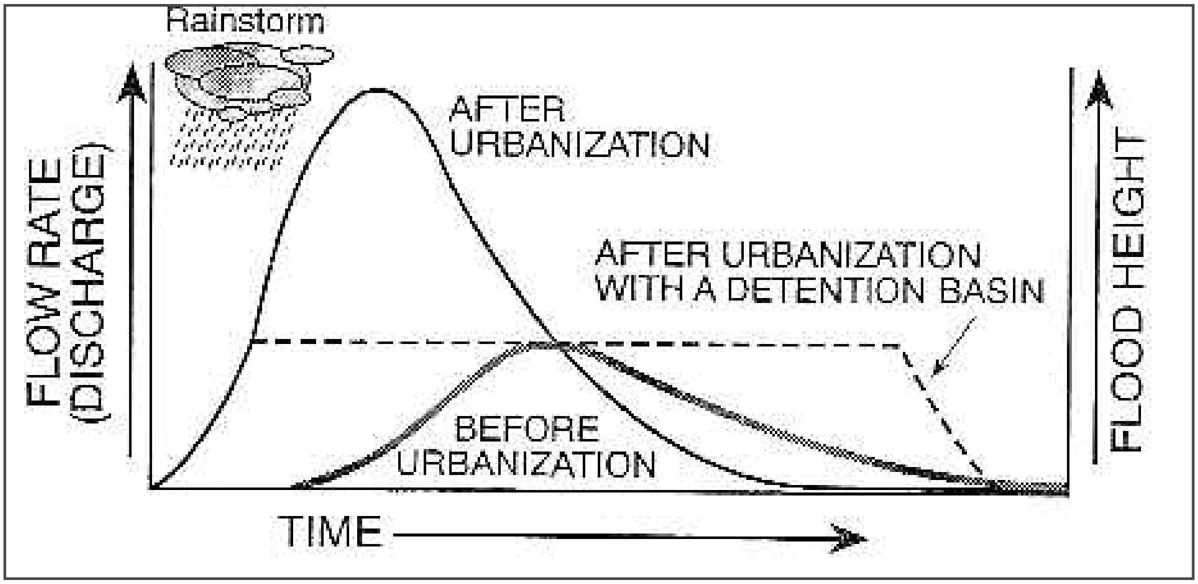

Figure 1

Impact of Urbanization on Stormwater Rates and Volumes

In 1999, a study was carried out in the GTA to characterize the discharge from six local tributaries to Lake Ontario. Although the Carruthers Watershed was not a part of the study, the results are indicative of pollutant loads throughout the GTA. A total of 76 parameters were monitored throughout the study, including nutrients, bacteria, metals, pesticides, polynuclear aromatic hydrocarbons and volatiles. Of the 76 parameters, the following eight parameters were selected as indicators: suspended solids, total phosphorus, escherichia coli, copper, lead, aldrin/dieldrin, phenanthrene, and total polychlorinated biphenyl. An analysis of the results indicated that, under wet weather conditions, all indicator parameters were consistently in exceedence of Provincial Water Quality Objectives (excluding suspended sSlids for which there is no PWQO). The study conclusions state that "stormwater management remains the single most important means of improving water quality in Toronto tributaries as well as the harbour and localized areas of Lake Ontario" (Boyd, 1999).

Best Management Practices

A wide variety of structural and non-structural best management practices are used in the design of stormwater management strategies in order to achieve the desired level of stormwater control. The adoption of a "treatment train" approach including, lot level, conveyance, and end-of-pipe controls is considered the most effective approach to the management of urban runoff because it ensures a wide range of opportunities for the implementation of protection measures. Traditionally, best management practices are often engineering structures, costly to construct and maintain, and are designed for mitigation purposes. Each form of control is designed to treat stormwater, before entering the receiving watercourse, through a settling or infiltration process and through the attenuation and reduction of flow volumes and velocities.

Additional efforts are required to identify best management practices which require fewer resources, involve a greater number of stakeholders and which focus on keeping the water as clean as possible from the moment it falls to the ground (at the source) to the time it enters our streams and rivers. Keeping the water clean at the source, will help to alleviate liability and financial strain on municipalities for operations and maintenance, reduce development costs related to engineering structures and ultimately result in improved watershed health. These efforts will depend on the cooperation of all stakeholders, including homeowners, developers, consultants, contractors and government agencies to make changes in their day-to-day management practices, development standards, operating procedures and lifestyle choices.

The following sections outline the best management practices available at the source, during conveyance and at the end of pipe.

Lot Level (Source) Controls

Lot level controls are designed to treat surface runoff at the source, where rain falls to the ground. Source controls are significant for reducing pollutant loads to local water bodies partially through their ability to promote the infiltration of runoff at the site, rather than having runoff leave the site, where sediments and other contaminants are normally picked up along the roadways and other conveyance routes. Source control measures can be structural or nonstructural in nature or may depend on soil characteristics, land use, size of individual lots, and municipal acceptance. Source control measures are particularly useful for their water quality benefit and ability to reduce downstream peak flows and should be recognized for their applicability in retrofit situations where other measures may be too land-intensive.

A study commissioned by the City of Toronto in 1999 presented a number of alternate measures that could be used for source control whether it be a residential, commercial, or industrial lot; a number of these measures are outlined below. The study suggested that municipalities should take a leadership role in showcasing innovative control measures and educating the public, and should encourage partnership and incentive programs where feasible (J.F. Sabourin and Associates, 1999). For further information relating to the following source control measures, readers should consult the City of Toronto report and the 1999 MOE Draft SWMP Manual.

Structural Practices

Downspout Disconnection

Average annual runoff from a typical residential roof could be used to flush a low flow toilet 12,000 times! (J.F. Sabourin and Associates, 1999)

- reduces volume of flow to sewer system and reduces size requirements for end-of-pipe facilities
- reduces frequency of basement flooding caused by sewer back-up
- reduces occurrence of combined sewer overflows (where applicable)
- promotes infiltration
- need for municipal incentives (i.e. disconnection free to residents) and development standards (i.e. by-laws) to require disconnection in new subdivisions

Rainbarrels

- promotes water conservation
- savings on utility bill - rain water can be used for watering lawns, gardens and indoor plants or for washing cars
- need for municipal incentives (i.e. cost recovery)

Backyard Ponds

- promotes water conservation
- reduces volume of flow to sewer system (if pond fed by downspout or rainbarrel)
- encourages wildlife habitat

Pervious Pavement

- promotes infiltration and underground storage
- reduces peak flow to sewer system through slow release

Tree and Vegetation Planting
- increases transpiration and evaporation rates as rainwater is captured by vegetation
- infiltration enhanced as plants absorb rainwater
- vegetation acts as natural filter removing pollutants and absorbing nutrients

Infiltration Trenches
- promotes infiltration by directing runoff to areas constructed with pervious material (i.e. granular stone)
- reduces volume of flow to the sewer system

Rooftop Gardens
- reduces volume of runoff to sewer system (where roof leaders are connected)
- saves money by reducing utility bill for heating and air conditioning costs
- promotes improved air quality because of filtering effect of vegetation

Parking Lot and Rooftop Storage
- reduces downstream peak flows
- may reduce required sewer sizes therefore reducing overall infrastructure costs
- applicable for infill development

Nonstructural Practices

Lawn Aeration
- urban soils are considered to be as impervious as paved surfaces due to compaction and often produce more runoff (Schueler, 1995)
- enhances infiltration of runoff
- beneficial to root systems of vegetation and promotes improved growth

Animal Waste Collection
- need for municipal by-laws
- encourage poop and scoop practices
- reduces potential for water quality impacts and eutrophication in water bodies because of presence of faecal bacteria and nutrients in pet waste

Car Washing Practices
- washing cars on gravel or grass surfaces to promote infiltration
- use biodegradable soaps
- use commercial car wash where water is recycled or treated

Municipal By-laws
- adoption of by-laws which support measures to clean up urban runoff (i.e. sewer use, topsoil preservation, erosion and sediment control, zoning, poop and scoop, water conservation)

Education/Public Relations
- municipalities should showcase alternative measures on municipal buildings/property
- need to educate residents regarding connection between their property and downstream water quality impacts – encourage environmental stewardship and lifestyle choices
- distribution of flyers, television and print ads, inserts in utility bills

Alternative Development Standards
- need to promote sustainable development - reduce ecological footprint
- need to weigh economic, social and environmental benefits associated with "traditional" development standards (i.e. curbs, gutters and storm sewers, large lots, front yard setbacks) with alternative development standards (i.e. cluster development, preservation of green space, natural drainage patterns, smaller, narrower lots)

Landscaping Practices
- Supreme Court of Canada has made it legally acceptable for municipalities to ban pesticide use on municipal and private properties (excluding golf courses)
- need for strict guidelines for use of pesticides on golf courses (i.e. licence from the MOE)
- improve water quality through reduced use of pesticides and fertilizers on urban lawns – majority of people do not know the phosphorus or nitrogen content of the fertilizer they apply

and only 10-20 per cent of people take soil tests to determine whether or not their lawn needs fertilization at all! (www.stormwatercenter.net)
- encourage lawn owners to compost grass clippings and leaves or to leave on the lawn to reduce the need for fertilizers
- encourage use of native species which are water and maintenance friendly
- encourage off peak watering and efficient water use

Road Maintenance and Street Sweeping Practices

- roadways (collectors and residential feeder streets) contribute highest levels of runoff-borne pollutants from impervious surfaces including *E.coli*., sediments, cadmium and copper (Arnold and Gibbons, 1996)
- municipal practices should be reviewed and modified to reflect environmental objectives
- limit amount of de-icing chemicals or road salts applied during winter driving conditions where possible
- encourage use of stormwater management practices within right-of-way limits

Government Policy

- Official Planning documents, Development Improvement Standards should reflect support for alternative stormwater protection measures
- need for legislation which allows municipalities to recover costs for long term operation and maintenance (i.e. allow for provisions in Development Charges Act)

Conveyance Controls

Conveyance control measures are designed to treat stormwater runoff as it is conveyed from the source to the end of pipe (i.e. along roadways and in storm sewers). Conveyance controls are generally designed to promote natural infiltration and reduce downstream peak flows. It is important to note that typical infiltration methods may not be feasible for the treatment of road runoff within the Carruthers Creek watershed because of the potential to impair the quality of sensitive groundwater resources. Innovative design techniques, as described below, will need to be considered for road construction and reconstruction projects.

An Evaluation of Roadside Ditches and Other Related Stormwater Management Practices

The use of alternative conveyance measures for urban road drainage was assessed in a study commissioned by the TRCA in 1997. The study, entitled An Evaluation of Roadside Ditches and Other Related Stormwater Management Practices was intended to evaluate the effectiveness of several alternative road drainage systems with regards to water conveyance, water quality treatment, safety, public attitudes, economics, planning requirements and groundwater recharge.

Alternatives considered:

- curb and gutter with catch basins and exfiltration system
- curb and gutter with backyard swales
- roadside ditches with raised culverts or check dams
- grassed swales with perforated pipes and infiltration trenches

Study findings:

- overall costs for some alternative drainage systems may be less than originally perceived and may be less than traditional curb and gutter systems
- peak flow reduction could be matched or exceeded by some alternative drainage systems
- municipalities were willing to consider the use of alternative systems for new development or retrofit situations
- acceptance of alternative systems may be affected by public opinion and perception
- alternative drainage systems are effective in terms of water quality protection, however additional monitoring is recommended

Performance Assessment of a Swale and Perforated Pipe Stormwater Infiltration System

An additional study, Performance Assessment of a Swale and Perforated Pipe Stormwater Infiltration System, was recently carried out to assess the performance of an innovative swale and perforated pipe infiltration stormwater system that was constructed in a residential neighbourhood in the City of Toronto. The existing, ditched road network within the community was replaced with a grass swale and underground infiltration trench with a standard roadside curb and gutter. The intent of the stormwater management system was to reduce runoff and peak flows, and to enhance the quality of stormwater runoff.

Study Findings:

- average runoff reduction of 91 per cent
- majority of rainfall events less than 5.5 mm produced negligible runoff due to storage and infiltration components within the system
- observed reduction in flow was primary factor in achieving 70 per cent load-based removal efficiencies for several key water quality parameters

Some of the typical conveyance control measures, currently being used in limited application within the GTA, include the following:

Grassed Swales

- typically associated with rural drainage
- used to filter and detain runoff
- useful where space constraints exist

Pervious Pipes/Catch Basins

- sewer system uses pervious pipe to promote exfiltration as runoff is conveyed to local watercourse
- should be used in combination with pre-treatment measures to reduce high levels of sediment
- catch basins connected to exfiltration storage media

Filter/Buffer Strips

- applicable for small drainage areas
- combination of flow spreaders and vegetation (natural or planted) to promote infiltration, filter pollutants, provide shade and reduce overland flow velocities

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End-of-Pipe Storm Water Facilities

End-of-pipe stormwater management facilities receive stormwater runoff from conveyance systems and are designed to release the treated water to the receiving watercourse at a predefined rate of flow. Early stormwater management practices, prior to the 1980s, were designed to provide water quantity control for a particular development area and generally consisted of large, dry ponds. Over the last 10 years, the focus of water management has shifted from being relatively site specific, to the adoption of an ecosystem approach. Along with this new approach came the need for evolving stormwater management measures which not only addressed the issue of flooding, but also addressed water quality and erosion concerns.

Design criteria for end-of-pipe facilities is generally outlined in watershed plans, or in the absence of these plans, criteria will be based on the condition/sensitivity of the receiving water course as determined through a secondary planning study for a particular development area. End-of-pipe facilities should be used in conjunction with lot level and conveyance controls to reduce the total pond volume required.

Various techniques are available and should be carefully assessed, keeping in mind the desired level and type of control. Often, water quality, quantity and erosion control can be achieved using a single facility; however, some techniques (i.e. infiltration trenches, filters) are better suited for quality control and have limited application for recharge, erosion control or quantity control.

As development in the GTA continues at a steady rate, the required number of stormwater management facilities is also increasing. In turn, numerous municipalities have developed landscape and design guidelines in an effort to integrate these engineering facilities into the overall appeal and landscaping plans associated with new subdivisions (Paul Wisner and Associates Inc., 1994). The intent of the guidelines is to provide design ideas which will maximize the aesthetic value and recreational opportunities of these facilities. The idea is to turn, what was once considered an engineering structure, into an attractive amenity, a local green space with a trail system, park benches, picnic areas, wildflower gardens, and interpretive signage.

End-of-pipe controls

Wet Ponds

- most common type of end-of-pipe facility in Ontario
- incorporates a permanent pool component
- less land intensive than wetland facilities
- can provide water quality, quantity and erosion control

Wetlands

- incorporates a shallow permanent pool component
- can provide water quality, quantity and erosion control
- requires greater area of land than wet pond

Dry Ponds

- typically used for quantity control only
- uses less land area that wet ponds and wetlands
- no permanent pool component
- resuspension of sediments is a concern

Hybrid Wet Ponds/Wetlands

- combination wetland and wet pond
- includes a deep water component and a shallow water component
- provides greater biological uptake and less thermal impact during summer months

Infiltration Basins/Trenches

- should be implemented for small drainage areas
- infiltration system is designed to treat multiple lots

Special Purpose Controls

Special purpose controls are measures designed to provide quality control of surface runoff and are generally implemented in areas where there is a significant risk of spills or where pretreatment is desirable.

Examples of special purpose controls include ultraviolet disinfection units, and various types of oil/grit separators. These measures are most efficient when used in conjunction with other treatment techniques.

Monitoring

In addition to the need for a comprehensive stormwater management strategy that incorporates all aspects of the treatment train, is the need for continued monitoring, at various scales, to assess individual performance capabilities and the overall benefit of stormwater management practices at a watershed scale.

Routine operation and maintenance work can be used to verify whether or not performance measures are operating as designed, and to ensure that maintenance of the measures is being carried out. Where problems are identified, control measures can be modified accordingly or additional measures put in place, so that the level of control is improved.

In addition, monitoring programs, like the TRCA Regional Monitoring Network can be used to assess the benefit of stormwater management practices in the context of the subwatershed or watershed. At this scale, monitoring results can be used to track the biological responses of a watercourse, downstream of any stormwater control facilities and to assess the cumulative benefits within the system.

The SWAMP program, previously discussed, was initiated in the 1990s to undertake monitoring work of stormwater management technologies and to distribute the findings of their work to relevant stakeholders. To date, SWAMP has monitoring a representative group of source control measures, end-of-pipe facilities and conveyance measures. It is recognized that additional studies is required to substantiate any performance claims and to enable recommendations for improvement or modification to be made. Monitoring strategies must specify not only the parameters to evaluate, but should also specify the relevant stakeholders and the parties responsible in the event that performance problems are discovered.

Operations and Maintenance

Tied to the monitoring component is the need for proper operation and maintenance of stormwater management measures. Source control measures implemented on private property are the responsibility of the property owner, unless an easement is granted to the municipality in which case, the municipality would be responsible. Proper operation and maintenance will be depend on the owner's commitment and understanding of the need for the protective measure, as well as their understanding of the implications in the event of a malfunction.

For the most part, conveyance and end-of-pipe measures are the responsibility of the developer during the time of construction and up until the site has been stabilized (generally within 2 years after construction is complete). Proponents constructing end-of-pipe facilities are required to obtain a Certificate of Approval from the Ministry of the Environment for all new stormwater facilities and a permit from the local conservation authority (for construction of the storm sewer outfall adjacent to the watercourse). Conditions set out in these certificates generally stipulate that the facilities must be maintained prior to assumption by the municipality to ensure that they are functioning as designed. A number of problems have been identified with this system. First, most municipalities do not have copies of the certificates and therefore do not know exactly what requirements the proponent is required to carry out. Second, it is not clear who is responsible for ensuring that the works, agreed to as a condition of the certificate of approval, have in fact been carried out by the proponent.

Up until the late 1980s, the majority of stormwater facilities were dry facilities which were less maintenance intensive. However, newer facilities are generally designed with a permanent pool component designed to remove sediments from urban runoff, and therefore, will eventually require that the sediments be removed to maintain treatment effectiveness. The need for pond maintenance is a growing concern as these facilities age and collect more sediment. Municipalities, as owners of these facilities, are facing substantial operating and maintenance costs for stormwater infrastructure. The Development Charges Act (DCA), originally enacted in 1996 and revised in 1997, allows municipalities to recover 70-90 per cent of the net capital costs for essential services required as a result of growth within their municipality (www.mah.gov.on.ca/inthenews/backgrnd/961125ae.asp). Services which qualify under the Act include roads, sewers, stormwater management facilities, transit, fire services, police services, libraries, and recreation facilities. The DCA does not allow a municipality to collect money for the long-term operation and maintenance of stormwater related facilities.

Very little documentation exists which outlines guidelines for maintenance of best management practices and any literature that does exist, generally relates to end-of-pipe facilities. The MOE SWMP manual suggests that end-of-pipe facilities should be cleaned out when the removal efficiency has been reduced by 5 per cent. Greenland International Consulting Inc. carried out a study for TRCA in 1999 to evaluate removal and disposal options for stormwater facilities. In order to prepare for maintenance costs, the Storm Water Management Facility Sediment Maintenance Guide identified that budget allocations should be requested as soon as a facility is constructed, or collected annually until maintenance of the facility is required. A unit cost of $65.00 per cubic meter of sediment was estimated.

Municipalities require more comprehensive data to substantiate requests for specific budget allocations and staffing requirements. A recent initiative by the Water Environment Research Foundation (WERF), a US based research organization, and United Kingdom Water Industry Research Limited, serves as an excellent example of the type of information required of any long-term study in this area. These organizations have recently partnered to undertake a 5 year study which will examine both the capital costs, and the costs associated with the operation and maintenance of urban best management practices. In addition, the study will evaluate the effectiveness of various BMPs in achieving improved water quality, through pollutant removal; will assess BMP performance in terms of hydrology/hydraulics, and; will also identify other ecological benefits associated with the use of good drainage practices (www.werf.org).

Erosion and Sediment Controls

Erosion and sediment control is an important aspect of stormwater management as it applies to the control of runoff during construction activities, a time when natural erosion rates can increase anywhere from 100 to 1000 times (MTRCA, 1994) and water quality is at its worst. A number of provincial guidelines currently exist which are well known to the development industry. Information contained in these documents include an overview of the problems associated with erosion and sediment control, a review of the existing legislative framework and descriptions and illustrations of proper installation techniques for a number of protection measures.

In addition to the guideline documents, a number of studies have been carried out since the late 1980s in partnership between various levels of government, local municipalities and the private sector to address the issue of erosion and sediment control including deficiencies in the system and recommendations for improvement. Most recently, TRCA completed the Urban Construction Sediment Control Study (Greenland, 2001) which was intended to monitor three active construction sites to evaluate the effectiveness of the erosion and sediment control measures, increase awareness of the issue, and make recommendations for improvement to the design and review process.

The findings from the TRCA study reaffirmed that current erosion and sediment control practices still result in a significant amount of sediment entering adjacent watercourses, and that water quality and instream habitat is being impaired as a result. Some of the main problems identified include a lack of understanding for the need for erosion and sediment control measures, confusion regarding responsibility and liability for the measures, a lack of enforcement by municipalities and government agencies, improper installation techniques and timing of installation, improper design of erosion and sediment control plans, and a lack of regular inspection and maintenance.

The TRCA study also included an evaluation of the design and review process relating to erosion and sediment control as a condition of draft plan approval. On any given site, construction progress may or may not proceed as planned given that it is ultimately influenced by housing sales within the development. The erosion and sediment control plan should be revised accordingly to reflect construction changes as they will govern the timing, location and implementation of erosion and sediment control measures. This process of revision is not a current practice in the development review process.

The responsibility for implementation, inspection and maintenance of the erosion and sediment control measures is not clearly defined. The developer, who owns the land hires a consultant to undertake the design work for the project including the erosion and sediment control plan. The consultant, in turn hires a contractor to carry out the physical construction activity on site. The contractor carries out the installation of the erosion and sediment control measures, but who is ultimately responsible for ensuring that they function properly over the course of the project? Is the contractor responsible because they installed it? Or is the consultant responsible because they designed it? Or, is the developer ultimately responsible because they own the land?

Further confusion stems from the extensive legislation relevant to the issue and the role of enforcement on construction sites. The 1994, TRCA Erosion and Sediment Control Guidelines, provide a detailed list of the relevant legislation, including the Topsoil Preservation Act, Conservation Authorities Act, Ontario Water Resources Act (OWRA), and the Federal Fisheries Act (FFA). Charges relating to erosion and sediment control are most commonly laid under the OWRA and the FFA. Administration of the OWRA lies with the Ministry of the Environment, while the FFA falls under the jurisdiction of the Federal Department of Fisheries and Oceans Canada, but is administered by the Ministry of Natural Resources and the local conservation authority (Section 35).

A number of recommendations were presented as part of the Urban Construction Sediment Control Study with regards to current standards (materials, installation and maintenance), current design and review process, and future study needs. Some of the most significant recommendations include the need for an improved sizing criteria for sediment control facilities, improved awareness and educational assistance for relevant stakeholders, the need for improved erosion and sediment control by-laws, and a need for improved erosion and sediment control plans that accurately reflect construction phasing.

Existing Stormwater Management Criteria

The control of stormwater runoff is obtained through the implementation of management criteria and/or the determination of performance targets. Stormwater criteria is usually defined through watershed or subwatershed studies and is applicable to all greenfield development proposals. Management criteria and performance targets need to be backed by comprehensive modelling studies and must be simple for contractors and developers to implement in their management plans. Factors affecting stormwater control criteria include land use designations, flood vulnerable areas, erosion sites, and environmental factors (i.e. baseflow, groundwater resources, terrestrial and aquatic habitat).

In 1991, Totten Sims Hubicki (TSH) was retained to develop a Master Drainage Plan for the Carruthers Creek watershed taking into account proposed development within the watershed as shown in the Durham Region Official Plan. Subsequent to this study, additional updates were prepared in 1995 and 1999, also by TSH, in order to address additional development which might result from the construction of Highway 407. The watershed was broken down into 29 hydrologic subcatchments in order to set up the hydrology model (Figure 2). For each subcatchment, specific parameters relating to soil conditions, land cover, land use, and slope were calculated and entered into the model. A synthetic rainfall event was then distributed over the watershed to determine the stream flow at specific locations (flow points) within the watershed. At the time of the study, there were no stream flow gauges in the watershed and the model was not calibrated.

The 1991 study addressed existing and committed land uses as outlined in the Region of Durham Official Plan. Subsequent to this study, TRCA identified the need to address possible future development which may occur as a result of the construction of Highway 407. Therefore, in 1995, TSH was retained to update the 1991 model to reflect additional future land use scenarios.

