BACKGROUND REPORT

East Credit Subwatershed Study

Subwatershed 13

December 2002

TOWN OF CALEDON

Region of Peel

CVC
CREDIT VALLEY CONSERVATION

East Credit Subwatershed Study

Background Report

December 2002

Credit Valley Conservation

Donald G. Weatherbe Associates Inc.
Environmental Water Resources Group
Golder Associates
Jacques Whitford Environmental Limited
Lura Group
Parish Geomorphic
Waterloo Hydrogeologic Inc.

CVC
CREDIT VALLEY CONSERVATION

east credit
SUBWATERSHED

Region of Peel

TOWN OF CALEDON

ACKNOWLEDGEMENTS

We would like to acknowledge those municipal agencies whose jurisdiction extends into the East Credit Subwatershed, and who provided valuable input throughout the subwatershed study process:

Region of Peel
Town of Caledon

Credit Valley Conservation would also like to acknowledge the assistance of all those who worked on the study. Specifically, we would like to acknowledge the following individuals and organizations:

Credit Valley Conservation ....Alison Humphries
Credit Valley Conservation ....Brian Morber
Credit Valley Conservation ....Casey Blakely
Credit Valley Conservation ....Hazel Breton – Subwatershed Study Project Manager
Credit Valley Conservation ....Jackie Thomas
Credit Valley Conservation ....John Perdikaris
Credit Valley Conservation ....Lisa Ainsworth
Credit Valley Conservation ....Lynne Gatzke
Credit Valley Conservation ....Merebeth Switzer
Credit Valley Conservation ....Mike Puddister
Credit Valley Conservation ....Patti Moynihan
Credit Valley Conservation ....Rae Horst
Credit Valley Conservation ....Robert Morris
Credit Valley Conservation ....Steve Davies
D.G. Weatherbe Associates Inc......................................Don Weatherbe
Environmental Water Resources Group ....Chris Doherty
Golder Associates...George Schneider
Jacques Whitford Environment Limited.........................Bruce Kilgour
Lura Group ....Joanna Kidd
Niagara Escarpment Commission ....Marion Plaunt
Parish Geomorphic…………………………………...John Parish
Region of Peel ....Alina Korniluk
Region of Peel ....Andrea Warren
Town of Caledon ....Marsha Paley
University of Guelph ....Lorne Bennett
Waterloo Hydrogeologic Inc ....Darron Abbey
Waterloo Hydrogeologic Inc ....Paul Martin
Wilfrid Laurier University..Rob Milne

Members of the focus group and general public, including landowners, interest groups and other interested parties are also acknowledged for providing valuable input during meetings. We also appreciated landowners whom granted permission for access to field stations.

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

1.1 STUDY BACKGROUND

In January 1992, Credit Valley Conservation (CVC) in concert with all member municipalities and the Ministries of Natural Resources (MNR) and Environment and Energy (MOEE), completed a watershed management plan titled *Credit River Water Management Strategy (CRWMS)*, Phases I and II (Triton Services 1992, Beak *et al.* 1992). These studies evaluated the present and future state of the Credit River Watershed with respect to its overall health (e.g. natural environment). The results for the future scenario indicated that with the ever-increasing pressures for development and resource use, the impacts to the watershed, if not managed properly, will be irreparable. The study recommended that the entire Credit River Watershed be subdivided into 20 subwatersheds and that plans be prepared in order to properly manage the health of the watershed.

The concept of subwatershed planning has become an accepted method for dealing with environmental concerns over broad areas of land. The subwatershed plan integrates the functions of resource management and the land use planning process. A subwatershed plan does not set out ideal land uses, but it does make valuable contributions to the land use decision-making process by developing a detailed understanding of the subwatershed ecosystem and making recommendations regarding the management of the ecosystem, in light of alternative land use patterns. Information derived from the subwatershed plan will be incorporated into planning documents as the basis for environmentally sound land use designations and development policies.

1.2 PURPOSE OF THE STUDY

This report is the first of a series of reports that will be developed for the East Credit Subwatershed. The purpose is to summarize the existing available data and information pertinent to the subwatershed. This is to ensure that work is not duplicated and resources are spent appropriately. As part of this Background Review work, data gaps will be identified. A field program will be designed to fill the identified data gaps.

As part of the background review process, a number of issues specific to the East Credit Subwatershed have been identified from various sources. This information will be summarized and questions will be formulated, the answers to which will be provided at the end of the subwatershed process.

1.3 SUBWATERSHED STUDY PROCESS

Subwatershed planning has been an ongoing activity within the Credit River watershed since 1992. To date, of the 20 subwatersheds identified, 15 have been initiated and are either underway or completed.

Figure 1.3.1 describes the subwatershed process that has been consistently followed to date. Typically there are four phases, Characterization, Impact Assessment, Implementation and Monitoring that flow in sequential order. It should be noted that one cycle of this process does not bring the level of understanding of the natural environment to an end. Rather, the first cycle provides a very comprehensive snapshot of the environmental resources i.e. their form, function and linkages. Using follow up monitoring to test assumptions made during the study and to assess how well management solutions are working, is an important and fundamental need. The results of this monitoring should be used to update and refine management solutions over time. Great importance is placed on the goals and objectives developed for the subwatershed as they will influence the choices made by the municipalities and agencies having jurisdiction over the area. This also allows the public the opportunity to have input and track the success of the implementation of the study findings.

Figure 1.3.2 describes the connection of the CRWMS and the subwatershed process and clearly identifies the questions that each phase will answer. The CRWMS sets out broad levels of direction from the watershed perspective. The subwatershed process then refines this information based on subwatershed scale data and assessment.