A comparison was made of the pre and post development flows to understand how the proposed development would affect peak flows within the watershed. Given the findings of this study, stormwater management criteria were developed to mitigate the potential impacts identified through the assessment, and to maintain where possible, the pre-development conditions throughout the watershed. Stormwater management criteria have been implemented in the Carruthers watershed for water quality and quantity control (flooding and erosion).

Efforts are currently underway to collect information required to update the TSH model. In 2000, a stream flow gauge was installed at the mouth of the creek at Shoal Point Road. Due to rising water levels in Lake Ontario, it was determined that the gauge should be moved to a new location further upstream. This gauge was relocated to Bayly Street in August 2001 in conjunction with the road widening currently taking place. An additional gauge has been proposed at Taunton Road and is scheduled for installation. It is anticipated that the TSH model will be updated in 2003 and calibrated using the stream flow data collected at the two gauging locations (Figure 3). The new watershed model will be used to update the current stormwater management criteria for the Carruthers.

Summary of Stormwater Control in Carruthers Creek

Given the existing stormwater criteria in the Carruthers, an assessment was carried out to determine the existing status of stormwater control within the watershed. Figure 4 illustrates the existing and proposed development and the

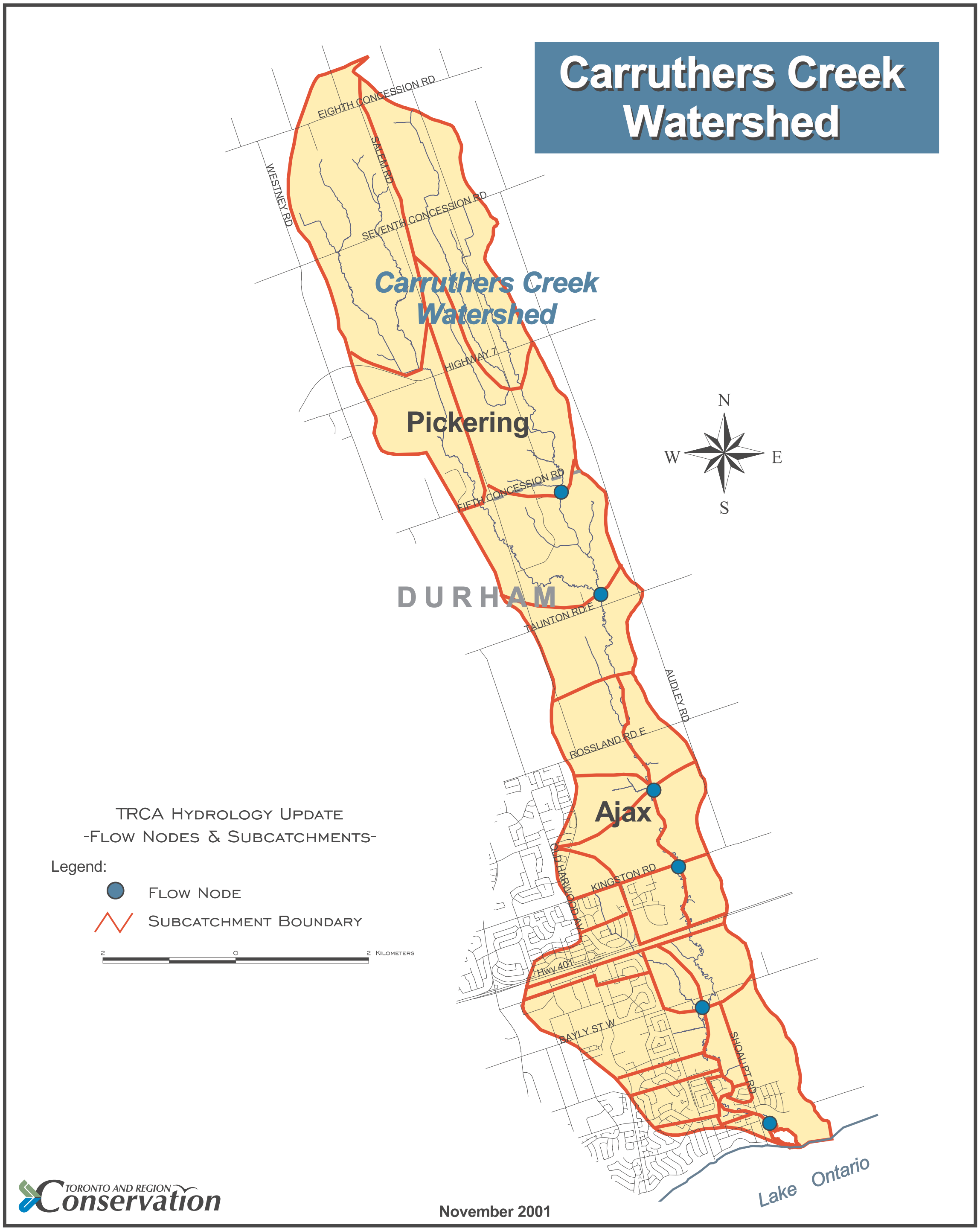

Figure 2:

TRCA Hydrology Update – Flow Nodes and Subcatchments.

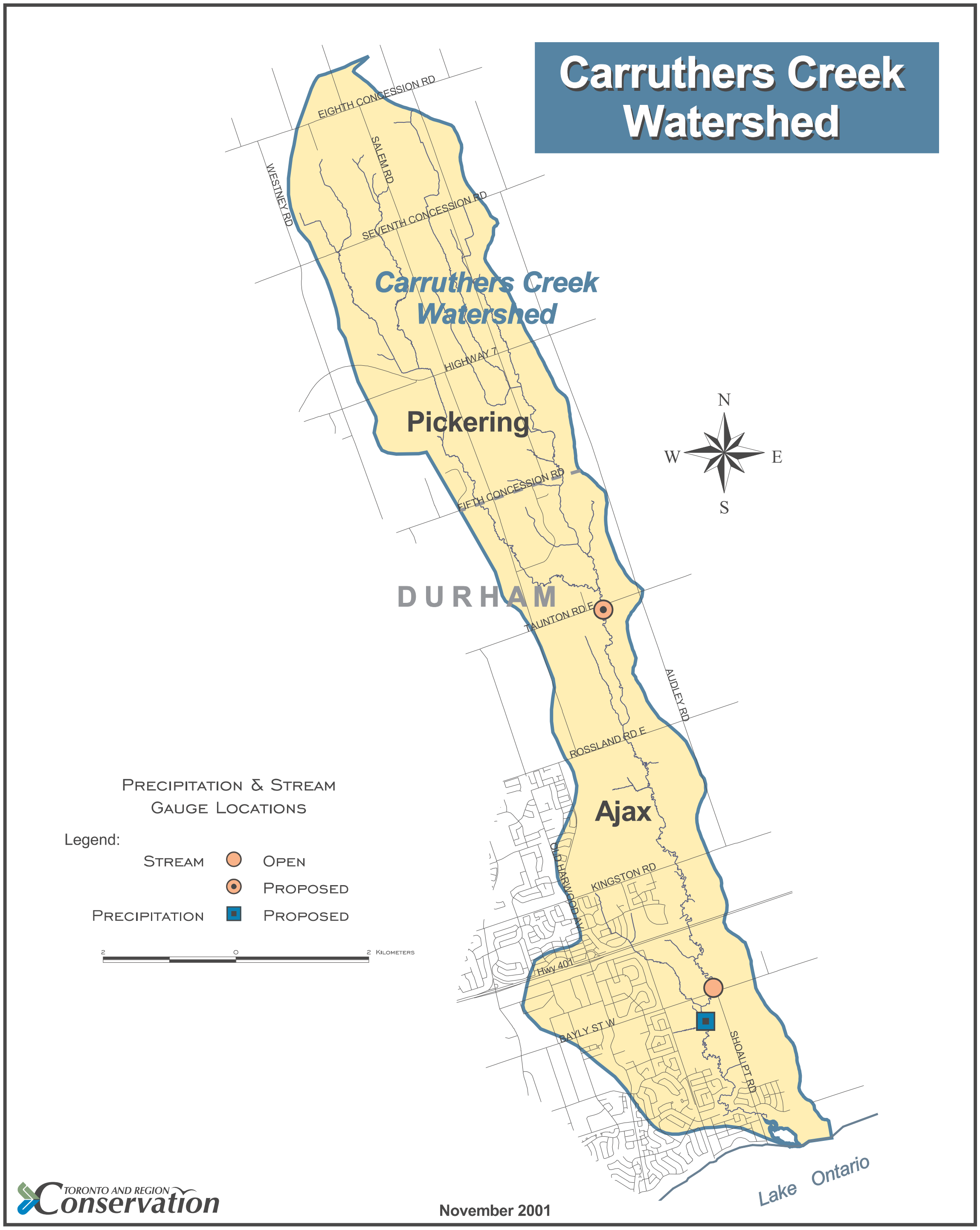

Figure 3:

Precipitation and Stream Gauge Locations.

corresponding level of control and also illustrates the location of the existing stormwater management facilities within the watershed. Approximately 64 per cent of the urban/developed areas have stormwater controls in place which meet current TRCA criteria as previously discussed (quality, quantity and erosion control). Of the remaining 36 per cent, 29 per cent have no stormwater management controls in place and 7 per cent have water quantity control only. These differences in the level of control are indicative of the age of development within the watershed and also reflect the change in management approaches that has occurred to date.

Water Quality Control Criteria

The level of control criteria is related to the water quality component of a stormwater management strategy. The intent of this criteria is to maintain or enhance the existing aquatic habitat within the receiving watercourse. The determination of habitat sensitivity is made by a qualified aquatic biologist who is familiar with local stream conditions including flow regime, temperature, community structure, habitat conditions, etc. Fisheries management plans have been prepared for a number of watersheds in the TRCA jurisdiction. These documents provide guidance with respect to the required levels of water quality protection.

The current requirement relating to level of control is outlined in the Ministry of the Environment's Stormwater Management Planning and Design Manual update (MOE, 1999). The manual identifies three levels of water quality control including enhanced, normal and basic, with each level corresponding to a specific percentage of total suspended solids (TSS) removal. As per the manual, enhanced control accounts for 80 per cent TSS removal (equivalent to Level 1 from 1994 manual); normal control accounts for 70per cent TSS removal (Level 2); and basic control accounts for 60 per cent TSS removal (Level 3). Relatively little monitoring work has been conducted to confirm these performance targets. Additional monitoring is required to ensure that existing stormwater facilities actually achieve these results. Where performance targets are not being met, additional control measures and management practices will be required to maintain or improve the current water quality conditions (i.e., encourage lot level controls, vegetated filter strips, etc. to achieve even higher TSS removal rates).

Within the Carruthers Creek watershed, TRCA requires enhanced control for all new development. The MOE guidelines stipulate that areas with high permeability soils, high base flow discharge, low upstream sediment loads, low predevelopment erosion characteristics, and areas where existing habitat is sensitive to sediment and siltation require enhanced protection for water quality purposes (MOE, 1999).

Water Quantity Control Criteria

Frequent Flow Criteria

Instream erosion is a naturally occurring process and is governed by the type of soil material within the stream banks and the stream bed. Different soil types react differently when subjected to the various stresses inherent in a watercourse (i.e. shear, tractive). Soils remain relatively stable until a critical velocity is reached within the watercourse, at which point the process of erosion begins. Under dry conditions, the velocity in a watercourse is generally less than the critical erosion threshold. However, under wet weather conditions, critical velocity is usually exceeded. The severity of instream erosion is governed by the volume of flow within the watercourse which directly relates to the magnitude of the rainfall event, the duration of time with which the increase in flow volume and velocity lasts, and the frequency of these critical rainfall events (curves to follow).

The frequent flow criteria was implemented to mitigate potential erosion impacts given that results of the hydrology study indicated that an increase in peak flows could be expected based on future foreseeable and approved development. Given these results, a frequent flow criteria was

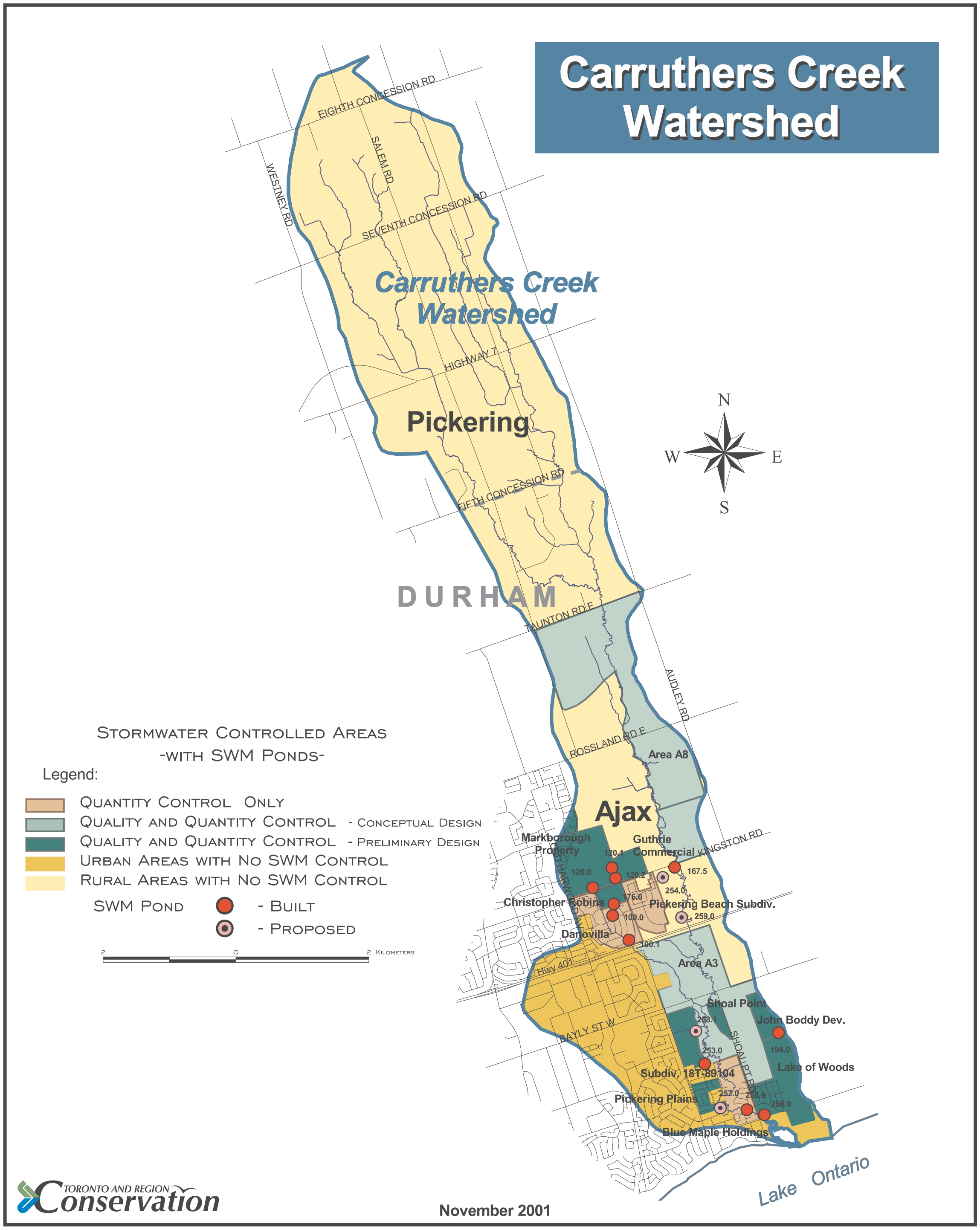

Figure 4:

Stormwater Controlled Areas.

recommended to mitigate potential erosion impacts. The criteria consists of two components, a run-off depth (usually equivalent to one inch of rainfall) and a release rate (usually specified in hours). The current frequent flow criteria in the Carruthers Creek watershed stipulates that, as a minimum, the runoff from a 25 mm storm event must be captured in a stormwater management facility, and released from that facility, over a minimum of 24 to 48 hours.

Additional studies, carried out since the TSH study, have indicated that the current level of control may not be sufficient to control in-stream erosion in all situations. Therefore, an erosion analysis is now required to determine if the blanket minimum criteria is sufficient, or if more stringent requirements are needed (i.e longer duration time or larger storm event). The erosion analysis uses the critical velocities for the watercourse, along with a continuous simulation model and meteorological data, to determine the total number of hours of exceedence, above the established erosion threshold, for both pre and post development scenarios. Various stormwater control options (source, conveyance and end-of-pipe) are then simulated in the post-development model, to determine the required level of frequent flow control, to match the flow regime under pre-development conditions. Results of the erosion analysis can also be used in retrofit situations to determine the nature of design modifications to existing, stormwater management facilities.

Flood Flow Criteria

The intent of the flood flow criteria is to identify, where in the watershed, stormwater controls are required to prevent an increase in the occurrence of downstream flooding, to reduce the potential for increased erosion, and to address local fisheries concerns.

To assess the impact of future development, TSH calculated the pre and post-development flows at each of the flow nodes identified on Figure 1, for both existing and future land use scenarios. The existing condition flows were first compared to the flows generated for each of the future land use scenarios assuming no stormwater controls in place. This assessment was used to identify the degree of impact the proposed development would have on existing peak flows. Each of the future land use scenarios was run a second time using simulated stormwater controls. These scenarios were used to identify where the implementation of flood flow controls would provide a net benefit to the watershed by reducing post-development peak flows to pre-development level. The existing criteria within the Carruthers reflects the findings of this assessment and is implemented as follows: 2 – 100 year post to pre-control is required for all new development north of Bayly Street while post to pre control is not required south of Bayly (it was determined through the assessment that post to pre control would not result in a net benefit downstream of Bayly Street).

Regular updates of the hydrology model are important to ensure that watershed criteria reflect existing conditions within the watershed. Changes to the hydrologic regime will have impacts not only to flood related concerns, but should be assessed in terms of management implications watershed wide (i.e. fisheries, erosion, terrestrial). As discussed in the Climate chapter, an increase in global temperatures is evident given the significant research relating to climate change. As noted, increased temperatures will lead to increases in evaporation rates which will ultimately affect demand on water supply. Given that the hydrologic models, used to set stormwater criteria, are based on historical, meteorologic data, modifications may be required to address the anticipated climate changes and the associated hydrologic impacts within the watershed. It is anticipated that the Carruthers Creek hydrology model will be updated in 2002.

Conclusions

The Carruthers Creek Watershed is relatively healthy in comparison to other watersheds in the GTA. Future development in the watershed must take place after careful planning consideration has been given to address watershed-wide impacts, including the need for any stormwater management measures/controls. A unique opportunity exists whereby proactive management measures can be implemented to ensure the long-term health and sustainability of the watershed's valuable resources. The continued support from both local and regional governments will serve to achieve this end.

Effective stormwater management criteria is one of the important management initiatives currently being practised in the watershed. The science of stormwater management is continually evolving and it is essential that watershed managers continue to demand the highest level of available technology and encourage the use of innovative design techniques.

References

Arnold, Chester L. and Gibbons, C. James. 1996. Impervious Surface Coverage: The Emergence of a Key Environmental Indicator. *Journal of the American Planning Association*, 62(2): 243-258.

Boyd, Duncan. 1999. *Assessment of Six Tributary Discharges to the Toronto and Area Waterfront: Volume 1 Project Synopsis and Selected Results*, Report prepared for The Toronto and Region Remedial Action Plan.

Center for Watershed Protection. "Fact Sheets on Community Pollution Prevention Practices." On-line. 1 June 2001. Available: http://www.stormwatercenter.net.

Greenland International Consulting Inc., 1999. *Stormwater Management Facility Sediment Maintenance Guide*, Report prepared for The Toronto and Region Conservation Authority

Greenland International Consulting Inc., 2001. *Urban Construction Sediment Control Study*, Report prepared for The Toronto and Region Conservation Authority.

J.F. Sabourin and Associates. 1997. *An Evaluation of Roadside Ditches and Other Related Stormwater Management Practices*. Report prepared for the Metropolitan Toronto and Region Conservation Authority.

J.F. Sabourin and Associates. 1999. *Demonstration of Non-Structural Stormwater Management Practices: Moore Park/North Rosedale*. Report prepared for the City of Toronto.

Metropolitan Toronto and Region Conservation Authority, 1994. *Erosion and Sediment Control Guidelines for Construction*.

Ministry of Municipal Affairs and Housing. "Background Information (2) – The Development Charges Act, 1996." On-line. 1 June 2001. Available: http://www.mah.gov.on.ca/inthenews/backgrnd/961125ae.asp.

Ministry of the Environment, 1999. *Stormwater Management Planning and Design Manual (Draft)*.

Paul Wisner and Associates Inc., 1994. *Stormwater Management Guidelines*. Report prepared for the Town of Markham.

Schueler, Tom. 1994. The Importance of Imperviousness. *Watershed Protection Techniques*, 1(3): 100-111.

Schueler, Tom. 1995. The Peculiarities of Perviousness. *Watershed Protection Techniques*, 2(1):233-238.

Stormwater Assessment and Monitoring Program, 2001. *Performance Assessment of a Swale and Perforated Pipe Stormwater Infiltration System, Toronto, Ontario.*

Sykes, Robert D. "Residential Cluster Development". On-line. 13 June 2001. Available: http://www.extension.umn.edu/distribution/naturalresources/components/7059-03.html.

Water Environment Research Foundation. On-line. 11 August 2001. Available: http://www.werf.org/requests/sub_rfp.htm.

Duffins and
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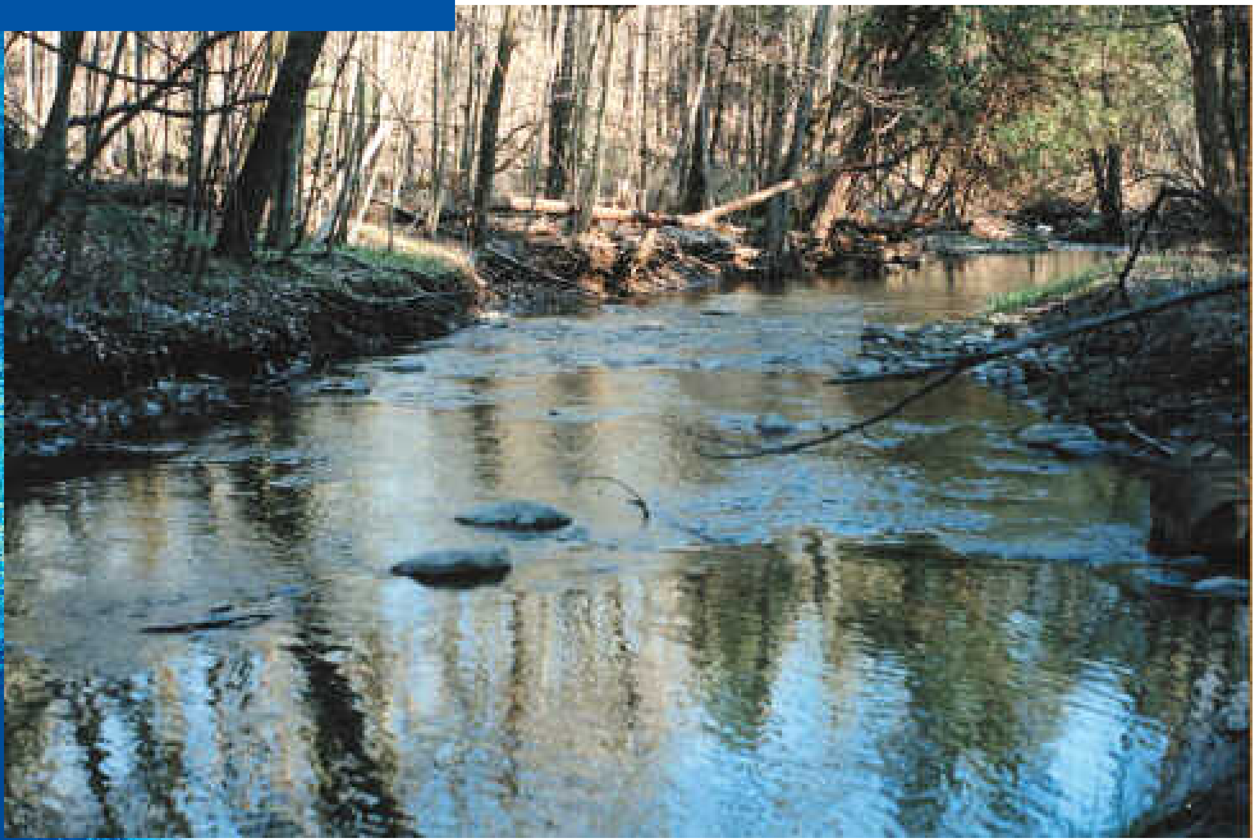

Carruthers Creek

State of the Watershed Report

Fluvial Geomorphology

Fluvial Geomorphology

June 2002

Other topics in this series for both the Duffins Creek and the Carruthers Creek include:

- Introduction
- Study Area
- Human Heritage
- Greenspace, Trails and Recreation
- Land Use
- Air Quality
- Climate
- Surface Water Quality
- Surface Water Quantity
- Stormwater Management
- Hydrogeology
- Aquatic Habitat and Species
- Terrestrial Natural Heritage

Cover photographs: Carruthers Creek north of Rossland Road. The channel in this forested section is typically wider than upstream but has similar substrate and bank characteristics.