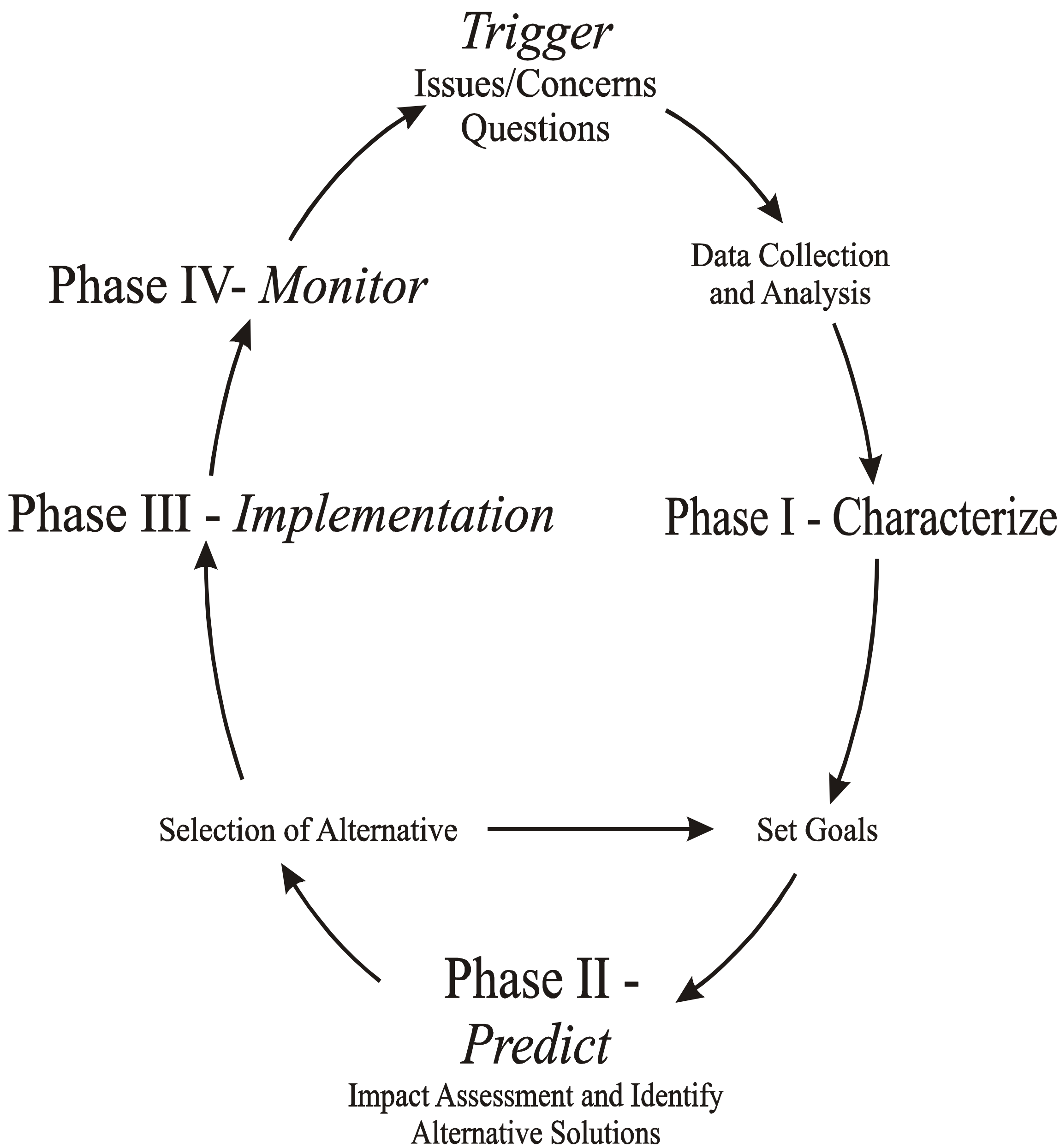

Figure 1.3.1 Monitoring and the Subwatershed Planning Process

Study Approach

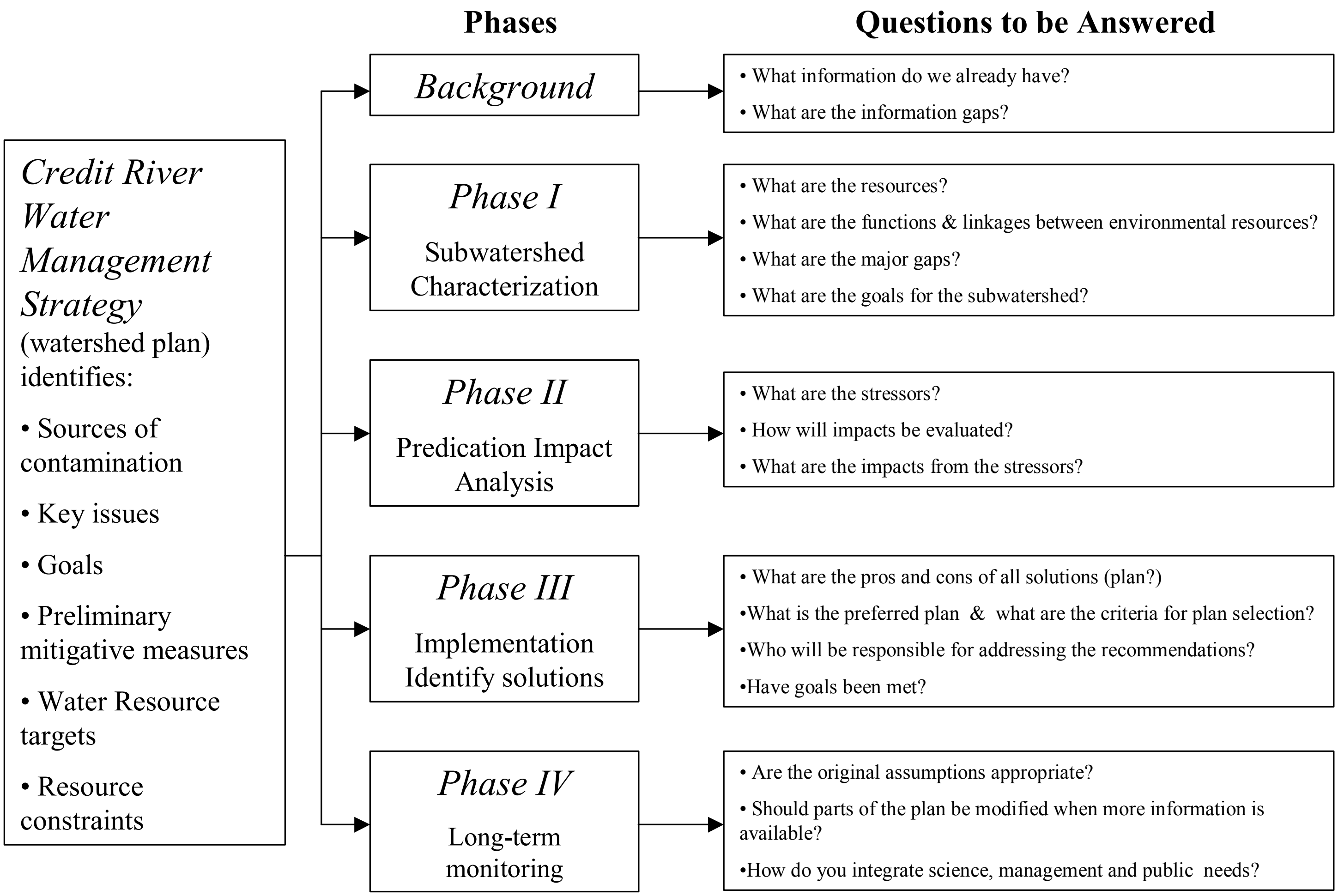

Figure 1.3.2 Subwatershed Study Process

1.4 STUDY AREA

The East Credit River is a tributary of the Credit River and is approximately 51 km^2 in area. The subwatershed is located in the upper north east portion of the Credit River watershed, and is entirely within the Town of Caledon. The landscape is dominated by the Niagara Escarpment and the Oak Ridges Moraine, which intersect within this subwatershed. The East Credit River joins the Credit River upstream of the Village of Inglewood. Figure 1.4.1 shows the location of the subwatershed within the Credit River watershed.

Mapping of the existing land use for the East Credit subwatershed was done using the Ecological Land Classification for Southern Ontario (Lee, H. et al., 1998) and the Credit Watershed Natural Heritage Project Detailed Methodology (CVC, 1998). The Ecological Land Classification (ELC) was used to map and describe the upland and wetland systems. This ELC and Existing Land Use mapping was completed based on 1996 spring aerial photography. The data from these photographs was transferred to 1:10,000 Ontario Base Mapping and then digitized into a GIS or Geographic Information System (Arcview 3.1). Agriculture is the dominant land use in the subwatershed, with only 3.4% characterized as ‘urban’ and 3.6% defined as ‘rural’, 15.6 % forest, and 6.3% wetland. The dominant landscape features are the Niagara Escarpment and Oak Ridges Moraine. Based on current planning/political boundaries, approximately 44.3% of the subwatershed is under the Niagara Escarpment Plan Area and approximately 37.1% is taken up by the Oak Ridges Moraine Conservation Plan Area.