Photo credit: Parish Geomorphic

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Toronto and Region Conservation

Duffins and Carruthers Watersheds

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Introduction to Fluvial Geomorphology

We all recognize that water moves downhill and that the more water there is, the deeper and faster it travels. Some of us have played with moving water, such as temporarily blocking the flow of small runoff channels (e.g., on a driveway or in a garden) to observe what happens. If we looked carefully, we would find different flow patterns and changes in the speed of flow, sometimes even causing dirt to be moved. This is essentially the science of fluvial geomorphology.

Fluvial geomorphology is a science that assesses the shape and form of watercourses. A key component of the science is identifying the processes responsible for the form of the channel. There are many different processes that may be at work within channels. The most important of these are physical, namely the movement of sediment (e.g., silt, sand, gravel) and water. Application of fluvial geomorphology is beneficial to watershed studies as the processes at work within the channels can be identified and quantified. This provides a better understanding of the form (shape and pattern) and function of the stream system. This understanding can be used along with knowledge from other disciplines such as hydrology and biology to assess the implications of change. Therefore a multi-disciplinary approach that includes fluvial geomorphology can be drawn upon to develop guidelines for proposed land use changes that will promote integrated management and minimize changes to existing processes.

Characterization of the Watershed

Understanding the fluvial geomorphology of a watershed involves examination of the watershed at various spatial and temporal scales. This is necessary due to the natural complexity of stream systems. The three common levels of examination, as shown in Figure 1, are the watershed, followed by stream reaches and then the site or channel cross-section scale. A stream in any one place can be influenced by the upstream drainage basin (spatial effect) and changes that have occurred in the past (temporal effect). It should be recognized that the dynamic response of a channel to a change can take years – even decades – to be fully experienced. In other words, the fluvial geomorphology of a watercourse is part of a series of linkages or relationships that compose the stream ecosystem. These linkages can be seen in many directions through a watershed. For instance, longitudinal or long profile linkages (following the trend of the watershed) include the flow and movement of water, movement of sediment and locations of sediment supply (e.g., eroding banks) and locations of sediment storage (e.g., point bars). Lateral linkages are generally seen at the reach or cross-section scale and incorporate the table lands, valley side slopes and riparian vegetation. Through these linkages, food and energy is supplied to the stream and distributed by the flowing water. Another linkage is a vertical flow and encompasses the interaction between surface water and groundwater.

At the watershed scale (the upstream basin), controls and modifying factors that influence processes operating in the drainage basin can be identified and assessed. Geology and climate exert the principal controls on the function and form of a drainage basin. The controls of geology and climate are modified by other factors present in the watershed.

Climate controls the amount of water delivered to the drainage basin and how and when it is delivered. Typically, this results in high flow events in the spring in conjunction with snowmelt while low flow conditions characterize winter and summer. Most of the precipitation in the basin is due to convection and frontal air mass activity, producing rainfall events in the fall and summer (see Climate chapter for a more thorough discussion).

Geology exerts a fundamental control on how the water, once supplied to the watershed from the local climate, is delivered to the stream. Properties, described in the Hydrogeology chapter, such as infiltration, evapotranspiration and runoff are applicable here in order to understand what the water does once it reaches the watershed. In general, the geology of the watershed affects the drainage pattern, the volume and properties of sediment supplied to the channel, and the erosion and sediment transport potential of the creek. One of the means of assessing the effect of climate and geology are morphometric analyses, which are various parameters measured at the watershed scale that provide a means of explaining how surface water travels through the watershed.

The next scale of analyses focuses on stream reaches, which are lengths of channel exhibiting similar physical characteristics (e.g., slope, planform). At the reach scale, detailed mapping and historic assessments are completed. These provide insight into how the channel has changed over time and allow a broad level identification of channel adjustments, such as rates of erosion and migration patterns. At the site or cross-section scale, an assessment would include field investigations to examine the physical characteristics of the river's form, and greater detail on properties comprising the channel, such as bed and bank material.

Elements within the watershed can modify the characteristics of the drainage basin that are controlled by geology and climate. These elements can be divided into either natural or unnatural factors. Natural modifying factors include debris dams from the accumulation of woody material, beaver activity, and the extent and quality of the

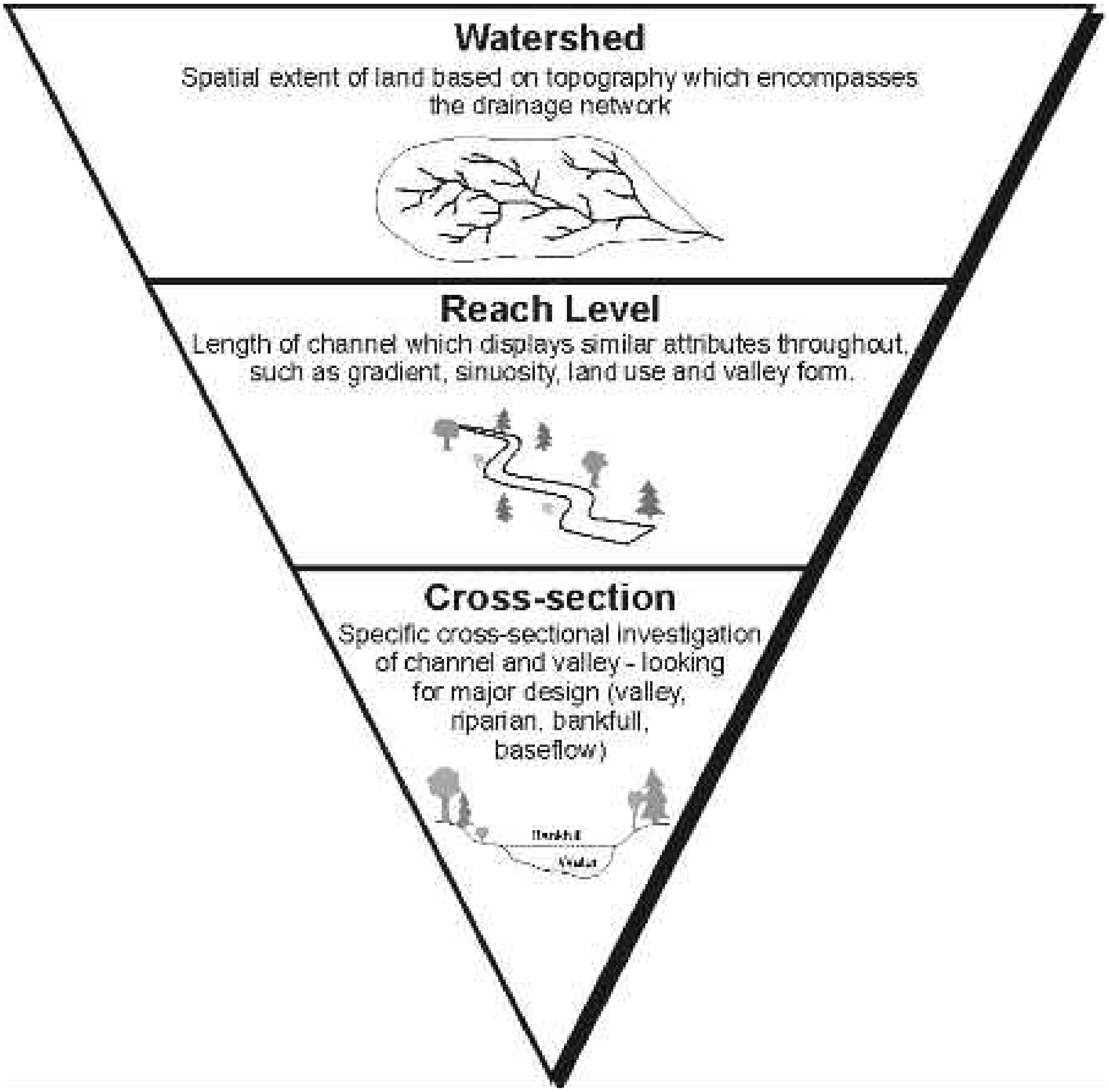

Figure 1:
Three Levels of Geomorphic Investigation

riparian vegetation (e.g., trees, shrubs and grasses that are adjacent to a channel); these factors tend to be temporary. Ponds or backwater areas behind debris dams or beaver dams are zones of deposition. Accordingly, the area downstream of the dam has an increased sediment carrying capacity, which may lead to increased erosion. These dams and associated backwater areas modify the drainage process and may cause shifts in channel pattern. Modifying effects of riparian vegetation include the ability to protect the channel banks (i.e. root depth, root density), resulting in narrower, but deeper channels than would normally be expected given flows produced from the upstream area. This is especially true in meadows, where the root density from grasses and sedges is denser than roots from mature trees.

Unnatural modifying factors, such as changes in land use, tend to be more permanent and, consequently, produce a more dramatic influence on the receiving streams. Land use in the basin primarily affects the hydrological cycle by influencing the amount of runoff, infiltration and evapotranspiration. Changes in land use and riparian vegetation within the basin, and especially along the stream corridor, can affect the intricate functions between the channel and its floodplain, as well as the primary functions regarding the movement of water and sediment.

Basin Scale Geomorphological Assessment

The Carruthers Creek watershed is approximately one-tenth the size of the Duffins Creek basin immediately to the west. The headwaters of Carruthers Creek are located near the hamlet of Mount Zion. The shape of the basin is very elongated and narrow. Underlying geology, which exerts a control on the shape and form of the drainage network, is primarily glacial till and fine-grained sediments from glacial Lake Iroquois. The topography is not nearly as complex as in the Duffins Creek basin.

As discussed in the previous section, morphometric analyses provide a means of assessing how surface water travels through the basin. Two of the main parameters are drainage density and the bifurcation ratio. Drainage density is a ratio of the total length of all streams divided by the drainage area. Thus the more streams within the watershed, the higher the value. Bifurcation ratio measures the degree of branching from the all the tributaries in the watershed. Morphometric analyses of the Carruthers Creek watershed, completed using 1:50,000 topographic mapping, produced results for the drainage density and bifurcation ratio of 2.08 and 3.2, respectively. While these values are higher than those from Duffins Creek, they are fairly typical for other streams and basins around the Greater Toronto Area. The drainage density value is low, given the fine-grained underlying geology (e.g., silt, clay), which generally produces numerous, small streams. The bifurcation ratio value is expected, given the shape of the basin. This value suggests a long main branch with large distances between tributaries. For an event hydrograph (e.g., plot showing the magnitude of flows over time), these values and basin shape indicate that water is gradually delivered to the main channel, producing a broad, gradual shape, with little peakedness.

Land use within the Carruthers Creek basin is principally rural, although the Town of Ajax has been rapidly growing during the last decade. While there is generally reasonable riparian vegetation along the creek, there is very little woody material. The creek itself has been altered to accommodate various agricultural practices. Alterations include realignment (e.g., straightening), local ponding of tributaries and tile drainage. The latter two affect the flow regime of the creek.

The profile of the basin is very typical, with a concave shape, which steepens in the headwater areas. Planform of the headwater channels is generally straight with an occasional abrupt bend, the product of geological control, vegetation, or human-induced alteration. Through the middle part of the basin, the channel gradient decreases slightly and the planform becomes more sinuous (e.g., slight curves, bends). From Highway 2 to Lake Ontario, the channel is very sinuous as it meanders across the old lake bottom. Accordingly, the gradient is fairly flat. This channel configuration (sinuous, low gradient), and fine-grained geology are sensitive to changes in either flow or sediment regime. Unfortunately, this area is surrounded by urban land use and is also subject to the effects from any change in the upstream watershed. If the land use were changed, such that there would be more runoff (i.e. urbanization), the hydrograph would change. Typically, there would be higher peaks and lower baseflow, and given the sensitive nature of the channel, there could be a pronounced change, including the potential for degradation.

Channel Function of Carruthers Creek

The main geomorphological function of all watercourses is the efficient movement of water and sediment through the system. This function entails both conveyance and storage components, which are critical to the healthy function of the stream. The term "efficient" is used to describe a key concept relating to the use of energy by a stream. A stream will find a shape, form or pattern that permits the necessary movement of water and sediment, with the energy available (e.g., slope). When this occurs, the system is referred to as being in a state of dynamic equilibrium.

Channel Stability

Dynamic equilibrium is generally synonymous with channel stability and suggests a channel form (planform and cross-section) that is in balance with the flow and sediment regimes that are operative within the system. Further, as the word "dynamic" infers, it is understood that the channel will shift and adjust to variations in either sediment or flow, but remains within some theoretical threshold limit. Once this limit is exceeded, a substantial channel adjustment is necessary and it enters a period of instability as it tries to regain a dynamic balance. When changes occur in one of the parameters that influence channel form, then the channel will make adjustments through one of its degrees of freedom. Channel gradient is one of these degrees of freedom although a change in gradient is unlikely to occur as quickly as changes to channel cross-sectional area. This concept was expressed by Mackin (1948) who described a 'graded stream' as follows:

> *A graded stream is one in which, over a period of years, slope is delicately adjusted to provide, with available discharge and with prevailing channel characteristics, just the velocity required for the transportation of the load supplied from the drainage basin. The graded stream is a system in equilibrium.*

Based on this definition, it is implied that a change in a stream's discharge or sediment supply can result in a dramatic change in the gradient and, if possible, the substrate within the channel.

It should be stated that most streams in southern Ontario have been altered at one point in time and consequently have been experiencing various levels of adjustment. It is important to understand these fundamental concepts of fluvial geomorphology, such that some interpretation is possible when looking at data from the Carruthers Creek watershed. Through reviewing various existing reports, some geomorphological data were found which provide some insight on the physical characteristics of the various watercourses.

Existing Conditions

The Carruthers Creek basin is less complex than the Duffins Creek basin, with the underlying geology primarily comprised of fine-grained sediments (e.g., silt and clay). The topography is also less complex, although in comparison to Duffins, the land use consists of more rural areas and fewer natural areas.

From a basin perspective, the use of regional curves or databases can provide some insight into the delivery and movement of water through the system. A regional curve illustrating the relationship between upstream drainage area and bankfull flow is shown in Figure 2. Bankfull flow is a flow stage that exerts the most influence on channel form. Typically, this discharge occurs once every year to once every two years in a natural environment. The data shown in Figure 2 comes from a variety of sources. The Carruthers Creek data was taken from a fluvial geomorphological report completed to assess erosion potential from the A8 Development Area (ORTECH, 1997), and as a result, focused on the creek south of Taunton Road. This data is plotted against regional data from Wilmot Creek (Robertson *et al*., 1999) and from data collected by PARISH Geomorphic over

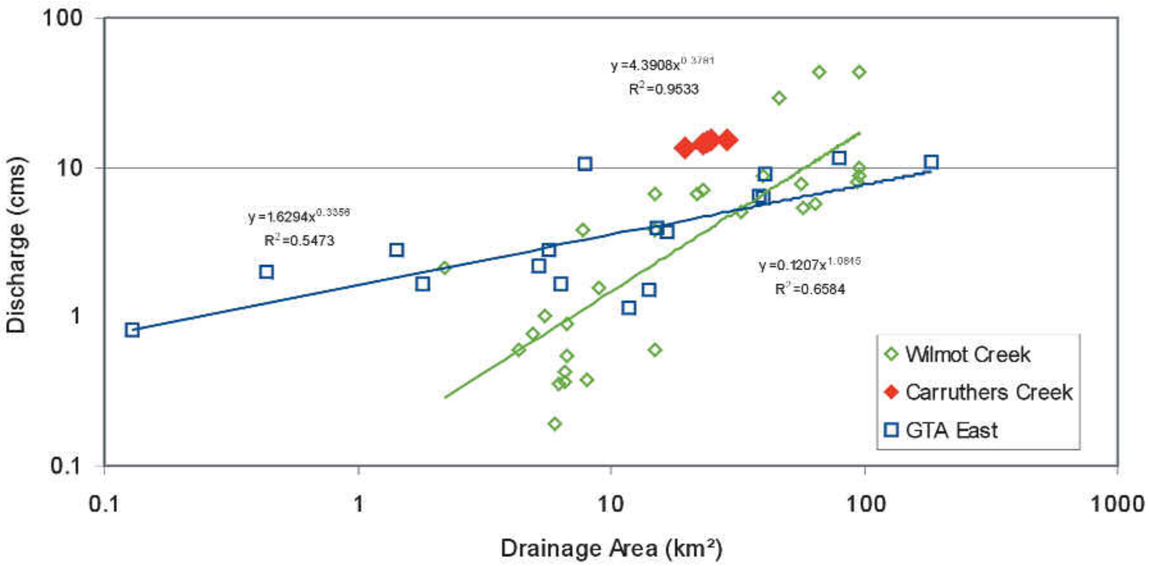

Figure 2:

Drainage Areas Versus Bankfull Using Data from the Wilmot Creek Watershed, East Greater Toronto Area Streams and Various Reaches Located on Carruthers Creek.

the last few years in the eastern part of the GTA (from the Rouge River eastward to Harmony Creek in Oshawa).

The relevance of the regional data is that it represents other systems with similar geologic and physiographic settings. While the Wilmot Creek data primarily represent a rural land use, the GTA East data include both rural and urban sites, which largely explains the differences in the trend line from these two sets of data. Specifically, the plots indicate that streams from the GTA East data set receive more water from a smaller drainage area, a function of impervious surfaces. Another important observation from Figure 2 is the variability in the data, which supports the discussion regarding how different geology and land use can influence the amount of water moved through the system. In all three data sets, when looking at one drainage area, a range in discharge of three- to ten-fold can be seen. Only five points are available for Carruthers Creek, but there is a strong pattern that clearly shows that Carruthers Creek gets proportionally more water from its upstream area. This can be attributed to the fine-grained geology, which produces more runoff and less infiltration. This pattern and relationship is also indicative of an urban system, which delivers more water to the stream than a natural area. With respect to channel form, this result would suggest that Carruthers Creek would have a proportionally larger cross-sectional area and, given the fine-grained geology, a cross-sectional shape that is narrow and deep. This is seen in Table 1, which contains the channel characteristics of the five sites used in the plot, shown in Figure 2.

The data in Table 1 show that the channel gradient decreases towards Lake Ontario, which is expected. The substrate sizes are also relatively fine, which is expected given the underlying geology. Using the bankfull dimensions and the bank parameters provides an indication that, in fact, the creek is relatively narrow and deep and likely somewhat confined. Photo 1 shows the channel in Reach B (south of Taunton Road), where it is a little steeper and has more gravel and cobbles on the bed. Photo 2, taken north of Highway 2 is more typical of Carruthers Creek.

A review of the ORTECH report (1997) provided further insight into channel characteristics. Some channel degradation was observed around

Table 1. Channel Characteristics for Various Reaches of Carruthers Creek

Creek Name	Bankfull			Drainage Area (km^2)	Substrate (D50-cm)	Bank		Gradient (%)
	Width (m)	Depth (m)	Discharge (cm)			Height (m)	Angle (º)	
Reach B – d/s of Taunton Road	9.30	0.50	13.48	19.67	3.10	0.75	53.50	0.60
Reach C – south of Rossland	5.15	0.76	14.26	23.09	1.96	1.23	63.00	0.25
Reach D –straight (u/s of Hwy 2)	7.40	0.65	14.78	24.02	0.03	0.40	42.50	0.22
Bayley North Ds of Hwy 401	5.27	0.73	15.02	25.02	3.70	0.94	42.75	0.13
Bayley South	6.00	0.84	15.43	28.55	0.009	0.89	54.50	0.13

Highway 2, which is attributable to the road crossing, lack of riparian vegetation and channel alterations (Photo 2). The creek has a very sinuous pattern over the lower section, stretching from Highway 401 to Lake Ontario. Given the low gradient, sinuous pattern, and fine substrate, this area of the creek is highly sensitive to changes in flow and sediment regimes. This is partially due to very little resiliency in these channel characteristics to accommodate any change.

The ORTECH report (1997) also presented hydraulic geometry relations. Hydraulic geometry are relations that describe the channel response, with respect to width, depth and velocity to increases in discharge. It is understood that as discharge increases there would be a corresponding increase in channel width, depth and velocity. The extent of the change in these parameters can provide some insight into channel processes. In Carruthers Creek, as discharge increases, there is little change in channel width, due in part to the cohesive channel material and high banks. Accordingly, if width increases little, then large increases are in seen in channel depth and velocity. While depth does increase, there is a much larger increase in average velocity. This is anticipated, as greater depth and less roughness from the fine substrate would result in higher velocities. The high velocity and greater depth indicate that creek bed scour would likely occur. If changing land use results in more flow volume, the effect of the creek would likely be bed scour and channel incision. This process would remove it from its floodplain and oversteepen the channel banks, resulting in some bank slumping.

It should be reiterated that there is very little geomorphic information available for the Carruthers Creek system. With each passing year, more local studies will likely be completed, but a broader basin-scale perspective will be lacking. A concerted effort is necessary to provide a more holistic understanding of the basin. This could be readily applied to management decisions regarding resources and natural ecosystems.

Channel Erosion

All stable creek systems erode (e.g., eroding banks, bed scour). Erosion is natural process that helps deliver sediment to the system. Sediment

supply, transport, and deposition is necessary to help the creek system dissipate stream energy and maintain a balance between flow and channel form. Channel erosion can be the result of numerous processes. Obviously, flowing water and the hydraulic processes active on the bank can be a powerful force. Erosion can also result from geo-technical processes causing slope failures. Ice and freeze-thaw cycles can also produce erosion. Eroded banks can provide information on the history of the valley. Eroded banks can also reveal areas of groundwater discharge. This observation suggests that groundwater is likely reaching the channel, which has implications on water quality and aquatic habitat. The presence of groundwater discharge in a bank can also indicate a cause of erosion as the saturated material is typically weaker and more prone to failure.

Photo 1:

Carruthers Creek South of Taunton Road. Note the large cobble substrate.

Photo 2:

Degraded Section of Carruthers Creek, North of Highway 2. Note the fine substrate and bank materials in this section.

Summary

Fluvial geomorphology is a science that assesses the shape and form of watercourses. Application of fluvial geomorphology is beneficial to watershed studies as the processes at work within the stream system can be identified and quantified. This understanding can be used in conjunction with other disciplines to assist in developing guidelines for watershed management (i.e. existing land uses, proposed land use changes) to ensure existing processes with stream and river systems are not impacted.

Understanding the fluvial geomorphology of a watershed involves the assessment of various spatial and temporal scales occurring at the watershed or basin level, stream reach scale and site or channel cross-section level. Climate conditions and basin geology are the primary factors that influence the processes affecting the form and function of a drainage basin. Additional natural and human factors that can also impact or modify the characteristics of a drainage basin can include beaver activity and the location and extent of riparian vegetation as well as the construction of dams, weirs and channelization. Changes in land use through urbanization of rural areas as well as agricultural land use practices can also impact the form and function of streams and rivers.

In order to understand these processes, a "morphometric" analysis is typically completed to understand, at a basin scale, how climate influences the amount and distribution of water to the system (e.g., rainfall and snow, location of precipitation, etc.) and how basin geology affects how the water is delivered throughout the basin (e.g., drainage pattern, erosion and sediment supply, etc.). "Stream reach" assessments are completed which groups channels into like reaches based on similar characteristics (e.g., slope, planform). Reaches are examined using detailed topographic mapping and historical information (i.e. aerial photographs) in order to gain insight into broad level channel adjustments such as rates of erosion and migration patterns. Site, or cross section information is also compiled using data collected through field investigations in order to provide further information on a stream or river's physical characteristics such as channel bed and bank material.

The Carruthers Creek watershed comprises a narrow elongated basin with underlying geology of primarily fine-grained sediments from the glacial Lake Iroquois. A morphometric analysis completed using 1:50,000 topographic mapping produced a drainage density (i.e. length of streams over basin area) and bifurcation ratio (i.e. degree of branching of tributaries) of 2.08 and 3.2, respectively. These values are typical of streams located within the Greater Toronto Area and indicate a relatively low number of tributaries and long main branch with large distances between tributaries, which is confirmed by the elongated shape of the basin.

FLUVIAL GEOMORPHOLOGY

Land use within the basin is predominantly rural with urban expansion occurring in the past decade primarily within the Town of Ajax. The basin profile is concave in shape, with steeper slopes in the headwater area which decrease in a southerly direction and become relatively flat south of Highway 401. The planform of the main channel is fairly straight in headwater areas where slopes are steeper and gradually becomes more sinuous south of Highway 401 given lower slope gradients. A comparison of Carruthers Creek geomorphic data with regional curves developed from collected information on streams within the eastern Greater Toronto Area indicates consistent patterns with that of urban type systems. Bankfull dimensions indicate that the Carruthers Creek channel is relatively narrow and deep and somewhat confined, which also confirms the findings of the regional comparison.