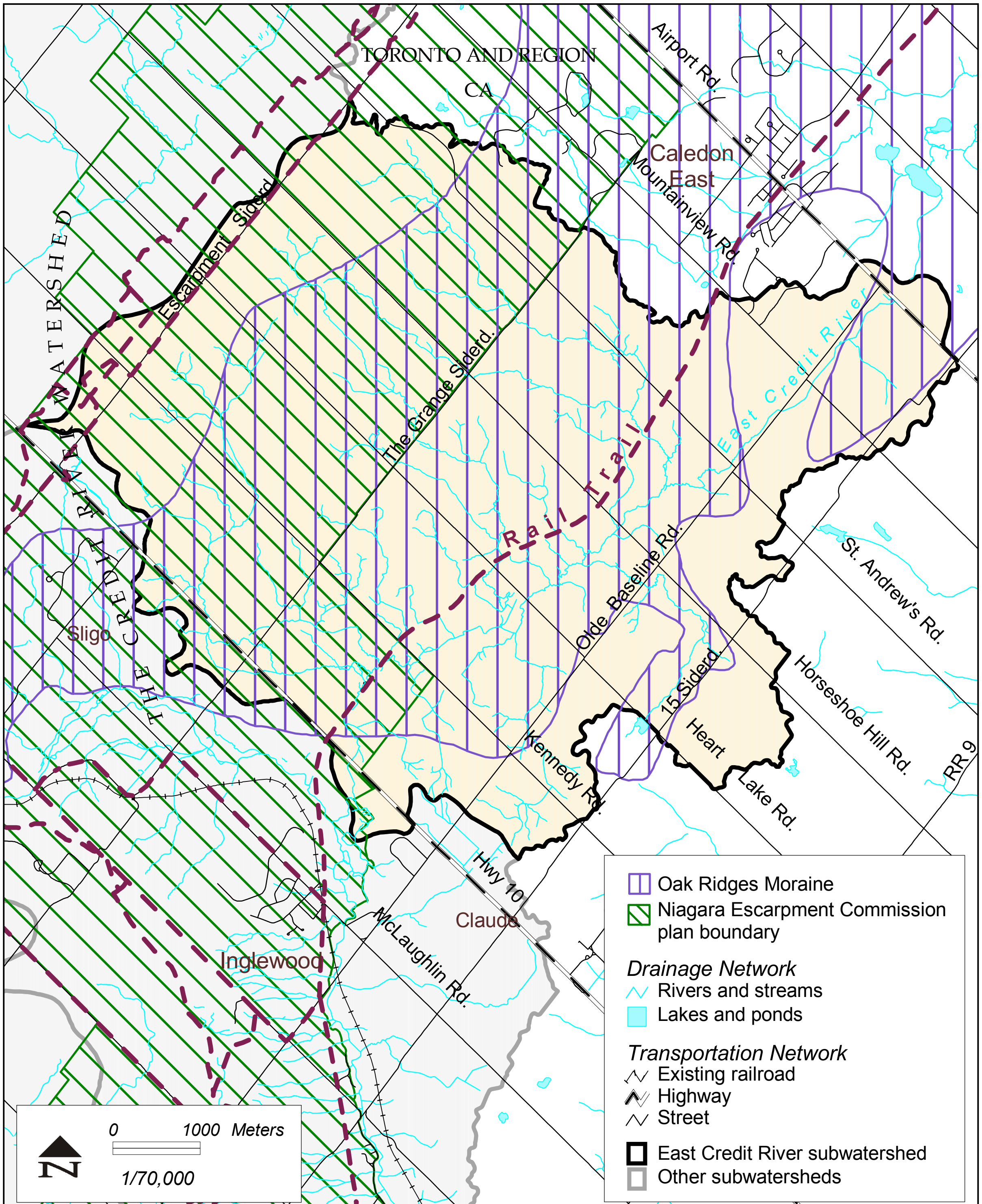

Figure 1.4.1 : The East Credit River Subwatershed

Sources: Credit Valley Conservation, 1999; Ontario Ministry of Natural Resources, 1982.

1.5 HISTORICAL INFORMATION ABOUT THE EAST CREDIT

At the time of printing this report, no historical information was available that directly related to the lands within the subwatershed boundaries of the East Credit. Credit Valley Conservation is working with the Town of Caledon to include any existing information for this area in the Phase I Characterization report.

1.6 WATERSHED GOALS

The following are the goals for all subwatersheds that have been established by the CRWMS as a starting point. The goals will either be replaced or refined specifically for the East Credit subwatershed by the Technical Committee, with input from the Steering Committee.

Table 1.6.1 Resource Management Goals for the Credit River Watershed

WATER QUALITY
Maintain or restore water quality to a level that maintains ecological integrity and permits desired uses including recreational opportunities.
GROUNDWATER
Protect and maintain groundwater recharge/discharge areas and baseflow to a level that ensures adequate supply for desired uses, including drinking water.
AQUATIC COMMUNITIES
Protect and enhance aquatic communities, with special regard for fish and fish habitat.
NATURAL FEATURES
Protect and maintain self-sustaining natural ecosystems and significant natural features.
RECREATION
Provide diverse recreational opportunities that are in harmony with the environment.
AESTHETICS
Protect and enhance the environment in a manner that is in harmony with the natural features of the watershed.
FLOOD PROTECTION
Control flooding within the watershed through remedial works and land use controls.
EROSION CONTROL
Minimize soil loss through land management practices and remedial control measures.

(Beak et al. 1992)

1.7 REPORT CONTENT

This report has been broken down into 6 chapters as follows:

Chapter 1 is a brief introduction to the subwatershed study process and provides a physical description of the area.

Chapter 2 is a description of the proposed communications plan for communicating the study to the public, and other interested parties.

Chapter 3 is a summary of issues, data gaps and future work necessary for each of the technical disciplines involved in the study: hydrogeology, hydrology, hydraulics, terrestrial, stream geomorphology, water quality, macroinvertebrates, aquatics and planning. Issues specific to each discipline are outlined, as well as areas where information is lacking. Field research plans have been refined using this information.

Chapter 4 describes the Oak Ridges Moraine Conservation Plan and Niagara Escarpment Plans, and the role that they play within the East Credit and the Subwatershed Study Process

Chapter 5 describes Adaptive Environmental Management as a tool that will be used in this study process to facilitate the integration of the work into an adaptive and comprehensive environmental study.