The channel substrate is comprised of fine-grained materials, which is consistent with the underlying geology. Some channel erosion was observed near Highway 2 which can be attributed to the local setting (e.g., lack of riparian vegetation), channel confinement and previous channel alterations. Areas south of Highway 2 also appear to be highly susceptible to erosion given the low gradient, sinuous pattern and fine substrate material.

In summary, the geomorphic information available for the Carruthers Creek watershed is limited and somewhat site specific. As a result, further work will be required to complete a basin-level assessment required to formulate future management decisions regarding resources and natural ecosystems.

References

Mackin, J.H., 1948. Concept of the Graded River. *Bulletin of the Geological Society of America.* 59: 463-512.

ORTECH, 1997. *Carruthers Creek – Fluvial Geomorphology Assessment A8 Development Area, Ajax Ontario.* Submitted to Cosburn Patterson Mather Ltd. Report No. 97-WTS-003.

Robertson, B.L., C.H. Taylor and J.M. Buttle, 1999. *A Comparison of the Hydraulic Geometry Between a Low-Energy and a High-Energy Drainage System.* Abstract from the 25th Annual Canadian Geophysical Union meeting, Banff.

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Carruthers Creek

State of the Watershed Report

Hydrogeology

Hydrogeology

June 2002

Other topics in this series for both the Duffins Creek and the Carruthers Creek include:

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Duffins and Carruthers Watersheds

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Introduction to Hydrogeology

Hydrogeology is the science that describes the movement of water beneath the ground surface (herein termed groundwater), and it's interaction or connection with water which moves upon the ground surface in rivers, lakes and streams. Inflow to the groundwater flow system (herein referred to as ***recharge***) occurs as infiltrating precipitation in the form of rainfall or snowmelt. The amount of infiltration is controlled by numerous characteristics including (but not limited to) the surficial soils or geologic materials, the slope of the ground surface, the type of vegetation and climate variables such as the amount of precipitation and evapotranspiration. Evapotranspiration is the combination of evaporation from open water bodies and transpiration which is the removal of water from the soil by vegetation. Outflow from the groundwater flow system takes place as ***discharge*** to streams (herein termed baseflow) and springs, as evapotranspiration and as groundwater pumping from wells.

Infiltrating water moves within openings called pores or voids within soil or rock. The ratio of the volume of voids in a deposit to the total volume of the deposit is known as the ***porosity***. At a certain depth below the ground surface all of the voids will be filled with water and the rock or soil will be referred to as saturated. The top of the saturated zone is known as the ***water table***. The speed with which groundwater will flow depends on the nature of the geologic materials, specifically the size and degree of interconnection of the pores. This factor is known as the ***permeability***. For example, groundwater will flow more easily through a sand deposit than a clay deposit. In this case the sand deposit would be considered more permeable than the clay deposit. Rock or soil units with sufficient porosity to store water and permeable enough to allow water to flow through them in economic quantities are called ***aquifers***. Rock or soil units of low permeability, such as a clay deposit, are called ***aquitards***. Some aquifers are overlain by aquitards which can restrict the movement of water in the aquifer. The water in the aquifer becomes confined under pressure where the water level in a well tapping the aquifer rises above the top of the aquifer unit. This type of aquifer is known as a ***confined aquifer***. An aquifer where the water level in a well is situated beneath the top of the unit, forming a water table, is known as an ***unconfined aquifer***. Finally, groundwater will move from areas of high pressure to areas of low pressure, or from areas of high hydraulic head to areas of low hydraulic head. ***Hydraulic head*** is defined as the sum of the elevation of the bottom of a well plus the height of a column of water in a well above the intake or screened zone at the bottom of the well.

As mentioned above, the quantity and rate of groundwater flow is dependent on the nature of the geologic materials through which it flows. These geologic materials also control the natural chemical quality of groundwater. Depending on the conditions encountered within the flow system, minerals contained within soil and rock units can be dissolved and transported within the flowing groundwater, or dissolved materials within groundwater can form minerals within the aquifer material through which it flows.

An understanding of the groundwater flow system is vital to many aspects of basin management ranging from the safe yield of a basin for water supply purposes to the maintenance of streamflow by groundwater discharge (baseflow), which ultimately forms the basis for the many ecosystems situated within the study area. The Carruthers Creek watershed is situated immediately to the east of the Duffins Creek watershed, which is unique in Ontario in that abundant hydrogeologic information exists from numerous research and consulting investigations (mainly related to landfills). This allows for a relatively detailed understanding of the groundwater flow system. Given the paucity of specific hydrogeologic information for the Carruthers Creek basin, this chapter applies the detailed hydrogeologic understanding for the Duffins basin to the Carruthers Creek basin where applicable.

Geologic Setting

In order to assess a groundwater flow system, it is first necessary to determine the extent and thickness of the subsurface rock and soil layers, or geologic layers. Once this geologic layering is determined, the individual layers can be classified as either aquifers or aquitards and their hydraulic properties assessed.

The landforms and surficial geologic deposits of the Carruthers basin, shown in Figure 1, are all related to a succession of glacial (when the climate was cooler than today) and interglacial periods (when the climate was similar to that of today) (Eyles, 1997). One of the dominant landforms is the height of land known as the Oak Ridges Moraine situated to the north of the study area. This ridge of extensive sand and gravel was deposited approximately 12,000 years ago, and marks the terminus of two glacial ice lobes, one from the north known as the Simcoe lobe and one from the south out of the Lake Ontario basin (Figure 2a). The Carruthers Creek occurs along the south slope, where the surficial deposits are largely till. Till is a term applied to a mixture of different clast sizes ranging from clay to boulders deposited directly by glacial ice. These till deposits are covered by a thin veneer (< 5 metres thick) of sand, silt and clay deposited in a lake (glacial Lake Iroquois) and by rivers within the Carruthers Creek river valley. A second prominent landform situated within the Carruthers Creek basin is an escarpment known as the Lake Iroquois shoreline (Figure 3). This escarpment delineates the historic shoreline of Lake Ontario formed approximately 10,000 years ago when water levels were tens of metres higher than the present lake level (Figure 2b). Surficial geologic deposits south of the Lake Iroquois shoreline consist of near shore beach sands and gravels, and deeper water silts and clays. Deposits of till from earlier glacial periods are also exposed.

The stratigraphic sequence described below is from the Duffins Creek basin, which occurs immediately to the west of Carruthers Creek. Part of this sequence appears to directly apply to the Carruthers Creek basin, as discussed below and illustrated on Figures 4a and b. Beneath the surficial deposits exposed at surface, the geologic layering basically consist of a series of alternating till and lake (silt and clay) or river (sand and gravel) deposits of up to 200 metres over the bedrock surface. Bedrock beneath the study area is composed of Late Ordovician shales of the Whitby Formation which were deposited over 400 million years ago (Johnson *et al*., 1992). The bedrock surface declines southward from an approximate elevation of 180 metres above mean sea level (amsl) beneath the Oak Ridges Moraine to approximately 50 to 80 metres amsl at Lake Ontario. Bedrock occurs at a depth of 9.9 metres (elevation of 76 metres amsl) where Carruthers Creek meets Kingston Road (ATSL, 1997). M.M. Dillon Limited (1995) encountered shale bedrock at a depth of 11 metres (elevation of 86.4 metres amsl) in the Carruthers Marsh area, which is where the mouth of the creek occurs at Lake Ontario. North to northwest trending channels marking ancient rivers have been eroded into the bedrock surface beneath and south of the Oak Ridges Moraine (Ostry, 1979; Eyles *et al*., 1993). In the general area, the most pronounced bedrock channels occur along the Duffins Creek valley to the west.

The unconsolidated sediments situated above bedrock were all deposited within the last 100,000 years. The geologic layers immediately overlying bedrock include the Scarborough and Sunnybrook Formations, which were deposited into Lake Ontario as glacial ice. The Scarborough Formation consists of sand, silt and clay deposited as a large delta in Lake Ontario approximately 70,000 years ago. These deposits are capped by lacustrine clays and pebbly silty clays of the Sunnybrook Formation. The Thorncliffe Formation overlies the Sunnybrook and consists of deltaic sands and lacustrine silt and clay interbedded with till units recording an oscillating ice front as the glacial ice-sheet was now in the Toronto area. To date, the presence or extent of these deposits has not been accurately identified for the Carruthers Creek basin due to the lack of available borehole data.

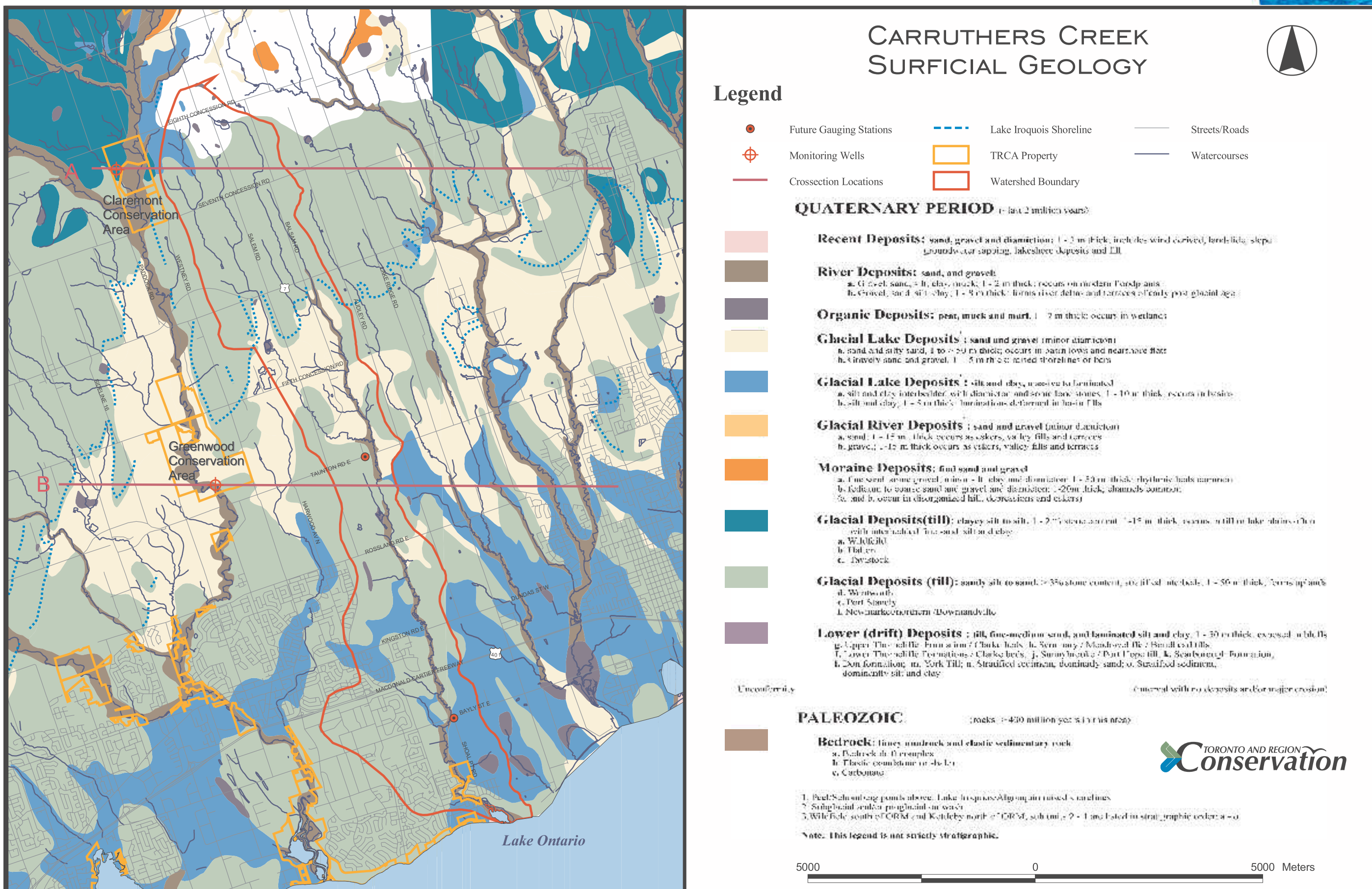
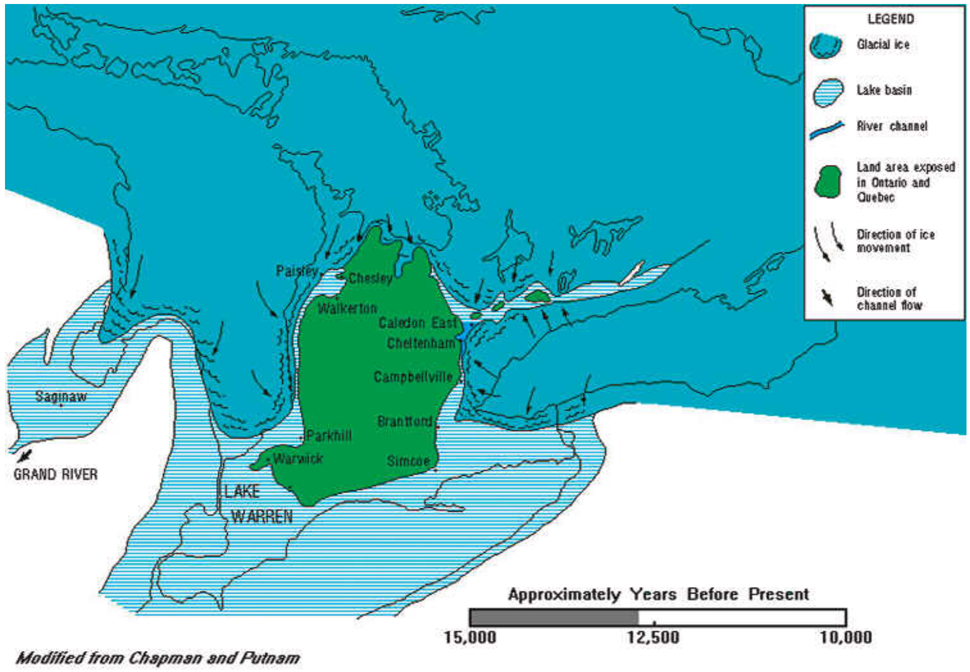


Figure 1:

Study Area and Surficial Geology.

The stratigraphy for the southern part of the Carruthers Creek basin has been identified at two locations by investigations between Taunton and Kingston Roads (ATSL, 1977) and in the Carruthers Marsh area (M.M. Dillon Limited, 1994; 1995). The stratigraphy encountered include a surficial topsoil unit underlain locally by silty sand till (Halton Till). This till is locally covered by a thin veneer of lacustrine and/or sand, silt and clay. The Halton Till is underlain by a more dense, silty sand till known as the Northern Till which occurs immediately above bedrock at these two locations.

Within the Duffins basin, the Northern Till overlies the Thorncliffe Formation, which extends throughout south-central Ontario and forms the base of the Oak Ridges Moraine (see Boyce *et al*., 1995 for correlations). The Northern Till is an overconsolidated, calcite cemented, sandy silt diamict deposited during the Late Wisconsinan Nissouri Stadial sometime between 23-18,000 years ago (Karrow and Ochietti, 1989; Berger and Eyles, 1994) by the southward flowing Laurentide ice sheet at the time of its maximum extent. The till is believed to be exposed north of the Oak Ridges Moraine where it has been mapped as Newmarket Till (Gwyn and DiLabio, 1973; Sharpe and Barnett, 1997a; 1997b; Barnett et al., 1998). Surficial geology mapping of the study area by Sharpe and Barnett (1997b) combines the Northern Till and overlying Halton Till into the Newmarket Till with Halton Till only occurring along the immediate south flank of the Oak Ridges Moraine. In contrast, local area investigations recognize



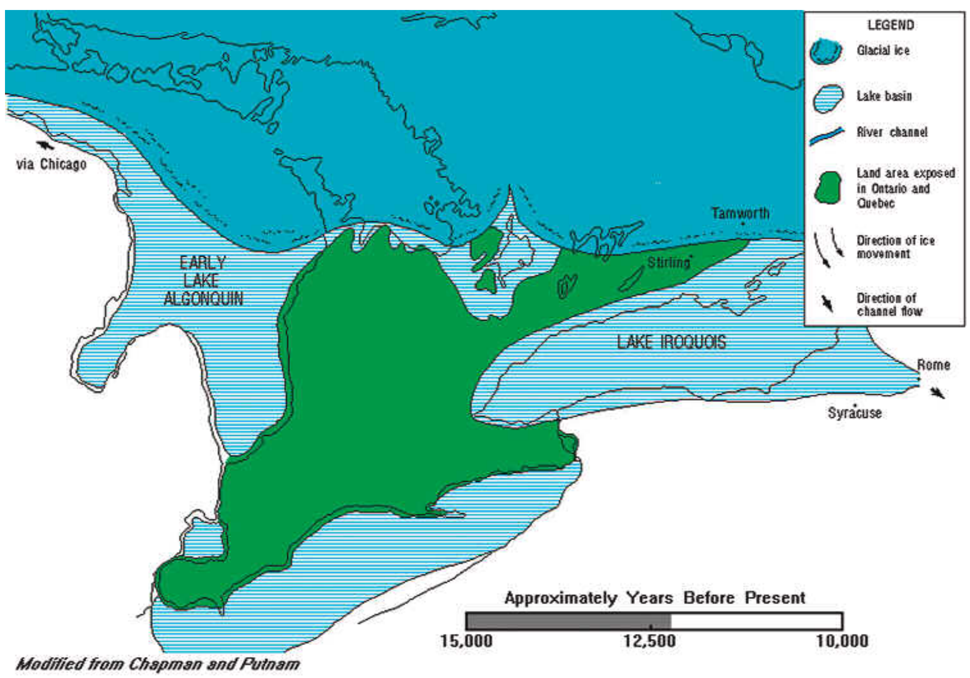


Figure 2:

Recent Glacial History of the Study Area (adapted from Chapman and Putnum, 1984). The retreat (melting) of the Wisconsinan glacier (approximately 15,000 to 10,000 years ago) shaped the landscape of southern Ontario:

(a) A high-level lake formed over the Oak Ridges Moraine as the Lake Ontario ice lobe split from the northern lobes approximately 12,000 years ago.

(b) As the ice lobe withdrew, Lake Iroquois formed in the Lake Ontario basin. The strength of its shorecliffs and beaches indicates that Lake Iroquois was longer lived than any of the earlier glacial lakes.

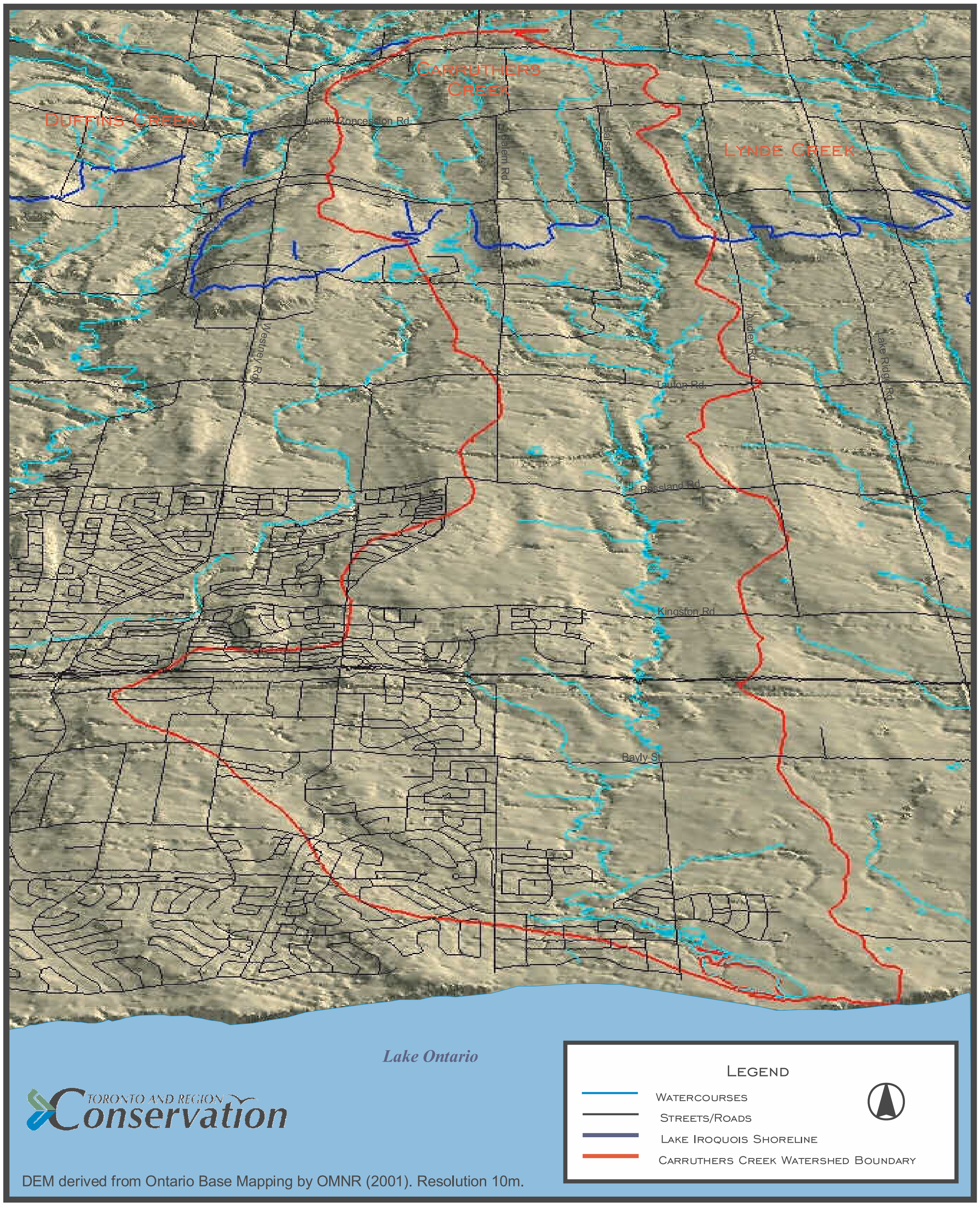


Figure 3:

3-Dimensional Surficial Topography Map.

the Northern Till and Halton Till throughout the study area, consistent with the lower and upper Leaside tills (Halton Till) of Karrow (1967) and the work presented by ATSL (1997) and M.M. Dillon Limited (1995). This nomenclature is adopted here to acknowledge the different hydrogeologic behaviour of the two till units.

Oak Ridges Moraine deposits consist of glaciofluvial and glaciolacustrine sediments including abundant sand and gravel outwash (Barnett et al., 1998). These deposits, along with the Halton Till, overlie the Northern Till in the northern part of the study area. South of the moraine, Mackinaw Interstadial deposits consisting of fluvial gravel with lacustrine silt and clay occur locally within topographically low areas on the upper surface of the Northern Till, and are in turn overlain by Halton Till. These interstadial deposits have been identified within the Carruthers Creek basin during geologic investigations situated between Taunton and Kingston roads (ATSL, 1997).

Glaciolacustrine deposits occur as a thin veneer (< 5 metres thick) over Halton Till deposits north of the Lake Iroquois shoreline. Glacial Lake Iroquois deposits occur over the southern part of the study area. These consist of beach sands and gravels and lacustrine silt and clay deposited subsequent to the final Laurentide ice sheet withdrawal from the study area.

Hydrogeology

Aquifer Units and Groundwater Recharge

Aquifers within the adjacent Duffins basin are classified as upper, middle and lower aquifer systems which occur within the unconsolidated sediments above bedrock discussed above. From a quantity and quality perspective, the deep shale bedrock does not contain useable aquifers (Sibul *et al*., 1977); however the overburden/bedrock contact may contain useable aquifers within weathered bedrock and overlying coarse grained sediments. The three aquifer classification used for the Duffins basin refines the previous classification of shallow and deep aquifers by Sibul et al. (1977), based on relative elevations of water well screen clusters, and places aquifer systems into a basin-wide geologic context.

Groundwater flow within all three aquifer systems is predominantly south to southeast from the Oak Ridges Moraine highlands toward Lake Ontario, at regional horizontal hydraulic gradients (difference in hydraulic head over a certain distance) of 0.001 to 0.01 for the middle and lower aquifers and 0.01 for the upper aquifer. Local deflections occur toward creeks and rivers where horizontal hydraulic gradients increase near discharge areas. Figure 5 shows the water table elevation and Upper aquifer groundwater flow directions within the Carruthers Creek basin.

The upper aquifer, or water table, occurs above the Northern Till within fluvial, glaciolacustrine and Halton Till deposits at depths generally less than five metres below ground surface (Gerber and Howard, 2000; ATSL, 1997; M.M. Dillon Limited, 1995). Groundwater flow within the upper aquifer system is generally horizontal and unconfined. Horizontal hydraulic gradients near Carruthers Marsh have been measured at 0.006 to 0.023 (M.M. Dillon Limited, 1995). For the adjacent Duffins basin, estimates of recharge through the Halton Till plain range from 125 to 200 mm/yr (IWA, 1994; Gerber, 1994). This is consistent with numerical model calibrated recharge estimates for other southern Ontario till deposits flanking the Waterloo Moraine (180 to 220 mm/yr; Martin and Frind, 1998) and the Oro Moraine (180 mm/yr; Beckers and Frind, 2001). South of the Lake Iroquois shoreline occur a wide range of surficial geologic materials ranging from till, silt and clay to sand and gravel deposits situated along the former shoreline. The sand and gravel deposits are estimated to have an annual recharge of 200 mm/yr whereas the lower permeability till, silt and clay are estimated to have an annual recharge of approximately 25 mm/yr. The lower recharge values reflect the

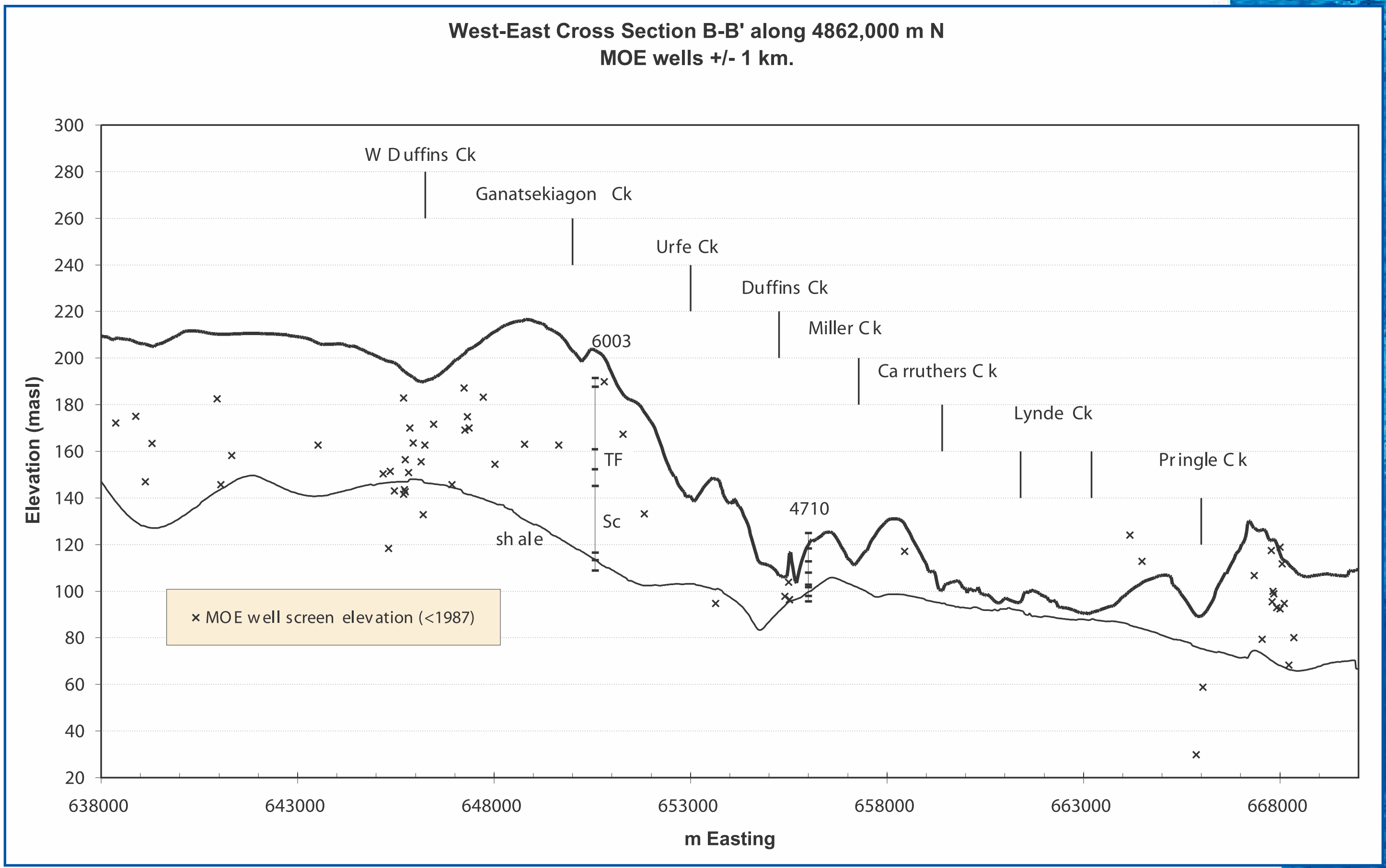


Figure 4:

West-East Cross-sections a) A-A' along 4,869,000 metres Northing and b) B-B' along 4,862,000 metres Northing. Ground surface elevation constructed from the MOE water well record database for wells prior to 1987 and river elevation data from ORMDEM.eoo from the MNR (30 metre grid). Borehole information from Sibul et al., 1977.

nature of the geologic materials and the impacts of urbanization such as impermeable surfaces on the water balance (Gerber and Howard, 2000). The total groundwater recharge to the Duffins basin accounts for approximately 25 per cent to 30 per cent of annual precipitation (Gerber and Howard, 1997). As noted in Table 1, these recharge estimates are consistent with estimates from other area studies for similar deposits.

Perched groundwater conditions also occur above the water table, or saturated zone, within sand layers in laminated silts and within deposits of the Halton Till. Seepage to the Carruthers Creek valley has been observed from these perched layers between Taunton and Kingston Roads (ATSL, 1997).

The lower aquifer system, formed by deposits situated beneath the Northern Till, is confined by overlying units of lower permeability (aquitards) and recharged primarily by downward vertical leakage from the Upper aquifer through the Northern Till. This downward vertical leakage has been estimated to be less than 35 to 40 mm/yr (Gerber and Howard, 2000). It is not known whether lateral flow within the lower aquifer(s) enters or leaves the basin across the surface drainage basin divide. In the southern part of the basin near Carruthers Marsh, groundwater flows

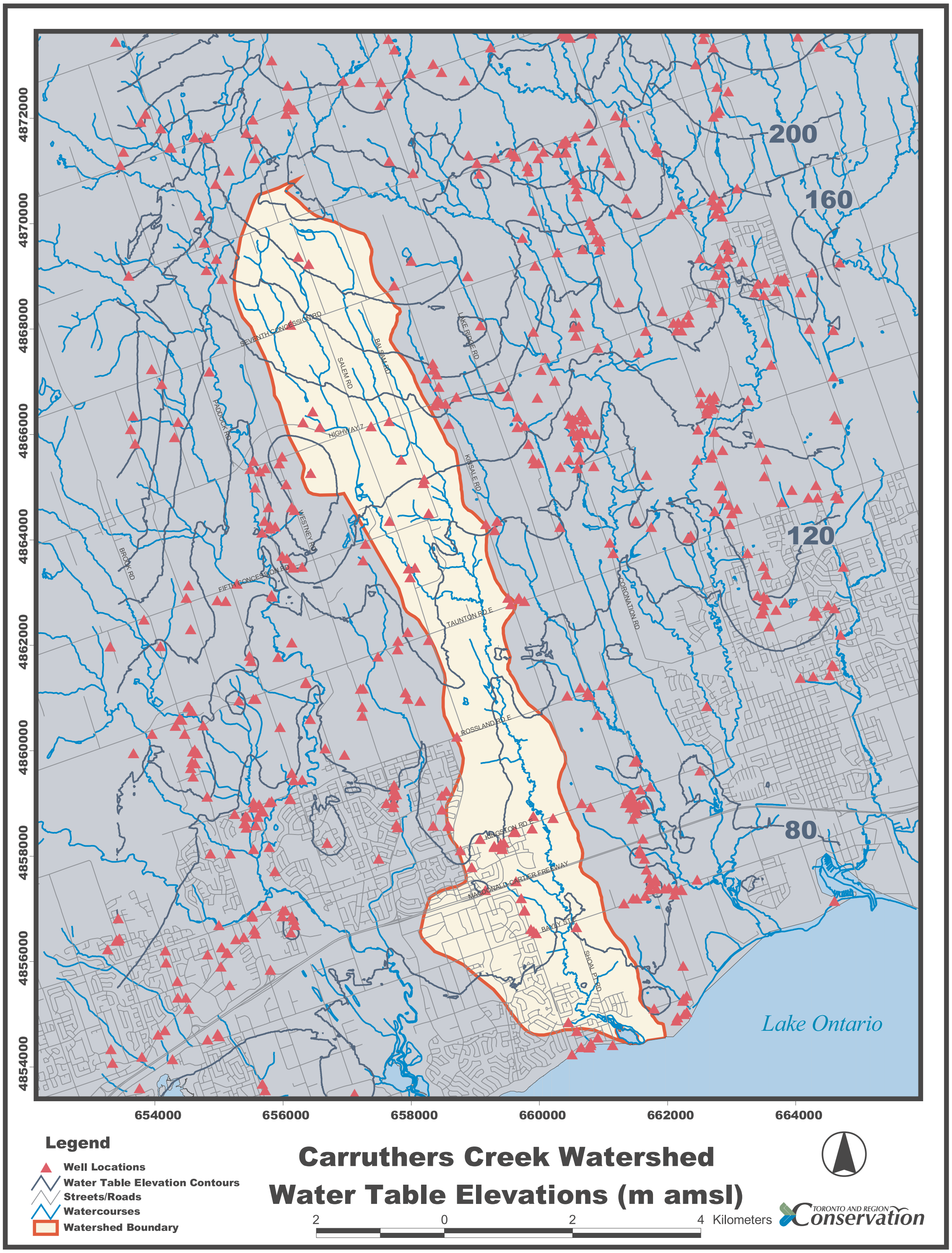


Figure 5:

Water Table Elevation and Shallow Groundwater Flow Directions. Water table surface compiled from MOEE water well record static water level information for boreholes less than 11 metres deep and installed prior to 1987; and river elevation data from ORMDEM.eoo from the MNR (30 metre grid). Note that some stream reaches are intermittent but have been interpreted to represent the water table surface (pending collection of suitable streamflow data).

from the lower aquifer upwards into the upper aquifer, driven by an upward vertical hydraulic gradient of 0.014 (M.M. Dillon Limited, 1995).

Water Balance

In order to properly manage our water resources, we need to develop a quantitative understanding of the hydrologic cycle for a particular area, known as a water balance. In its most simple form, the water balance consists of five major components: precipitation, evapotranspiration, runoff, infiltration and groundwater recharge. Evapotranspiration is a combination of evaporation from lakes and streams and transpiration from plants. Runoff refers to the water which flows upon the land surface to nearby lakes and streams. Infiltration is the amount of precipitation which percolates beneath the ground surface. Some of this water flows within the unsaturated zone (interflow), forming the perched water layers mentioned above; some infiltration reaches the water table, forming recharge. The amount of interflow is very difficult to measure accurately and is usually lumped in with either runoff and/or recharge.

Estimates of various components of the water balance for the regional area (which includes Carruthers Creek) are included in Table 2. Estimates from a more detailed water balance conducted for a site investigation within the Carruthers Creek basin for the Carruthers Marsh area (M.M. Dillon Limited, 1994) are also included in Table 2. This analysis consisted of a soil moisture balance conducted using daily temperature and precipitation data from the Oshawa WPCP climate station (CDC 20492) for the period 1972-1982. The estimates apply to a loam soil which would develop from a geologic deposit such as the Halton Till and assumes a soil moisture capacity of 150 mm, consistent with other estimates completed by Gerber (1994) and Singer (1981). During this period the average total precipitation was 897 mm/yr consisting of 735 mm/yr of rain and 165 mm/yr of snowmelt. Annual average actual evapotranspiration was equal to 572 mm/yr. This leaves a surplus of 318 mm/yr available for runoff and recharge. Note that the surplus water estimate will vary according to soil type with different soil moisture capacities for different soil types. The amount of runoff and recharge will vary depending on many factors including ground surface topography, ground cover or land use, the presence or absence of tile drains, soil characteristics, etc. For the Carruthers Marsh area, M.M. Dillon estimate an average annual surplus of 500 mm/yr with much of this forming runoff over the more clay-rich soils into the marsh.

The present lack of streamflow data for Carruthers Creek precludes any meaningful separation of water surplus into infiltration and runoff. Two streamflow gauges were installed during the summer of 2001 at Taunton Road and near the mouth of the creek above Carruthers Marsh (Figure 1). These data will provide calibration targets for estimates of recharge and runoff.

Groundwater Discharge

The spatial distribution and amount of groundwater discharge or baseflow is very important for maintaining annual streamflow, which in turn supports various habitats such as cold water fisheries. In general, most of the groundwater recharge flows within the shallow subsurface prior to forming groundwater discharge to streams and lakes. For the adjacent Duffins basin, 80 per cent of the total basin baseflow is estimated to discharge from the upper aquifer. This is consistent with the work of Toth (1963), who suggests that deep regional groundwater flow is probably unimportant as far as contributions to the major stream in a basin is concerned, because of the low rate of flow and that a large portion of recharge water (~90 per cent) never reaches this deeper flow system.

Low streamflow was measured at various points throughout the watershed during the summer of 2000. Two areas of significant discharge within the Carruthers Creek basin are shown on Figure 6. One area is situated in the northern part of the basin north of Highway 7. It is expected that this

Table 1: Summary of Groundwater Recharge Estimates for General Area.

a) Carruthers Creek basin - summary of unit recharge rates (mm/a) from other studies.

	Gerber 1994	Meriano 1999	Hunter et al. 1996	Smart 1994	Singer 1981	IWA, 1994e Site EE11 2-D	IWA, 1994e Site EE11 3-D	M.M. Dillon 1990 Site P1 3-D
Oak Ridges Moraine								
ice contact	300-400	400	300-400	350	280-380			
hummocky till		335						
Halton Till Plain	150-250	150-200		170-250	150-200	126	189	100-150
Glacial Lake Peel								
silty clay		35		50				
sand		200						
Glacial Lake Iroquois								
sand and gravel		200		150				
clay and silt				0-40	50-100			
diamict					50-100			
Urban		50		0-40				

Note: Hunter et al. (1996) estimate for Oak Ridges Moraine > 275 m amsl.
2-D = two-dimensional groundwater flow model; 3-D = three-dimensional groundwater flow model.

b) Numerical model calibrated recharge for the Duffins Creek study area

	total area km^2	recharge area km^2	% of recharge area	unit recharge mm/a	total recharge m^3/a	total recharge m^3/d	% of total recharge	river cells	rech area (m2)	281,296,465 3,679,944
Duffins Basin	282									
Petticoat Basin	54									
Oak Ridges Moraine										
ice-contact	40	35	13%	400	14,173,700	38,800	31%	112	35,434,200	
hummocky till	39	36	13%	325	11,592,000	31,800	25%	80	35,667,800	
Halton Till Plain	111	85	30%	150	12,726,300	34,900	27%	398	84,842,000	
Glacial Lake Markham	58	50	18%	50	2,476,200	6,800	5%	208	49,523,200	
Glacial Lake Iroquois										
sand and gravel	24	20	7%	200	3,959,500	10,800	9%	104	19,797,600	
silt and clay	34	32	11%	25	792,100	2,200	2%	60	31,682,000	
diamict	30	25	9%	25	623,100	1,700	1%	100	24,922,200	
	336	282	100%		46,342,900	127,000	100%	1062	281,869,000	

recharge area = total area minus area of river & river valley cells where discharge occurs.
unit recharge rates from Gerber and Howard, 2000.

discharge is from the upper aquifer. The other area of significant baseflow occurs between Taunton Road and Highway 401 in the central part of the basin. Although more analysis is necessary, it is expected that this baseflow is realized from both the Upper aquifer and lower aquifers based on the relationship of the river channel to the bedrock surface in this area (Figure 7). Further analysis will require more borehole information to construct the three-dimensional architecture of the sedimentary deposits over the bedrock surface.

Groundwater Travel Times

Groundwater travel time estimates can provide an understanding of how quickly dissolved contaminants may move through a groundwater flow system. It should be noted that hydraulic changes to a groundwater flow system such as those induced by changing land use are expected to occur relatively rapidly. Groundwater travel times will vary throughout the basin. For instance, much of the recharge to the upper aquifer will discharge to local streams on the order of years to decades. In contrast, water which recharges further from streams and closer to local drainage divides is more likely to reach deeper aquifers, where travel times of hundreds to thousands of years can be expected prior to discharge. This is consistent with regional groundwater flow modeling for the Oak Ridges

Table 2: Summary of Average Annual Water Balance Information for General Area.

	Gauging Station	Climate Station	Period	P	PET	AET	Surplus	Recharge		Streamflow		
								monthly	daily	total	baseflow	runoff
Regional												
Lake Ontario, South Slope and Simcoe and Kawartha Lakes			30-50 yrs	813	584-610	533-559	280-330					
Great Lakes Basin			1935-64		585	533-559						
				866	584							
					610	559						
W Duffins Creek at Green River	02HC026	Stouffville WPCP	1982-87	932	619 (591)	507 (547)	425	231	270	422	267	155
Duffins Creek above Pickering	02HC019	Stouffville WPCP	1982-89	908	619 (593)	492(538)	416	209	254	464	303	161
Duffins Creek at Pickering	02HC006	Stouffville WPCP	1982-89	908	619 (593)	496 (540)	412	224	267	397	252	145
Local - Carruthers Creek												
Carruthers Marsh		Oshawa WPCP	1972-82	897		572	318 loam					
							500 clay					

Note: all values in mm/year
619 (593) daily (monthly) Thornthwaite and Mather (1957) calculation.

Moraine (Smart, 1994) and for the Duffins basin (Gerber and Howard, 2000).

Groundwater flows at relatively slow velocities compared to surface water flow in a stream. For the upper aquifer, average horizontal groundwater flow velocities are expected to be less than approximately 0.5 m/yr (assuming a hydraulic conductivity of 3x10-7 m/s (M.M. Dillon Limited, 1994), a horizontal hydraulic gradient of 0.02 (M.M. Dillon Limited, 1995) and a porosity of 0.3). This estimate largely reflects Halton Till and lacustrine silt and clay deposits. Local sand-rich deposits will have average horizontal groundwater flow velocities on the order to 50 m/yr. For the deeper aquifers, groundwater flow velocities are expected to be slower, and generally less than 25 m/yr (K = 5x10-5 m/s; i = 0.005; n = 0.3). The lower groundwater flow velocities within the deeper aquifers occur mainly because of the lower regional horizontal hydraulic gradients. The slowest groundwater velocities will be experienced during vertical flow through aquitards where hydraulic conductivities are far less than in aquifers. A compilation of hydraulic conductivity estimates for the deposits found in the Carruthers Creek basin are provided in Table 3. Average linear groundwater flow velocities are estimated by dividing the product of the hydraulic conductivity and the hydraulic gradient by the porosity.

Groundwater Quality

Groundwater quality is largely unknown for the Carruthers Creek basin. The following is a brief summary from groundwater quality studies conducted in adjoining basins. The first extensive local study of groundwater quality was completed by the MOE (Sibul et al., 1977) in 1970 and 1974 and involved the analysis of 44 groundwater samples from the Duffins and Rouge drainage basins situated to the west of Carruthers Creek. The groundwater encountered in the shale bedrock was found to have poor water quality, particularly high sodium and sulphate concentrations, consistent with subsequent analyses conducted for landfill investigations (M.M. Dillon Limited, 1990; IWA, 1994) and aquitard studies during the summer of 2000 (Gerber, unpublished data).

Groundwater quality does not appear to vary significantly within any of the three aquifers within the unconsolidated deposits above bedrock (Sibul *et al*., 1977; Howard and Beck, 1986) and appears to be of generally good quality for domestic use. Local occurrences of natural high hardness and iron values have been reported, along with locally elevated levels above (drinking water criteria) for nitrates and chlorides, believed to represent contamination (Sibul *et al*., 1977). A subsequent analysis of 260 groundwater samples in the Duffins and Rouge basins between 1982 and 1984 (Howard and Beck, 1986) also

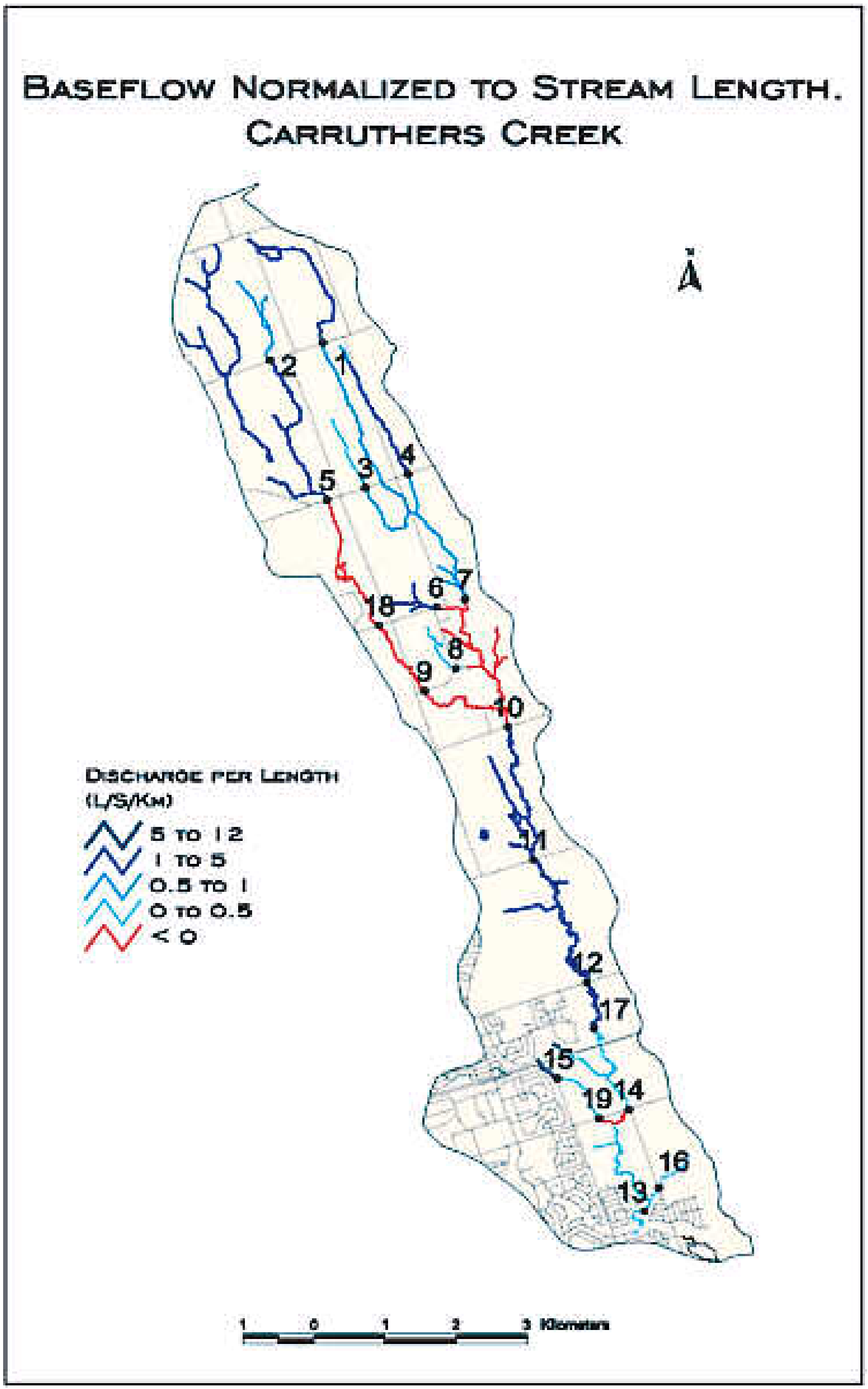


Figure 6:

Observed Low Streamflow - August 2000.