Chapter 6 is a summary of what the technical disciplines will be working on for the next phase of the study.

2.0 COMMUNICATIONS PLAN

Communication activities will act as a catalyst to help the community to have meaningful opportunities for participation and to better understand the subwatershed study findings and, in the long run, to assist in implementing the project's recommendations.

2.1 EAST CREDIT SUBWATERSHED STUDY FOCUS GROUP

We have identified key groups to work with and to be members of the East Credit Subwatershed Study Focus Group. We initially identified a number of groups including: Coalition of Concerned Citizens, Citizens for a Clean Caledon, ORM Land Trust, STORM (Save the Oak Ridges Moraine), Ontario Federation of Anglers and Hunters, Peel Agricultural Working Group, CEAC, local naturalist clubs, and fishing clubs. As the study continues, other groups or individuals may be identified and added to this Focus Group or to our larger contact list.

The Focus Group will meet a minimum of two times during the course of the study beginning with the introductory meeting which took place on June 25th, 2002.

The next meeting will be held in the final weeks, or at the conclusion of the Phase 1 of the study. This meeting will have the following goals:

2nd Meeting – Completion of Phase 1
- to review findings of characterization study
- to review environmental goals for the study

2.2 PHASE I FOCUS GROUP

The introductory meeting was used:
- to connect with community groups and networks
- to begin a dialogue to bring forward issues specific to study
- to draw upon community and historic knowledge
- to solicit input or involvement in areas of interest (for example - bird surveys, natural history research, monitoring)
- to seek input to help in creating the most effective approaches to communicating the plan to the public.

This meeting was attended by 12 individuals representing 9 different organizations, a Councillor and concerned residents. A discussion was held to bring out various concerns of those present and participants were asked to continue to provide contacts or input to the project throughout the course of the subwatershed study.

2.3 ISSUES IDENTIFICATION

As part of their initial meeting the Focus Group identified the following list of issues of concern (related items have been placed under specific headings for ease of references but they are likely, in fact, related to more than one heading):

LAND USE, AGRICULTURE AND DEVELOPMENT ISSUES

- Highways, future expansions, paved roads
- Airport Road Auto Wreckers
- Proposed golf courses?
- Farming
  - -Sludge spreading on agricultural lands
  - -Milk house waste
  - -Agriculture is predominant land use: presents challenges and opportunities (nutrient management, tilling practices; types of farms including horse, livestock, crops, other)
  - -Active vs. passive agricultural lands
- Old landfills
- Land ownership patterns, resident, non-resident, developers
- Future gravel pits, secondary (sand) resources
- Social and economic information: population shifts, housing types, average age of farmers, type of farm (horse, active, crop, pasture), numbers and ages, gender, income, resident vs. commuters, non-residents, general demographics?
- Lot information: number of vacant lots, number of lots to be built, severances, etc.
- Future industrial or institutional users, small scale?
- Heritage: archaelogical, cultural, architectural

NATURAL FEATURES

- Historical information, 1950s aquatics distribution compare to current data and relate to land use
- Spawning surveys to be added Fall 2002, more comprehensive, Trout Unlimited to help with volunteers
- Deer yarding, wild turkeys, birding area: CVC can acquire Upper Credit Naturalists bird data
- Herptefauna: frogs, toads, salamanders (in process through Natural Heritage Project)
- Wetland complexing: requires MNR approval, CVC can't designate
- Invasive species: flora and fauna
- Flora diseases (blights, eg. Dutch Elm disease, Spruce budworm, butternuts here?)
- Rail Trail crosses subwatershed, watercourse inventory done by CVC, fish barrier assessment Trout Unlimited could help

WATER QUANTITY ISSUES

- Devil's Pulpit golf course, water takings- any existing hydrogeology reports?

WATER QUALITY ISSUES

- Salt use on paved roads, calcium chloride
- Stream running through autowrecker?
- Golf course use of fertilizers, pesticides, herbicides
- Organopesticides, parameter tested for in WQ? CVC identified other water quality parameters of concern
- Livestock access to watercourses
- Online ponds, including increasing numbers and violations all the time

OTHER

- Stream restoration potential, especially tributaries along Olde Baseline channelized, cropped/pasture, lack riparian vegetation
- Land use restrictions: NEC and ORM, mapping due from MMAH in fall?
- Warwick and Ken Whillans land owned by CVC, other important properties to identify for Greenland Strategy acquistition?
- Rumour of low-level radioactive waste dumped in past, around Mono Road/Caledon East, flyover with radioactive meter?
- Possible fly-over of subwatershed for photo record?