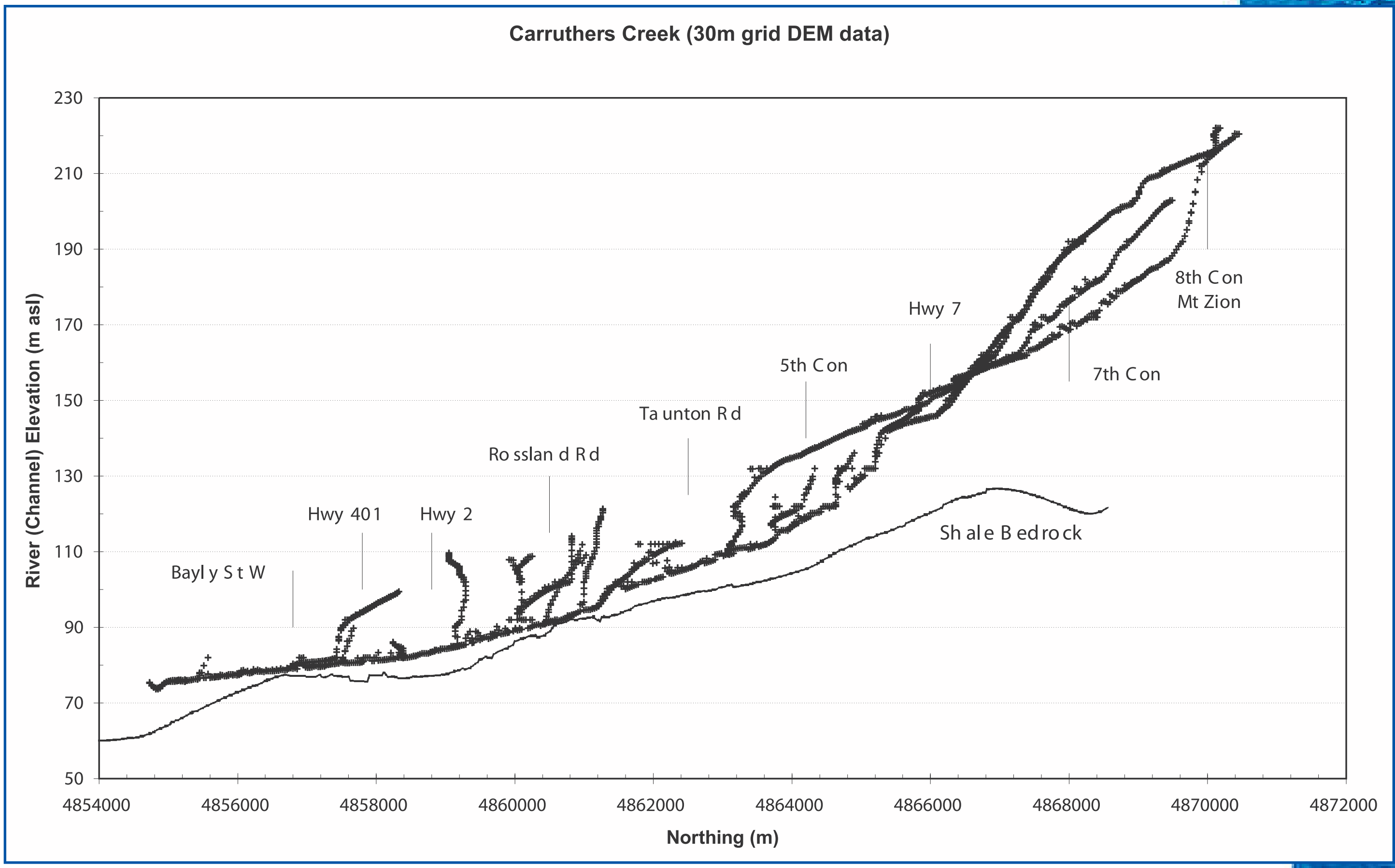


Figure 7:

River Profile - Carruthers Creek. River channel elevation data from 30 metre grid DEM. Bedrock elevation data from MOE water well records (< 1987).

revealed the presence of elevated chloride and nitrate values attributed to road salt and nitrate fertilizer contamination, respectively. The surface waters associated with the Carruthers Marsh also indicate impacts from contaminants such as pesticides, road salt and fertilizers (M.M. Dillon Limited, 1995). The chloride concentration of Carruthers Creek surface waters measured at Shoal Point Road also show an upward trend from about 20-40 mg/L in 1964 to approximately 60-80 mg/L in 1994, presumably reflecting the application of road salt (Figure 8).

Table 3: Summary of Applicable (a) Estimated (Duffins Basin) and (b) Calibrated Estimates of Hydraulic Conductivity (metres per second) for General Area

		a) estimated K					b) numerical model calibrated K_h						n
		Min	Max	Mean	no.	geom. mean	3-D Duffins Gerber 2000	3-D Rouge Meriano 1999	3D Smart 1994	3-D Site P1 Dillon 1990	2-D Site EE11 IWA, 1994e	3-D Site EE11 IWA, 1994e	
Upper aquifer													
HT	slug K_h	2×10^{-9}	2×10^{-5}	3×10^{-6}	54	4×10^{-7}	6×10^{-6}	9×10^{-6}		1×10^{-4}	2×10^{-6}	2×10^{-7}	0.20
	pump K_h			6×10^{-6}	1					5×10^{-6}		1×10^{-6}	
	pump K_v	1×10^{-8}	1×10^{-7}		1								
LM							1×10^{-6}	5×10^{-7}					0.20
								2×10^{-5}					
ORM	sc K_h	2×10^{-6}	7×10^{-3}		1287	5×10^{-5}	4×10^{-5}	5×10^{-7}					0.30
	slug K_h (2)		1×10^{-5}					2×10^{-5}					
	tracer K_h (3)		6×10^{-4}										
MIS	slug K_h	3×10^{-8}	5×10^{-4}	5×10^{-5}	16	6×10^{-6}	6×10^{-5}	1×10^{-5}					0.30
								4×10^{-5}					
Northern till (aquitard)													
	lab K_v	1×10^{-11}	7×10^{-10}	5×10^{-11}	40	3×10^{-11}	1×10^{-8}	4×10^{-8}	1×10^{-8}	4×10^{-10}	1×10^{-8}	1×10^{-12}	0.15
	slug K_h	3×10^{-12}	3×10^{-6}	3×10^{-7}	39	8×10^{-10}	5×10^{-8}		1×10^{-7}	1×10^{-9}	1×10^{-7}	2×10^{-7}	
	pump K_h			6×10^{-6}	1								
	pump K_v	3×10^{-11}	3×10^{-7}		4								
Middle aquifer (Thorncliffe Formation)													
	slug K_h	1×10^{-8}	3×10^{-4}	2×10^{-5}	42	2×10^{-6}	2×10^{-5}	2×10^{-7}		1×10^{-7}	1×10^{-6}	1×10^{-7}	0.30
	pump K_h	1×10^{-7}	9×10^{-5}	3×10^{-5}	4	5×10^{-6}	5×10^{-5}	2×10^{-5}		2×10^{-5}	1×10^{-5}	1×10^{-5}	
	sc K_h	1×10^{-6}	2×10^{-3}		286	4×10^{-5}							
Sunnybrook diamict (aquitard)													
	slug K_h (1)	3×10^{-7}	4×10^{-7}		2		1×10^{-9}	1×10^{-9}		1×10^{-10}	1×10^{-8}	1×10^{-9}	0.30
										5×10^{-9}			
Lower aquifer (Scarborough Formation)													
	slug K_h	2×10^{-8}	2×10^{-4}	5×10^{-5}	5	2×10^{-6}	1×10^{-5}	4×10^{-5}		2×10^{-5}	2×10^{-6}	2×10^{-6}	0.30
	sc K_h	6×10^{-7}	7×10^{-4}		311	2×10^{-5}				4×10^{-5}			
	pump K_h (4)		2×10^{-4}										
Shale bedrock (aquitard)													0.20
	weathered									2×10^{-7}	2×10^{-6}	2×10^{-6}	
	unweathered						1×10^{-11}	1×10^{-11}			impermeable		

Note:
ORM = Oak Ridges Moraine; MIS = Mackinaw Interstadial; HT = Halton Till; LM = Lake Markham
sc = specific capacity estimates from water well data (method of Bradbury and Rothschild (1985) by Boyce (1997)).
slug = slug test; pump = pump test; tracer = tracer test to determine hydraulic conductivity.
K_h = horizontal hydraulic conductivity; K_v = vertical hydraulic conductivity; n = porosity
Estimated K data from M.M. Dillon Limited, 1990; IWA Limited, 1994a-e; Smart, 1994; Meriano, 1999 and Gerber, 1999.
For model K estimates; K_h = 10 K_v (consistent with Martin and Frind, 1998) except Site P1 where isotropy assumed.
(1) piezometers in sand layers within aquitard unit.
(2) Proulx and Farvolden, 1989; (3) Kaye, 1986; (4) Palmer and Nadon, 1986.

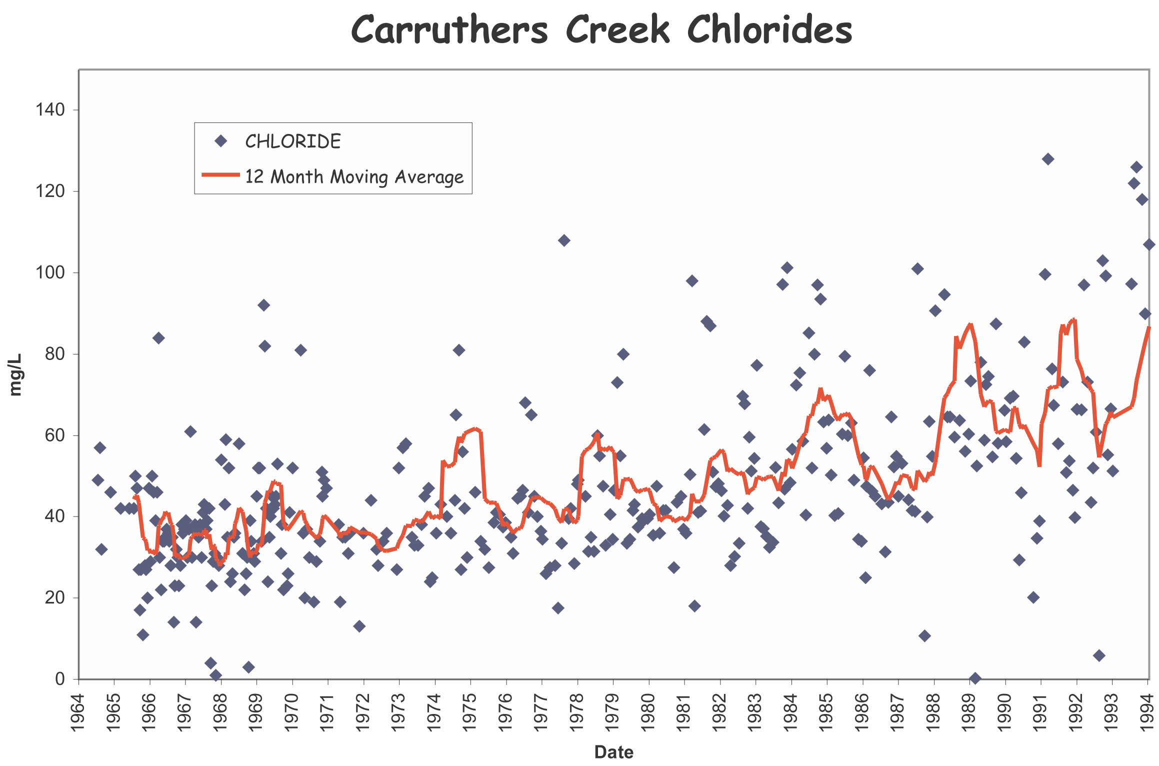


Figure 8:

Carruthers Creek Chloride Concentrations Measured at Station Shoal Point Road.

Summary

In order to properly manage and plan the use and protection of groundwater resources, the entire flow system must be adequately understood and quantified. For example, regulation of the amount of groundwater takings must be coupled with an estimate of the amount of water which recharges and is available within each aquifer. This in turn must be linked to possible changes which may be induced in other parts of the groundwater flow system. Within the Carruthers basin area, there is a poor understanding of the amount of groundwater utilized by the various users (private homes, industry, golf courses and agriculture) coupled with the present lack of understanding of the amount of water which recharges, the three-dimensional architecture of the sedimentary deposits, the amount of flow through the various layers of the groundwater flow system, and the groundwater discharge at various locations.

Groundwater quality concerns at the present time appear to be isolated occurrences of 1) nitrates and bacteria associated with septic system effluent entering private wells and 2) high chloride values above drinking water criteria (250 mg/L) occurring in private wells situated next to salted roadways. The full impact (reaching steady state) of any quality changes to the groundwater flow system may not be fully realized for decades to thousands of years based on groundwater travel path and time assessments. Physical or hydraulic changes to the groundwater flow system are however, expected to be realized within a much shorter time frame.

Finally, any physical or chemical changes to the groundwater flow system are unlikely to be properly noticed and quantified unless baseline or background conditions are known. This involves long-term monitoring of both groundwater hydraulic head, groundwater chemistry and streamflow conditions in order to understand natural changes which occur within the system and to then interpret whether anthropogenic changes are occurring.

References

ATSL (Associated Testing Services Limited), 1997. *Hydrogeologic Assessment, A8 Development, Town of Ajax*. Prepared for Cosburn Patterson Mather Limited, March.

Barnett, P.J., Sharpe, D.R., Russell, H.A.J., Brennand, T.A., Gorrell, G., Kenny, F. and Pugin, A., 1998. On the Origin of the Oak Ridges Moraine. *Canadian Journal of Earth Sciences* 35: 1152-1167.

Beckers, J. and Frind E.O., 2001. Simulating Groundwater Flow and Runoff for the Oro Moraine Aquifer System. Part II. Automated Calibration and Mass Balance Calculations. *Journal of Hydrology* 243: 73-90.

Berger, G.W. and Eyles, N., 1994. Thermoluminescence Chronology of Toronto-Area Quaternary Sediments and Implications for the Extent of the Midcontinent Ice Sheet(s). *Geology* 22: 31-34.

Boyce, J.I., Eyles, N. and Pugin, A., 1995. Seismic Reflection, Borehole and Outcrop Geometry of Late Wisconsin Tills at a Proposed Landfill Near Toronto, Ontario. *Canadian Journal of Earth Sciences* 32: 1331-1349.

Chapman, L.J. and Putnam, D.F., 1984. *The Physiography of Southern Ontario*. Ontario Geological Survey, Special Volume 2.

Eyles, N.E., 1997. Environmental Geology of a Supercity: The Greater Toronto Area. In *Environmental Geology of Urban Areas*, edited by N. Eyles. Geological Association of Canada, Geotext 3: 7-80.

Eyles, N, Boyce, J.I. and Mohajer, A., 1993. Bedrock Topography in the Western Lake Ontario Region; Evidence for Reactivated Basement Structures? *Geographie Physique et Quaternaire* 47: 269-283.

Gerber, R.E., 1994. *Recharge Analysis for the Central Portion of the Oak Ridges Moraine*. M.Sc. Thesis, University of Toronto, 172p.

Gerber, R.E. and Howard, K.W.F., 1997. Ground-water Recharge to the Oak Ridges Moraine. In *Environmental Geology of Urban Areas*, edited by N. Eyles, Geological Association of Canada, Geotext 3: 173-192.

Gerber, R.E. and Howard, K.W.F., 2000. Recharge Through a Regional Till Aquitard: Three- dimensional Flow Model Water Balance Approach. *Ground Water* 38(3): 410-422.

Gwyn, Q.H.J. and DiLabio, R.N.W., 1973. *Quaternary Geology of the Newmarket Area, Southern Ontario*. Ontario Division of Mines Preliminary Map, p. 836.

Howard, K.W.F. and Beck, P., 1986. Hydrochemical Interpretation of Groundwater Flow Systems in Quaternary Sediments of Southern Ontario. *Canadian Journal of Earth Sciences* 23: 938-947.

Interim Waste Authority, 1994. Detailed Assessment of the Proposed Site EE11 for Durham Region Landfill Site Search, Technical Appendices Parts 1 and 3 of 4. Prepared by M.M. Dillon Limited, October 1994.

Johnson, M.D., Armstrong, D.K., Sanford, B.V., Telford, P.G. and Rutka, M., 1992. *Paleozoic and Mesozoic Geology of Ontario*. Ontario Geological Survey, Special Volume 4, Part 2, pp. 907-1010.

Karrow, P.F., 1967. *Pleistocene Geology of the Scarborough Area*. Geological Report 46, Ontario Department of Mines, Toronto.

Karrow, P.F. and Ochietti, S., 1989. Quaternary Geology of the St. Lawrence Lowlands of Canada. In *Quaternary geology of Canada and Greenland*. Edited by R.J. Fulton. Geological Survey of Canada, Geology of Canada, no. 1, 321-389.

Kaye, B.G., 1986. *Recharge Characteristics of the Oak Ridges Complex: The Role of Musselman Lake*. Unpublished M.Sc. thesis, University of Waterloo, Waterloo, Ontario, Canada.

Martin, P.J. and Frind, E.O., 1998. Modeling a Complex Multi-aquifer System: The Waterloo Moraine. *Ground Water* 36(4): 679-690.

Meriano, M., 1999. Hydrogeology of a Complex Glacial System, Rouge River - Highland Creek Watershed, Scarborough, Ontario. Unpublished M.Sc. Thesis, University of Toronto, Toronto, Ontario.

M.M. Dillon Limited, 1990. *Regional Municipality of Durham Contingency Landfill Site Assessment Technical Support*, Volume B, Technical Report, Hydrogeology. September 1990.

M.M. Dillon Limited, 1994. *Carruthers Creek Marsh, Wetland Environmental Impact Study*. Prepared for Runnymede Development Corporation. November 30.

M.M. Dillon Limited, 1995. *Somerset Cove, Warbler Swamp, Water Balance Study*. Runnymede Development. DRAFT. Prepared for Runnymede Development Corporation. May 8.

Ostry, R.C., 1979. *The Hydrogeology of the IFYGL Duffins Creek Study Area*. Water Resources Report 5c, Ministry of the Environment, Water Resources Branch, Toronto, Ontario.

Palmer, C.D. and Nadon, R.L., 1986. A Radial Injection Tracer Experiment in a Confined Aquifer, Scarborough, Ontario, Canada. *Ground Water* 24(3): 322-331.

Phillips, D.W. and McCulloch, J.A.W., 1972. *The Climate of the Great Lakes Basin*. Climatological Studies, Number 20, Environment Canada, Atmospheric Environment Service.

Proulx, I. and Farvolden, R.N., 1989. *Analysis of the Contaminant Plume in the Oak Ridges Aquifer*. Ontario Ministry of the Environment, R.A.C. project No. 261, 134p.

Sharpe, D.R. and Barnett, P.J. (Compilers), 1997a. Where is the water? Regional Geological/Hydrological Framework, Oak Ridges Moraine Area, Southern Ontario. Geological Association of Canada - Mineralogical Association of Canada, Joint Annual Meeting, Ottawa 1997, Field Trip A1, Guidebook, 49 p.

Sharpe, D.R. and Barnett, P.J., 1997b. *Surficial Geology of the Markham Area*, NTS 30M/14, Southern Ontario. Geological Survey of Canada, Open File 3300, Scale 1:50,000.

Sibul, U., Wang, K.T. and Vallery, D., 1977. *Ground-Water Resources of the Duffins Creek- Rouge River Drainage Basins*. Water Resources Report 8, Ministry of the Environment, Water Resources Branch, Toronto, Ontario.

Singer, S., 1981. *Evaluation of the Ground Water Responses Applied to the Bowmanville, Soper and Wilmot Creeks IHD Representative Basin*. Ontario Ministry of the Environment, Water Resources Report 9B.

Smart, P.J., 1994. *A Water Balance Numerical Groundwater Flow Model Analysis of the Oak Ridges Aquifer Complex, South-central Ontario*. Unpublished M.Sc. Thesis, University of Toronto, Toronto, Ontario. 155p.

Thornthwaite, C.W. and Mather, J.R., 1957. *Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance*. Drexel Institute of Technology, Laboratory of Climatology, Publications in Climatology, Volume X, Number 3, Centerton, New Jersey.

Toth, J., 1963. A Theoretical Analysis of Groundwater Flow in Small Drainage Basins. *Journal of Geophysical Research* 68: 4795-4812.

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Cover photograph: A pumpkinseed (Lepomis gibbosus), more commonly known as a sunfish, in its habitat.

Photo credit: TRCA

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Introduction to Aquatic Habitat and Species

The health of the aquatic environment and the condition of the Carruthers Creek watershed are interconnected. This is because the aquatic environment is directly affected by the quality and quantity of water that flows over or through the land. The health of the aquatic habitat, therefore, is an indicator of the health of the watershed.

The aquatic ecosystem is most often described as fish habitat since fish communities are important resources, and as such, have a long history of being used as indicators of aquatic ecosystem health. Aquatic habitat is an integral part of the watershed's ecosystem as it provides feeding, breeding and rearing areas for resident and migratory fish and invertebrate species. Within the watershed, aquatic habitats can be divided into several different habitat categories on the basis of suitability for differentiating aquatic communities. These habitat categories fall into three broad groups: riverine habitat (creeks and rivers), lacustrine habitat (ponds and lakes) and estuarine habitat (coastal marsh). In the following sections each habitat category is identified and its significance, condition and any changes in condition over time are described.

In 2000, a survey of fish communities and habitat was conducted to provide a benchmark of our current knowledge of the watershed, allowing for the identification of significant management issues as well as gaps in our knowledge. A comprehensive analysis of the fish community, aquatic habitat and a management plan for the aquatic ecosystem will be completed early in 2002.

Riverine Habitat

Carruthers Creek is a small watershed containing only 61 kilometres of streams. Riverine habitat is by far the most common type of habitat along Carruthers Creek. Riverine habitat can be divided into coldwater and warmwater habitat categories. The determinants of which type of habitat exists in a particular location is a result of a number of watershed and more local level characteristics that affect fundamental components of the habitat such as flow regime and water temperature. The underlying geology, in conjunction with riparian vegetation (i.e. vegetated areas adjacent to stream) and land use, produce the flow, water temperature, water quality and associated aquatic community that we see today. To understand the current health of fish communities and their potential, it is necessary to interpret these communities in the context of these factors.

Unlike many of the Lake Ontario watersheds, the headwaters of Carruthers Creek does not begin on the Oak Ridges Moraine (see the Hydrogeology chapter for more details). Carruthers Creek begins in the Halton Till, flowing south across the sands and gravels of the historic Lake Iroquois shoreline and then the deep water silt and clay deposits of Lake Iroquois. Below the deposits at the surface, the geology alternates between the layers of lacustrine silt and clay and fluvial deposits (i.e. associated with a stream or river) of sand and gravel. The deeper deposits reach the surface within the valley south of the 5th Concession. In fact, groundwater discharge to Carruthers Creek is thought to be from the deeper "middle aquifer," as opposed to the regional upper aquifer which dominates groundwater. Each of the geologic deposits the river drains from or crosses influences the characteristics of the river and thus the conditions that support the aquatic communities.

The principal way in which the geology of the watershed influences the fish community is by moderating flow and water temperature. Coarse surficial deposits encourage infiltration of surface water across the landscape on which they occur, thus reducing overland surface flow to local streams. As a result, streams draining from areas with coarse soils such as the Oak Ridges Moraine or the Iroquois shoreline tend to have less frequent storm flow conditions and a significant baseflow component due to groundwater discharge. This combination results in an overall more stable flow regime.

Groundwater, a characteristic related to geology, is another important factor that determines the type of habitat and associated fish community that can be sustained. Groundwater seeps or flows into the creek where the aquifers are exposed. The more groundwater discharge into the watercourse, the greater the potential for coldwater habitat. At 8-10°C year round, groundwater is the source of cold water to watercourses. The addition of warm flow from parking lots or streets moderates the cold water and reduces the area of coldwater habitat.

A good way to understand and measure whether groundwater inputs are significant for aquatic habitat is to examine the ratio of baseflow, a measure of groundwater input, relative to the annual flow. Research indicates that a ratio of greater than 20 per cent groundwater discharge to average annual flow is required to support trout species. This occurs when roughly 20 per cent of the total average annual flow is derived from groundwater discharge into the creek. Unfortunately, a stream gauge has only recently been installed in Carruthers Creek and it will be some time before the baseflow ratio can be estimated. One indication that the baseflow ratio in Carruthers Creek is at least 20 per cent of the total annual flow is the presence of young-of-the-year (i.e. juvenile) rainbow trout, which suggests that successful spawning is occurring. By comparison, estimates of baseflows in the neighbouring Duffins Creek watershed range from 50 per cent for Duffins Creek south of Highway 2, to 37 per cent for the West Duffins at Green River, 61 per cent for the East Duffins above Pickering, and up to 50-60 per cent for Ganatsekiagon Creek and Urfe Creek (Eyles *et al*., 1997: Sibul *et al*., 1997).

Table 1: Cumulative Fish Species Recorded from Carruthers Creek

Common Name	Scientific Name
American brook lamprey	Lampetra appendix
rainbow trout	Oncorhynchus mykiss
northern pike	Esox lucius
white sucker	Catostomus commersoni
redside dace	Clinostomus elongatus
northern redbelly dace	Phoxinus eos
common shiner	Luxilus cornutus
brassy minnow	Hybognathus hankinsoni
bluntnose minnow	Pimephales notatus
fathead minnow	Pimephales promelas
blacknose dace	Rhinichthys atratulus
longnose dace	Rhinichthys cataractae
creek chub	Semotilus atromaculatus
brown bullhead	Ameiurus nebulosus
banded killifish	Fundulus diaphanus
brook stickleback	Culea inconstans
threespine stickleback	Gasterosteus aculeatus
rock bass	Ambloplites rupestris
largemouth bass	Micropterus salmoides
pumpkinseed	Lepomis gibbosus
yellow perch	Perca flavescens
johnny darter	Etheostoma nigrum

Source: TRCA, OMNR

One way to determine the health of the aquatic community is to calculate an Index of Biologic Integrity (IBI). The IBI is used to determine the ecological condition of the fish community by incorporating species richness, tropic balance and the abundance of fish and the presence of indicator species. This method was first proposed by Karr (1981) and was further modified and calibrated for southern Ontario streams by Steedman (1988).

To date, a total of 22 species have been recorded from Carruthers Creek (Table 1). Of these recorded species, only one species is non-native, the rainbow trout. In the 2000 survey of the Carruthers Creek fish community, 10 species were encountered. that fewer species were found in the 2000 survey is most likely a reflection of the lower sampling effort, sampling locations and normal variations that occur over time. The IBI results for the six sites surveyed in 2000 produced a median score of "good" (Figure 1). Of note in the survey were young rainbow trout caught below Highway 401, and mottled sculpin found near Whitevale Road.

Historically, most areas would have supported coldwater communities. Brook trout, slimy sculpin and mottled sculpin are traditionally associated with this habitat, and other than the mottled sculpin, they have not been seen in the creek for some time. The rainbow trout found near Highway 401 are not new; spawning migratory rainbow trout and young-of-the-year rainbow trout were previously found in the middle reaches north of Highway 401(Bird and Hale, 1997).

The middle and upper reaches are coldwater habitats as indicted by the geology and the presence of temperature-sensitive species such as rainbow trout and mottled sculpin. Conversely, the lower creek below Bayly Street suggests it is fundamentally warmwater habitat due to its very low gradient, its distance from groundwater sources, its close proximity to Lake Ontario, and observations of young-of-the-year northern pike.

The Carruthers Creek watershed has experienced a number of changes over the years. Historically the watershed was dominated by vast forests that had a tremendous influence on the hydrology of the watershed. The hydrologic cycle would have first been impacted by the clearing of forests that once covered the watershed and their replacement by agriculture. The loss of forest cover allowed more water to flow over the land, reaching watercourses faster than when forest cover was extensive. The shift from agriculture to urban further impacted the hydrologic cycle. The impermeable surfaces associated with urban areas

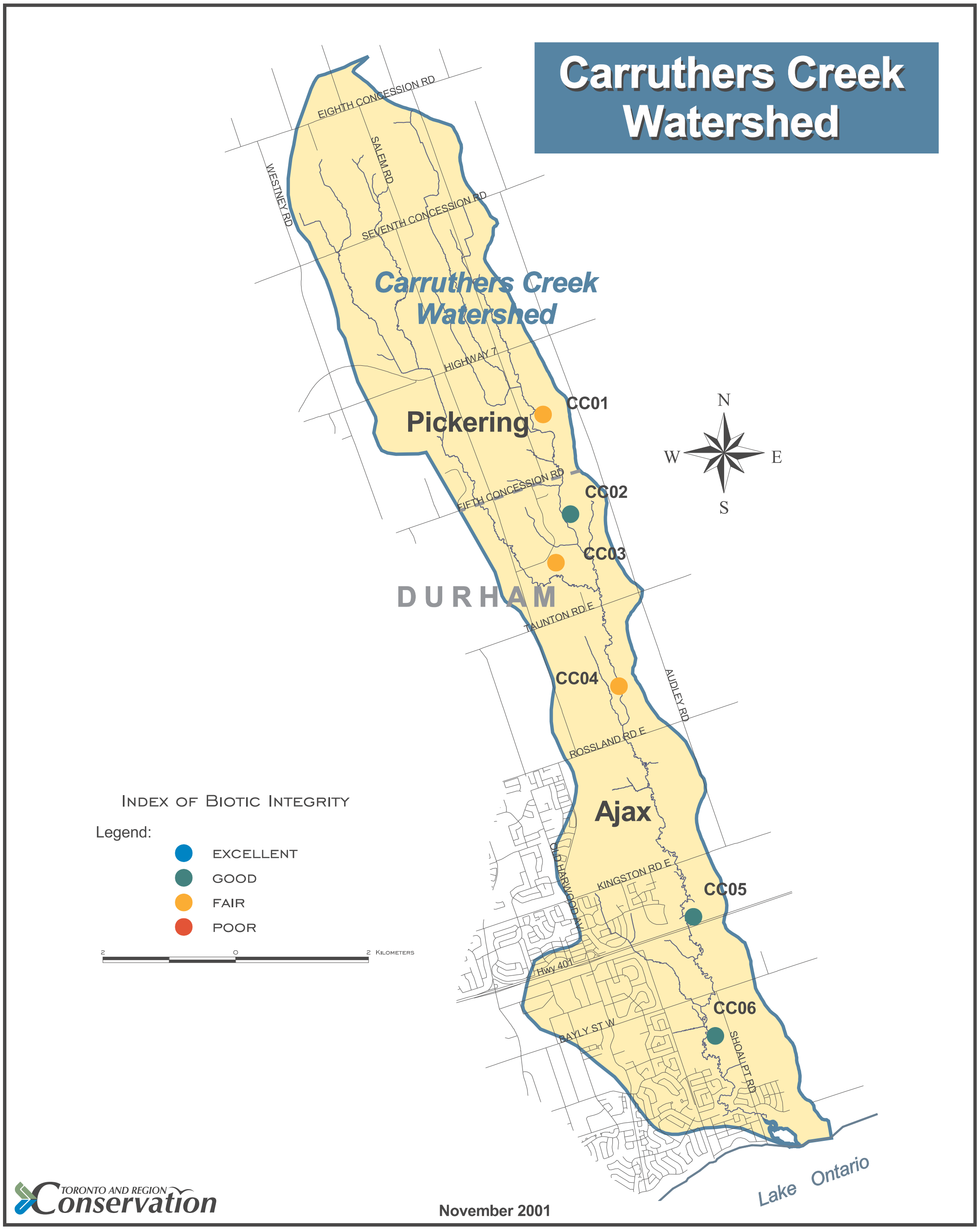

Figure 1

The IBI results for six sites surveyed in 2000.

significantly increase the volume of surface runoff as well as the frequency of runoff. It also reduces the time it takes for runoff to reach the creek. For the creek, this change in runoff causes the creek to become 'flashy,' meaning that water levels rise and drop quickly. In response to storm events, the creek enlarges, destroying cover and increasing sediment loads. If these changes to the surface and groundwater regimes are extensive enough, they can significantly impact fish habitat.

Some rural land use activities may also affect riverine habitat. The primary impact to the creek ecosystem in rural areas is the loss of woody vegetation from the riparian zone and other vegetative buffers. In many areas, especially the headwaters, the area next to the watercourse has been cleared of woody vegetation and the land has been cropped very close to stream banks. However, over the past 40 years the condition of the riparian zone has been improving. Based on a qualitative assessment of 1958 and 1999 aerial photography, there is currently more woody riparian vegetation in the watershed than was present in 1958. There also appeared to be more vegetated buffers present in 1999 than in 1958. Overall, the riparian zone appears to be in better condition today than in recent history, although there is still much room for improvement.

The presence of in-stream barriers to fish passage in the watershed can have an impact on the aquatic system. Structures that act as barriers include dams, weirs, level crossings, and some culverts. In-stream barriers in the Carruthers Creek watershed generally occur north of Tauton Road, fragmenting the habitat and limiting access to summer refugia, feeding areas or spawning habitat. Managing the effects of in-stream barriers is an important issue that must be addressed in the development of a watershed fisheries management plan.

In the Carruthers Creek watershed, changes such as transportation, urbanization, water taking, and ponds, among others, have impacted the watershed, however their extent within the watershed is limited and the system can likely be rehabilitated. Management efforts in the future should address five areas:

- ensuring that future developments do not alter the flow regime
- retrofit stormwater controls in areas already developed
- planting riparian zones with trees and shrubs
- modifying in-stream barriers to allow fish passage
- expanding tableland forests to reduce runoff.

Lacustrine Habitat

Lacustrine habitat is characterized by the presence of slow moving or standing water. In general, there are two types of lacustrine habitat in the Carruthers Creek watershed – online and offline ponds. Online ponds are directly connected to a stream or river with the creek passing directly through the waterbody. Offline ponds are isolated with little or no connection to a stream or river, or indirectly connected through a subsurface pipe or a channel that directs some flow from the stream to the pond. In total, there are seven online ponds and 20 offline ponds with a combined surface area of three hectares within the watershed.

Ponds can also be created through a variety of acts of nature. Many ponds are created by beaver buildimg dams with wood and other debris. These structures are generally not a concern as they are natural and tend to be transient in nature. Ponds may also be formed through the normal migration of the creek, which can create oxbow lakes or ponds.

Online ponds are depositional areas that accumulate sediments and tend to evolve into wetlands and eventually uplands over time. The accumulated sediments can pose a risk to downstream fish communities if released from the pond or reservoir. Online ponds may also contribute to warming of the creek because large ponds and lakes, such as the ponds north of Taunton Road, slow the water and allow the surface temperatures to rise. This results in increased temperatures downstream and may make the habitat less suitable for coldwater species. In some cases this warming effect can be mitigated if the water is released from the bottom of the pond where it is usually cooler.

Estuarine Habitat

The estuarine area, located at the confluence of Carruthers Creek and Lake Ontario, covers eight hectares. This habitat serves as a transition zone between the lake and the creek and a total of 24 species have been recorded here (Table 2). Species found here include warmwater fish, such as largemouth bass and carp, as well as exclusively lake species such as white bass, white perch, gizzard shad and alewife. This area is important to both lake and creek species because it provides spawning areas for 10 species and provides rearing areas for 16 species. In total, 75 per cent of the species found in the marsh use the area for either spawning or rearing purposes (Stephenson, 1988). This is a consequence of the dense plant growth that serves as excellent cover for maturing fish. Another important fact is that marshes are highly productive because they receive significant amounts of nutrients from upstream areas. These nutrients provide a resource/food base for the developing fish and prey.

Maintenance and protection of the coastal marshes is of critical importance. This area not only supports creek species but lake species as well. Thus, by protecting the marsh we will be maintaining spawning, rearing and feeding habitat for a wide variety of species.

Table 2. Cumulative Fish Species Recorded From the Carruthers Creek Estuarine Marsh Area.

Common Name	Scientific Name
alewife	Alosa pseudoharengus
gizzard shad	Dorosoma cepedianum
northern pike	Esox lucius
central mudminnow	Umbra limi
white sucker	Catostomus commersoni
carp	Cyprinus carpio
golden shiner	Notemigonus crysoleucas
emerald shiner	Notropis antherinoides
common shiner	Luxilus cornutus
spottail shiner	Notropis hudsonius
bluntnose minnow	Pimephales notatus
fathead minnow	Pimephales promelas
creek chub	Semotilus atromaculatus
brown bullhead	Ameiurus nebulosus
white perch	Morone americana
white bass	Morone chrysops
rock bass	Ambloplites rupestris
pumpkinseed	Lepomis gibbosus
smallmouth bass	Micropterus dolomieui
largemouth bass	Micropterus salmoides
black crappie	Pomoxis nigromaculatus
yellow perch	Perca flavescens
johnny darter	Etheostoma nigrum
logperch	Percina caprodes

Data T. Stephenson, 1985

Summary

Carruthers Creek is the smallest and least-studied watershed within the TRCA's jurisdiction. Since initial clearing of forests for agriculture there has been little recent development in the middle to upper reaches. This has led to a fish community that is in good condition. There is still potential for improving the aquatic ecosystem and a number of measures can be implemented to achieve this goal.

Recent surveys in 2000 indicate that Carruthers Creek is now developing a wild rainbow trout run. These trout were never stocked into Carruthers Creek but were stocked in nearby watercourses such as Duffins Creek and the Rouge River. Rainbow trout have spread from these stocked watersheds and colonized Carruthers Creek and many other watersheds. The Watershed Fisheries Management Plan that is being prepared should address efforts to maintain and enhance this coldwater fishery.

References

Bird and Hale, Ltd., 1997. *Natural Heritage Assessment and Evaluation, Additional Herbaceous Plant and Fisheries Information.* Town of Ajax A8 Community Plan Area.

Eyles, N., Boyce, J. and Gerber, R., 1997. *Hydrological Study of the North Pickering Development Corporation Lands and the Duffins Creek Watershed.* Prepared for the North Pickering Development Corporation

Karr, J.R., 1981. Assessment of Biotic Integrity Using Fish Communities. *Fisheries* 6: 21-27.

Sibul, U., K.T. Wang and D. Vallery, 1997. *Groundwater Resources of the Duffins Creek – Rouge River Drainage Basins.* Water Resources Report: 8. Ministry of the Environment, Water Resources Branch. Toronto, Ontario.

Steedman, R.J., 1988. Modification and Assessment of an Index of Biotic Integrity to Quantify Stream Quality in Southern Ontario. *Canadian Journal of Fisheries and Aquatic Sciences* 45: 492-500.

Stephenson, T., 1988. Fish Utilization of Toronto Area Costal Marsh Areas. M.Sc. Thesis, Department of Zoology, University of Toronto, Toronto, ON., Canada. 222p.

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Introduction to Terrestrial Natural Heritage

What follows is an outline of existing terrestrial habitat conditions in the Carruthers Creek watershed. It is preparatory to the development of a more comprehensive Terrestrial Natural Heritage Strategy for the watershed, which will analyse existing conditions using the Terrestrial Natural Heritage Approach (TRCA, in progress).

The Carruthers Creek watershed drains 38.4 km^2. It is one of the smaller watersheds within the Toronto and Region Conservation Authority's (TRCA) jurisdiction, and lies entirely on the South Slope and Iroquois Plain below the Oak Ridges Moraine. It is the furthest east watershed within the TRCA's jurisdiction.

Historically, the region was converted from the dominant forest cover to agricultural land after the arrival of Europeans. Clearing of the forest occurred in three stages: firstly, the tall white pines were coveted for ship masts; secondly, the ash from burnt lands was used for potash production; and, thirdly, the cleared land was used for agriculture. By the end of the 19th century, natural cover was already highly fragmented. The flat terrain of the Carruthers watershed was almost entirely cleared. With the expansion of Toronto as a major commercial and industrial centre, the Carruthers watershed is now feeling the pressure of urbanization. This is resulting in an incremental loss of natural habitats as well as valuable agricultural lands.

This study outlines the current status of the three major terrestrial habitat types discernible at the landscape level from aerial photography: forest, wetland and meadow. These broad categories (together referred to as natural cover hereafter) will be used for the landscape ecology analysis outlined in the following section. Detailed vegetation community mapping (e.g., Ecological Land Classification, Ministry of Natural Resources) has yet to be done for the Carruthers Creek watershed, but digital mapping is available for a finer forest delineation than the broad categories above, including deciduous, coniferous, mixed, plantation and successional. This study also reviews some of the designated sites of the watershed, including Environmentally Significant Areas (ESAs), Areas of Natural and Scientific Interest (ANSIs), and Classified Wetlands.

Natural Heritage System

Natural cover is described here according to the Terrestrial Natural Heritage Approach. Rather than an overview of discrete habitat blocks or types, the condition of natural cover in the watershed as a whole is examined, as well as its linkages to adjoining watersheds. This approach explicitly recognizes the indivisibility and interconnectedness of the natural system instead of treating natural areas individually. Thus, the approach evaluates the function of the natural habitat in the watershed as a functional entity, rather than focussing on rare or endangered species. Moreover, the natural system's relationship with the rest of the watershed is also considered. The approach recommends that site-level decisions be made according to this understanding.

The landscape, vegetation communities, and species of the Duffins Creek watershed can be described according to the criteria of the Terrestrial Natural Heritage Approach. Outlined below, five indicators for the watershed link together the various criteria of the Natural Heritage Approach as they apply to the landscape, vegetation community, and species levels, including: (i) Quantity of Natural Cover; (ii) Distribution; (iii) Matrix Influence; (iv) Patch Size and Shape; and (v) Landscape Connectivity. A sixth indicator, biodiversity, is treated in this Approach as the goal of the strategy, which depends upon the preceding five.

These five indicators are related to the objectives of the Natural Heritage Approach for TRCA's jurisdiction. The question then becomes, "How does the Duffins watershed fit within the regional natural heritage system, and how should its contribution to this system – and its different scales or subunits – be protected and maximized?" This Approach enables us to evaluate the Duffins watershed's contribution to the entire TRCA jurisdiction; to the other defined areas or planning units such as Lake Ontario coastal (waterfront) plans; watersheds and subwatersheds; specific sites; municipalities; the Duffins headwaters area; and the Oak Ridges Moraine. The indicators can also be related to the data collected at the landscape, vegetation community, and species scales. Their interrelations are outlined in Table 1.

Total Natural Cover and Distribution

GIS mapping derived from 1993 aerial photographs provided the basis of the estimates of natural habitat cover in the watershed; an update based on 1999 digital ortho-photos is in progress.

This watershed is unusual within the TRCA Region because it is overwhelmingly dominated by agricultural land uses which cover approximately 83 per cent of its 38.4 km^2. By this estimate, only 3.7 per cent is natural cover (Figure 1), the least for any of our watersheds, and far below the 30 per cent minimum recommended by many ecologists (e.g., in Environment Canada's guidelines) (Note: Landsat estimates for total natural cover are much higher but tend to be overestimated). However, only 13 per cent of the land is urbanized, the most irremediable type of use from a natural heritage perspective. Therefore, this watershed, which has the least natural cover, has the highest potential for preserving agricultural uses (see Matrix Influence below) and for restoring natural cover, to obtain a more balanced mix of natural, agricultural and urban cover. This vision would be a closer approximation to sustainable communities and a natural system than most other watersheds in the TRCA jurisdiction provided today.

The Carruthers watershed was once entirely covered by forest and wetland. Therefore, the ecological functions that these habitats provided were once much better distributed than present. An example of the effects of degraded distributions is the lack of opportunities for migratory birds to find safe passage through the southern (and urbanized) portion of the watershed.

Potential changes to the distribution of habitat can occur through the lost or increase of natural

Table 1: Terrestrial Natural Heritage Approach

Strategy Objective (Action)	Indicator	Measure (Analysis)	Scale of Detail (Data Collection)
1. Promote the per cent natural cover to a quantity which provides targeted of biodiversity	Quantity	Total Natural Cover	Landscape
		Vegetation Community Abundance	Vegetation Community
		Species Abundance	Species (Flora and levels Fauna)
2. Distribute natural cover to maximize opportunities for intraspecific variation	Distribution	Distribution of the Natural Cover in relation to the region	Landscape
		Distribution of Vegetation Communities of Concern (L1 - L3)	Vegetation Community
		Distribution of Species of Concern (L1 - L3)	Species (Flora and Fauna)
3. Improve habitat patches to provide for species needs and promote population variability	Size and Shape	Habitat Patch Size	Landscape
		Patch Shape	Landscape
		Habitat Interior	Landscape
		Area-sensitivity	Species (Fauna)
4. Improve the opportunities for species to move safely across the landscape	Connectivity	Natural Cover Connectivity	Landscape
		Vegetation Type Connectivity	Vegetation
		Community Species Mobility	Species (Fauna)
5. Protect the natural system quality and function from the influence of surrounding land uses	Matrix Influence	Matrix Influence Score	Landscape
		Sensitivity to Development	Species (Flora and Fauna)
6. Protect and restore all native vegetation community types and species to adequate levels	Biodiversity	Vegetation Type Representation	Vegetation Community
		Geophysical Requirements	Vegetation Community
		Species Representation	Species (Flora and Fauna)
		Habitat Dependence	Species (Flora and Fauna)

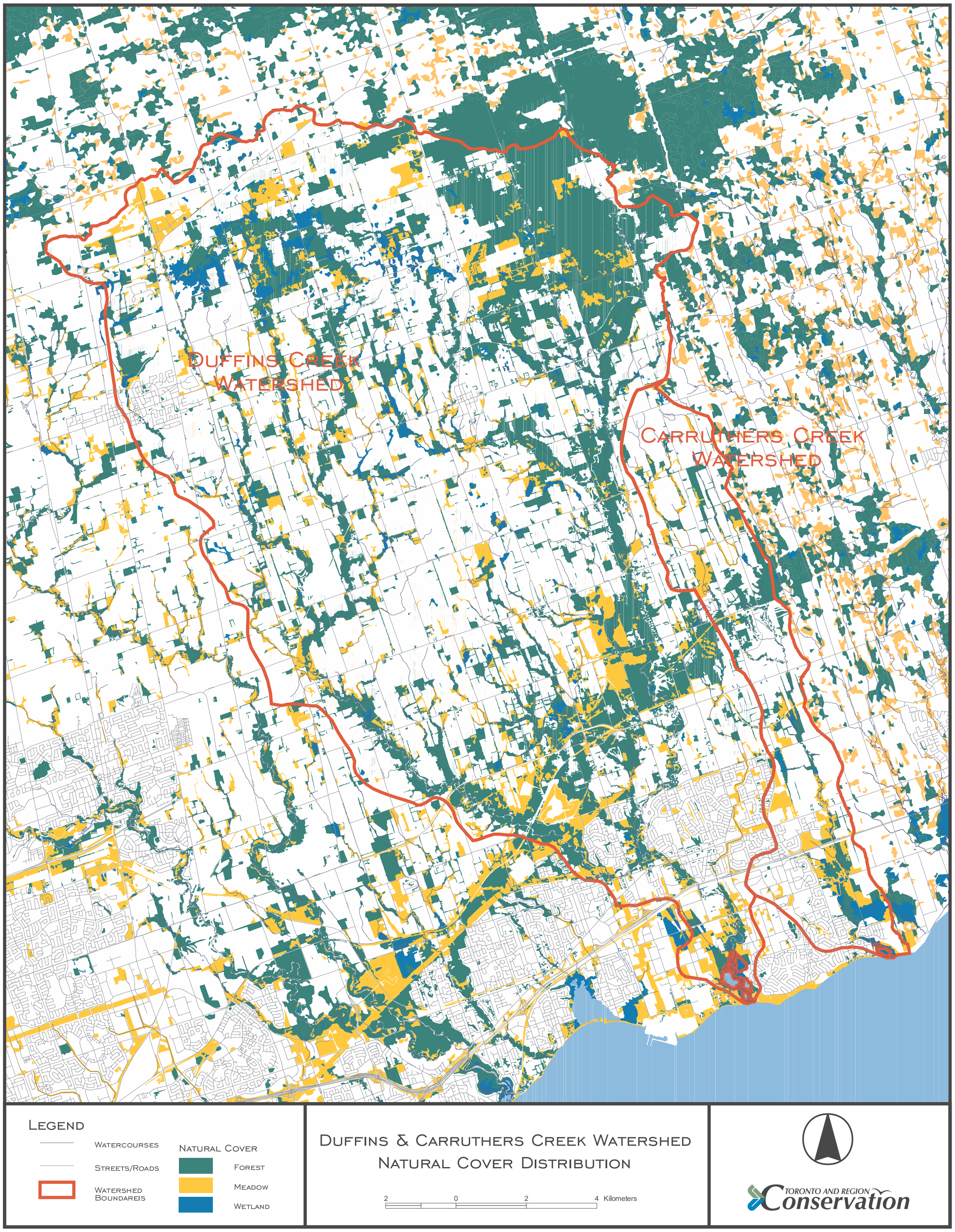

Figure 1:

Duffins Creek and Carruthers Creek Watershed Natural Cover Distribution cover in the watershed. One method to quantify changes and to prescribe better distribution is by mapping various "centroids" in the watershed for comparison. A centroid is the geometric centre of a sample area or study subject. In this study, the geometric centre of the watershed surface area was compared against the centroid that represented the distribution of natural cover. The Carruthers Creek watershed has a good distribution of total natural habitat, with the habitat centroid being less than one kilometre north of the watershed centroid (see Figure 2). This means that there is a slight preponderance of natural habitat in the northern half of the watershed. However, most of the habitat in the northern half of the watershed is old-field, including fallow agricultural lands, with little of the other two habitat classes, forest and wetland (see Figure 3).

The first major habitat class, forest, has very limited coverage in the Carruthers watershed. Unlike other TRCA watersheds, most of the forest cover occurs in the lower reaches. North of Highway 401 there are only isolated patches, including some in the vicinity of the old Lake Iroquois Shoreline (around the 5th Concession Road).

Carruthers Creek lies within the Great Lakes-St. Lawrence Mixed Forest Zone. The dominant climax tree species which characterize this zone are sugar maple, American beech, white pine and eastern hemlock, although other species associations occur where conditions permit. Much of the cover in the central and northern sections of the watershed is in a relatively early stage of succession[1]. Further south, the forest cover grades into wetland in the form of deciduous and mixed swamp.

MEADOW AS NATURAL COVER

Old-field is designated as "cultural meadow" in the Ontario Ecological Land Classification System. This is in contrast to natural grassland habitats such as tallgrass prairie or savanna, both of which are rare in southern Ontario and not known in the Carruthers Creek watershed at this time. The figures for meadow used here are based on aerial photo interpretation. Although they typically refer to old field, it is possible that ground-truthing could identify a few of these as meadow marsh (a wetland type), or in rare cases, as prairie or savanna.

Since old-field habitats are culturally-created within this region as a result of past agricultural uses, it can be argued that, unless they are supporting species of concern, their greatest value here may be their restoration potential. Left alone these areas would eventually revert to forest which is the dominant natural vegetation in our bioregion, or to wetland on poorly-drained sites. The result would be an overall increase in forest cover and connectivity between forest patches. In addition to many other values of forests, this would enhance the viability of wildlife populations, many of which have long been suffering from the effects of fragmentation. Increasing forest cover in meadow areas can be aided by tree and shrub planting projects. Carruthers Creek, in particular, would benefit from reforestation efforts. Moist or lowland meadows present opportunities for wetland restoration.

The amount and distribution of wetland cover is difficult to ascertain, due to the limitations of aerial photography. Although large cattail marshes are easily identified, smaller wetlands are difficult to discern. Swamps are wetlands with woody cover and therefore can be hard to distinguish from upland forest and thicket habitats. Most wetland in the Carruthers watershed is concentrated in two complexes in the southern reaches.

[1] Habitat patches which appear in the TRCA Geographic Information Systems (GIS) database as "successional" are those which are beginning the process of reverting to forest. These areas are treated by the TRCA Natural Heritage Approach as potential forest. Thus successional habitat is treated as forest cover in landscape analysis of habitat patches. They would be defined by the Ecological Land Classification system as "cultural thicket" or "cultural savanna."

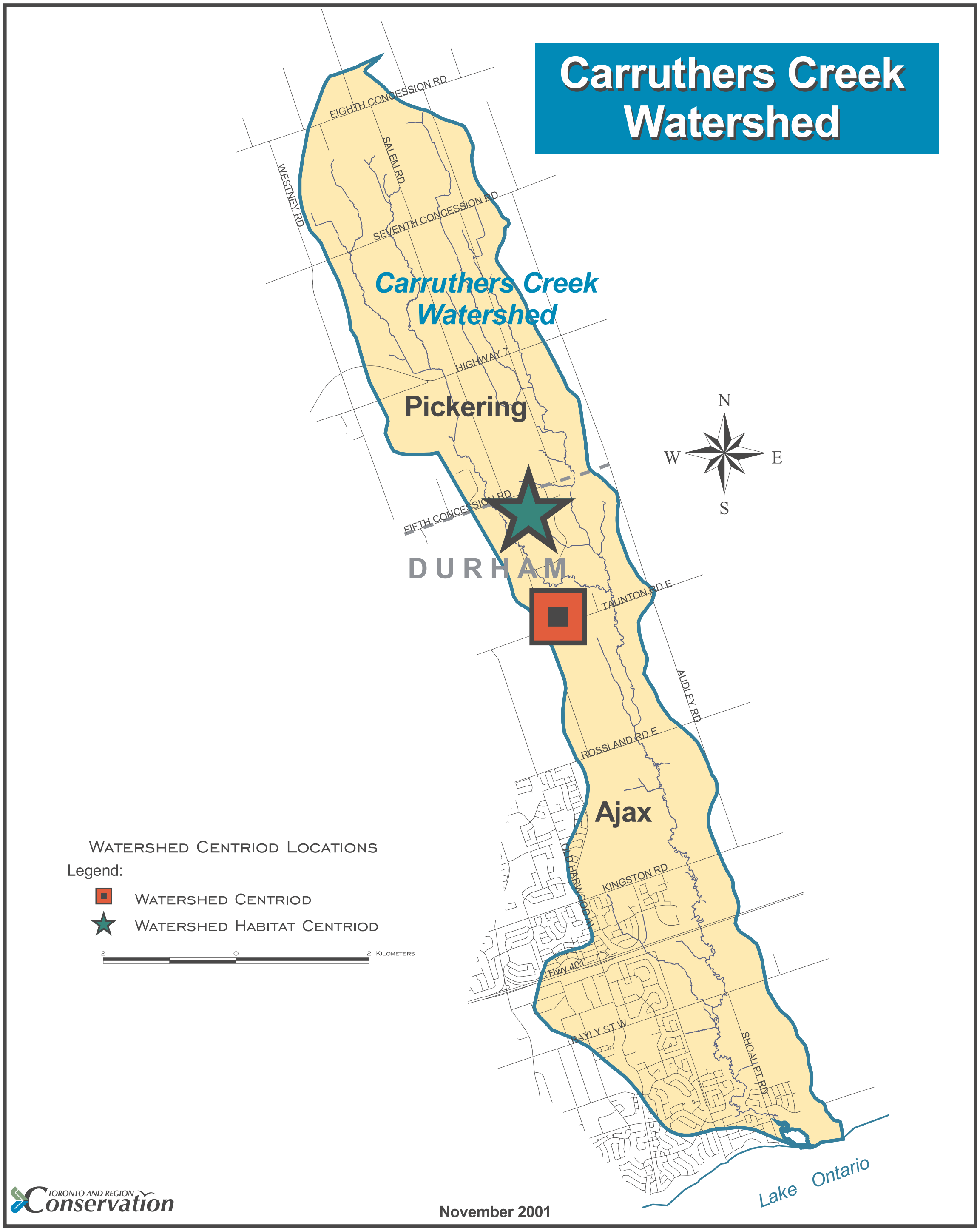

Figure 2:

Carruthers Creek Watershed Natural Habitat and Watershed Centroids.

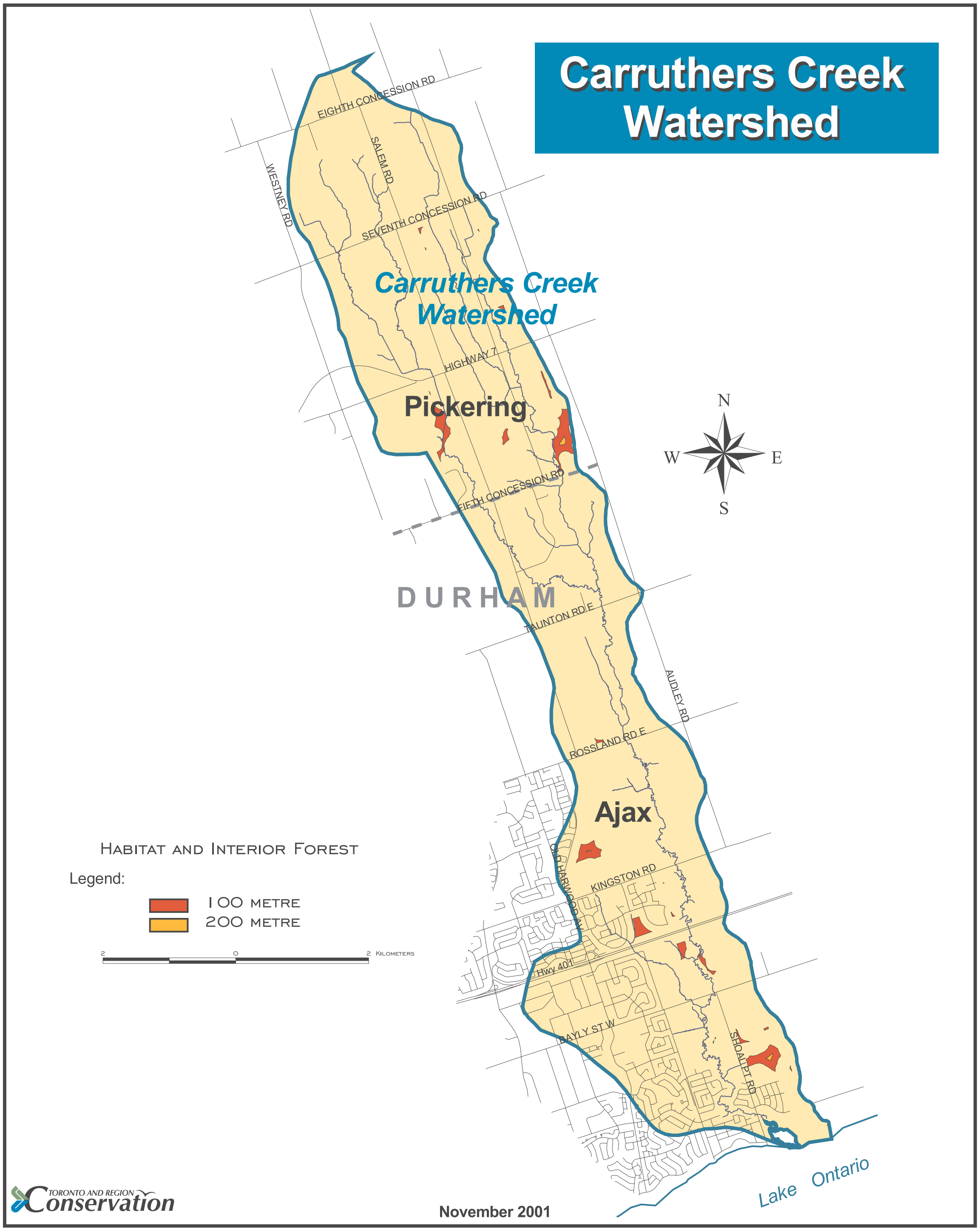

Figure 3:

Distribution of Natural Habitat within the Carruthers Creek Watershed.

The third landscape category is meadow. Meadow is a broad term that can be used to describe a variety of open habitats dominated by grasses and wildflowers (forbs). Technically speaking, most of what is typically considered to be meadow habitat is actually "old-field," i.e. areas that have been allowed to naturalize after human use (such as fallow agricultural fields).

Meadows support a diversity of associated fauna and flora species; although in the case of old-field, the flora tends to be exotics that proliferate in disturbed areas, mixed with meadow-adapted native species, such as tall goldenrod, which are likely much more abundant now than in pre-settlement forest openings. In many cases, the most desirable course of action is to regard meadow as potential forest (see insert "Meadow as Natural Cover"). Larger meadows, once reverted to forest, would eventually provide habitat for area-sensitive forest species such as scarlet tanagers. However, in the meantime, they can provide habitat for birds such as bobolink and eastern meadowlark, and the monarch butterfly. If these open-land species (originally of prairie affinities) are to be preserved in this forest bioregion, where meadows revert naturally to forest, then their meadow habitat would need ongoing management. At this point, the main concern is that natural habitat of any kind, be it forest, wetland, or meadow, be protected from urban development. Maximizing total habitat cover is paramount.

Habitat Size and Shape

Once the fundamental question of total habitat cover in the watershed has been considered, other landscape parameters such as size and shape of patches, connectivity and the influence of surrounding land uses (matrix influence), can be evaluated to determine their effect on the quality of the natural system.

Generally, the larger a habitat patch is, the more diverse the vegetation and fauna species found within it. Also, larger habitats can support larger and more resilient populations. Many species in the TRCA Region are not represented in viable populations and would be sensitive to small changes in the landscape, land use or climate. Large habitat patches, especially those with a more circular as opposed to a linear shape, have more interior. Shape becomes more important as patch size shrinks.

Forest interior is that area of the forest which is considered to be relatively free from negative external influences such as desiccation, wind damage, predation by generalist fauna that use both forest and human-dominated landscapes and parasitism of songbird nests by the brown-headed cowbird. In addition, "edge" forest and the disturbance associated with it favour the incursion of invasive exotic flora such as European buckthorn. The degree to which these "edge effects" can penetrate a patch determines how a forest can be divided into edge or interior. A minimum of 100 metres in from the outside edge of a patch is a widely accepted figure for defining where interior habitat begins. Since cowbirds can penetrate over 400 metres, a forest with interior beyond this point is a more desirable minimum, albeit this rarely occurs in a fragmented landscape. The intensity of edge effects are closely associated with the surrounding land use (see Matrix Influence below). Fauna species of concern associated with particular habitat patches present in the Carruthers Creek watershed reflect the quality of habitat. For example, area-sensitive forest birds include scarlet tanager, Canada warbler, and black and white warbler, as well as forest interior birds such as veery and ovenbird. Flora species of concern such as some of the ferns present in the Carruthers watershed may also be sensitive to edge effects.

Size and shape are also important considerations affecting the health of wetland and meadow habitats, but even small wetlands can contribute to ecological health and biodiversity in a significant way, especially if connected with other natural habitat. Small wetlands were an integral part of the original forest landscape, and many wetland species are adapted to them. Some meadow birds, such as bobolink, are area-sensitive.

Once again, it is important to note that the context is significant, and that size (and shape) should be considered after total habitat cover. Where natural cover falls below 30 per cent, as is emphatically the case in the Carruthers Creek watershed, habitat patches should be seen as valuable no matter what size and shape they are, even if they lack interior. The lack of interior habitat in a patch provides a rationale for increasing its size and improving its shape. Also, small, linear habitats can be important to the distribution of habitat cover, distributing biodiversity and function (e.g., reducing temperature of stormwater, increasing water retention to reduce runoff, etc.) in the watershed. Small patches can also contribute to connectivity.

Natural System Connectivity

Native species in this forest bioregion have evolved in the continuous forest and wetland cover that preceded European settlement, and are thus suited both physically and behaviourally to moving freely within forests and wetlands. Therefore, in the current landscape, natural habitats that are well-linked or closely adjacent to one another can support more native biodiversity. Forest fauna are able to move (in varying degrees) between patches which are in close proximity; and so a cluster of relatively small individual patches may support viable populations which could not occur in individual fragments. The situation is most acute with fauna of low mobility. Linkages between forest and wetland are particularly important for certain amphibians, which may explain why wood frog and eastern newt were not found in the wetlands at the south end of the watershed. Though the wetlands there are of high quality, and urban development is only recent, the upland forests which are necessary as summer and winter habitat for these species, are not found within a kilometre of the breeding wetlands. Most birds are very mobile physically but some species, like ruffed grouse, are behaviourally limited in ability. Grouse are found as far south as the Duffins Marsh woodlands, next door to the Carruthers watershed. This may be due to a better north-south connection in the Duffins watershed. A high degree of connectivity is also important for certain forest plants such as bloodroot whose seeds are dispersed by ants or other short-distance vectors.

When considering the extent of connectivity in the Carruthers watershed, the narrow belts of riparian vegetation in the main agricultural parts of the watershed should be examined. Riparian corridors have contributed enormously to connectivity and often comprise most of the natural habitat, with vegetated tableland areas being few and isolated. Riparian corridors along Carruthers Creek are often meadow or successional habitat, dominated by more-or-less weedy species, often exotic, such as crack willow, Manitoba maple, reed canary grass and creeping thistle. Even in their degraded condition, these areas provide wildlife habitat and riparian protection. For example, they are important for songbird migration in spring and fall, which reveals the role connectivity plays on a continental scale. The GTA is a very important area for these migrants, that have either just crossed Lake Ontario on their way north from the tropical Americas in the spring and need to replenish their energy reserves, or are about to cross the lake in the fall on their way south. The more habitat that can be made available for birds during their migration, the more likely it is they will obtain sufficient energy, avoid stress, predation and competition in limited habitat fragments.

Matrix Influence

If size and shape are thought of as measures of a habitat patch's potential vulnerability to impacts from its surroundings, then matrix influence a measure of what a patch is exposed to and what is affecting it from its surrounding (the "matrix"). "Matrix" is defined as anything within two kilometres of the outer edge of a patch and is divided into three types of land uses: natural, agricultural and urban. Natural area exerts a beneficial influence on a habitat patch; agricultural use introduces some disturbing influences; and urban development brings severe disturbance.

The result along this gradient is a range of effects from positive ones to an aggravated "edge effect." In urbanized areas, impacts on forests include trampling, dumping, and predation by roving pets and other generalist fauna such as raccoons that have high populations in urban areas. Hence adjacent urban development can degrade a habitat even if the site is "protected" from direct elimination. White trillium or other spring woodland flowers may not be rare in rural areas, but tend to disappear from urban habitats because they are sensitive to development. They may be collected, trampled, out-competed by invasive exotics, or affected by changes in hydrology or soil. Ground-nesting birds such as ovenbird are vulnerable to predation by cats and raccoons in forests affected by nearby development. Matrix influence is really an examination of the odds of species and vegetation communities surviving given their surroundings. The fewer wildflower pickers or cats there are, the more potential there is for a wildflower to remain unpicked or a nestling to survive to maturity.

Agricultural uses introduce some of the same problems to habitat patches as nearby urban development, notably water pollution; but generally the level of impacts from trampling, collection and disturbance are much lower. The benefits of nearby natural areas within the matrix of a habitat patch include potential replenishment of genetic diversity, sources of individuals for re-colonization, areas of dispersal for young of the year, improved air quality and microclimate conditions, etc.

Matrix influence is a core concept of the Terrestrial Natural Heritage Approach which draws attention to the relationship between the natural system and the rest of the watershed. The interactions between urban, agricultural, and natural areas are very complex, and they breach the line drawn around the borders of the natural system. A natural system which is protected has no guarantee of maintaining its habitat quality and biodiversity because those qualities also depend on the character of the surrounding matrix.

At the same time, the quality of the watershed and its ability to perform ecological services are affected by the amount and quality of natural habitat. That depends, in turn, upon the ratio of natural, agricultural and urban land uses. If that is in balance, the urban heat island effect is reduced, and runoff is reduced in favour of infiltration, resulting in increased groundwater recharge and less flooding. Air quality is also improved, and there is less competition by people for quality recreational open space. A watershed has a carrying capacity for all who share it, including humans. Matrix influence is closely linked to human quality of life as well as biodiversity.

Matrix influence is a particularly critical issue for the Carruthers Creek watershed since it is currently relatively unurbanized, yet the largest areas of natural habitat are in the lower end of the watershed, directly in the path of urban expansion. Indeed, the Carruthers Marsh at the mouth of the creek (part of the larger Carruthers Wetland Complex and a most significant natural area in the watershed), has become surrounded by residential subdivisions within the past couple of years.

Selected Site Descriptions

Natural habitats in the Carruthers watershed are related to the surficial geology. Geology helps to determine the type of vegetation on a site and may also encourage or discourage agricultural use. While the watershed does not include any portion of the Oak Ridges Moraine, characterized by coarse sand and gravel based soils, the heavier-textured clay soils that exist in parts of the Carruthers watershed also tend to discourage agriculture. The clay areas often remain as natural habitat and are characterized by water retention. Most of the watershed both above and below the Iroquois Shoreline is covered by silty-textured till (Newmarket or Northern till) which yields the loamy soils prized by agriculture. The clays of glacial lake-origin, are generally concentrated toward the lower end of the watershed, although pockets are scattered throughout. When in their natural state, these often support wetlands especially forested wetlands. In some cases, organic wetland soil builds up on the surface of the impervious clay where there is little riparian action or human disturbance, notably in the Carruthers Wetland Complex. Sands associated with Lake Iroquois occur immediately below the old shoreline.

The known natural areas in the Carruthers watershed are associated with three main clusters: the Lake Iroquois Shoreline, the Rossland Road Wetland Complex and the Carruthers Wetland Complex. In addition, the undeveloped greenbelt area on the east side of the creek extending down to Lake Ontario is of critical importance from a natural heritage perspective.

The Lake Iroquois Shoreline area contains meadow and successional habitat along with fragments of forest. It shares some of the complex surface geology of the shoreline area in the Duffins watershed, including a small embayment, an esker fragment and small drumlins. Restoration work in this area could have good results, and could also link it with more extensive forested areas in the Duffins watershed (as well as areas to the east of Carruthers in the Lynde Creek watershed) that occur along this feature.

The second identified natural area in the watershed is the Rossland Road Wetland Complex. The main patch is located south of Rossland and Salem Roads. Lesser patches occur north of Rossland Road. It includes a mixed cedar-hardwood swamp, possibly on organic soil, with some ash deciduous swamp, red osier dogwood thicket swamp and cattail marsh. Good records on flora and fauna species of concern are lacking; but tamarack, black ash, yellow birch, foamflower and spikenard were observed (Gregory, 1999; Leadbeater, personal communication, 2000).

The third and most intact area of natural habitat is the Carruthers Creek Wetland Complex which was identified in 1982 (MTRCA, 1982). At that time it was considered to be two Environmentally Sensitive Areas, one being the lakeshore marsh and the other being the forested area inland. Later, the Ajax Warbler Swamp to the east of Shoal Point Road was added and the whole complex was designated as an ANSI and a provincially-significant wetland (Class I) (OMNR, 1998).

The coastal part of the complex includes a floating aquatic community with fragrant water lily, bullhead lily and an extensive cattail marsh. The bay-mouth bar supports a sand beach plant community, which still requires a formal flora and fauna survey. Like other Lake Ontario coastal wetlands, however, the marsh appears to have shrunk during the second half of the 20th century. Inland areas include deciduous, mixed, and thicket swamps with red ash, swamp maple, white cedar and hemlock. Flora species of concern include eastern manna grass, purple fringed orchid, swamp rose, wild licorice and wood anemone (MTRCA, 1982; OMNR, 1998). A high diversity of breeding or probable breeding birds include such sensitive species as American bittern, American woodcock, wood duck, marsh wren, veery and several warbler species. The presence of numerous species of concern at this site is indicative of its size and quality. Although there is some fragmentation, the units of forest and other natural cover in this complex (and areas to the east) are in close proximity, maintaining a relatively high level of connectivity that benefits birds and other fauna.

The belt of undeveloped land east of Ajax, about two kilometres wide, is the only place in the Greater Toronto Area (from Burlington to Oshawa) where there is a distinct break in urban development along the Lake Ontario shoreline. It is the best linkage between coastal ecosystems and the undeveloped lands along the northern rim of the GTA. This belt includes much agricultural land, but also forest and wetland. Notably, the forested wetlands of the Carruthers Creek Complex extend east of the TRCA jurisdiction into this greenbelt. The greenbelt also includes the Lynde Shores Conservation Area and Cranberry Marsh, under the jurisdiction of the Central Lake Ontario Conservation Authority (CLOCA).

Summary

Current conditions regarding the terrestrial natural heritage of the Carruthers Creek watershed may be summarized based upon the five indicators of the Terrestrial Natural Heritage Approach.

Quantity: The entire Carruthers watershed is 38.4 km^2, of which 3.7 per cent is natural or semi-natural cover. Of the remaining area, 83 per cent is agricultural, while only 13 per cent is urban.

Distribution: This watershed currently contains a low amount of natural cover, most of which is concentrated in the southern portion, unlike most other watersheds in the region which have more northern distributions of natural cover. Wetlands in the south of the Carruthers contain an array of vegetation types and flora and fauna species of concern (L1 - L3). The Lake Iroquois Shoreline area contains meadow and successional habitat along with fragments of forest. The South Slope, which accounts for the vast majority of the watershed, is deficient in natural cover.

Patch Size and Shape/Habitat Interior: There is a general lack of large habitat patches with interiors beyond 100 metres, although parts of the Carruthers Wetland Complex near Lake Ontario are larger.

Connectivity: The connectivity of habitat patches is generally poor, mostly consisting of narrow, successional riparian belts in agricultural land. However, there is potential for improvement.

Matrix Influence: Fair to good matrix influence, with agriculture predominating. Urban cover only accounts for 13 per cent of the watershed and is generally restricted to the south.

Biodiversity, the overarching goal of the Terrestrial Natural Heritage Approach, is dependent upon these five indicators. In the Carruthers watershed, biodiversity is considered high, due to the character of the vegetation communities on the South Slope, the Lake Iroquois Shoreline, and the coast of Lake Ontario. Species of flora and fauna are also relatively diverse in this watershed.

Although the biodiversity in the Carruthers Creek watershed is good in comparison with other watersheds in the region, it is not as high as it once was historically. Improvements made to the existing natural cover would not only enhance the terrestrial system, but would contribute positively to water quality and quantity, and therefore to the health of aquatic communities of flora and fauna in the ponds and creeks of the Carruthers watershed.

References

Gregory, D., 1999. *Ajax Integrated Ecological Study.* Toronto: Hough Woodland Naylor Dance Leinster.

Leadbeater, D., 2000. Personal communication.

MTRCA (Metropolitan Toronto and Region Conservation Authority), 1982. *Environmentally Significant Areas Study*. Toronto: Metropolitan Toronto and Region Conservation Authority.

OMNR (Ontario Ministry of Natural Resources), 1998. *Re-Evaluation Summary of the Carruthers Creek Wetland Complex.* Aurora, Ontario: Ministry of Natural Resources Aurora District Office.

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