POSSIBLE RESOURCES OR ADDITIONAL CONTACTS

Private trout/fishing clubs
-to be contacted by Trout Unlimited

Golf course (rep invited)

Ontario Federation of Agriculture (rep invited)

Landowners
- general Open House to come, act as sounding board

Soil and Crop Improvement Agency for area
- Harold Rudy and Randy Grain to be contacted by CVC

Ontario Streams
- Steve Copeland to be contacted by Trout Unlimited

Trails
- Bruce Trail Association
- Caledon Trailway Association

Horse Breeders and Keepers Association

Armstrong Bros.
- aggregates and horses

Scott Mission

Niagara Escarpment Commission, Land Trust for NEC

CONE
- Coalition of Niagara Escarpment, Biosphere Reserve

Bed and Breakfast operators

2.4 COMMUNICATIONS ACTIVITIES

The group recognized that it would take to time to clarify the audiences, the mechanisms and the messages that need to be communicated and that this might not occur until later in the study.

Suggested contact methods included flyers in mailboxes with follow-up phone calls due to the small population in this subwatershed, web links with notices for all meetings, postings at libraries and stores in Inglewood, Caledon and Caledon East since there is no defined settlement area within the subwatershed boundaries.

From our past experience we recognize that the communication activities for the East Credit Subwatershed will have to respond to community needs as determined by the Focus Group. They will also be designed based on the type of information that needs to be presented as the research progresses. Examples of some of the type of activities that have taken place in response to community and study needs in previous subwatershed studies include:
- presentations by CVC staff and/or project team members to special interest groups
- public open houses including displays
- guided bus tour of areas of special interest or concern
- four page, colour insert into local newspapers
- partnerships with local educators to have students conduct parts of the field work as a learning experience

CVC will also highlight the findings and activities relating to this project on its new website. In addition, the site will include reciprocal links between it and the sites of other interested community partners.

All materials needed for focus group and Steering Committee meetings will be produced by CVC.

3.0 BACKGROUND REVIEW

3.1 HYDROGEOLOGY

3.1.1 Background Information

Background information regarding the hydrogeology of the East Credit subwatershed was available from a number of sources. The primary types of existing information are:

- 1:50,000 scale provincial government maps / publications (i.e., Quaternary geology reports);
- Ministry of Environment (MOE) Water Well Record Database;
- Geological Survey of Canada reports and mapping completed as part of the Oak Ridges Moraine Hydrogeology Project
- Various published papers and consultant's reports related to the Oak Ridges Moraine;
- An in-progress CVC study of the water budget of the CVC watershed, including the Silver Creek Subwatershed, which includes numerical modeling of the entire watershed; and
- Other reports containing surface water and fisheries data.

Much of the existing data is related to the Oak Ridges Moraine. It should be noted that much of the information available is fairly general in nature and more appropriate for larger regional studies. The following hydrogeological summary to Subwatershed 13 was based on this limited information. Additional refinements or corrections will be made after the characterization phase of the study.

3.1.2 Preliminary Interpretation of Existing Data

The hydrogeology of Subwatershed 13 is strongly influenced by the local geological and physiographic setting. Local rural residences rely on groundwater for drinking water. Furthermore, the subwatershed has many naturalized areas and important fish habitat that is, in part, reliant on groundwater in terms of both quantity and quality.

The study area comprises portions of three major physiographic regions: 1) The South Slope; 2) The Oak Ridges Moraine (ORM); and 3) The Niagara Escarpment. The ORM and Niagara Escarpment are two of the most extensive and recognizable landforms in Southern Ontario and a large portion of the west end of the ORM terminates at the Escarpment within the study area. This makes the study area quite unique from a physiographic point of view.

The three physiographic regions typically have distinct topographical and geological characteristics and these in turn strongly influence the hydrogeology of the study area. The following subsections provide generalized comments about the significant characteristics of each physiographic region

Figures 3.1.1, 3.1.2 and 3.1.3 present the regional physiography, surficial geology and bedrock geology of the study area, respectively.

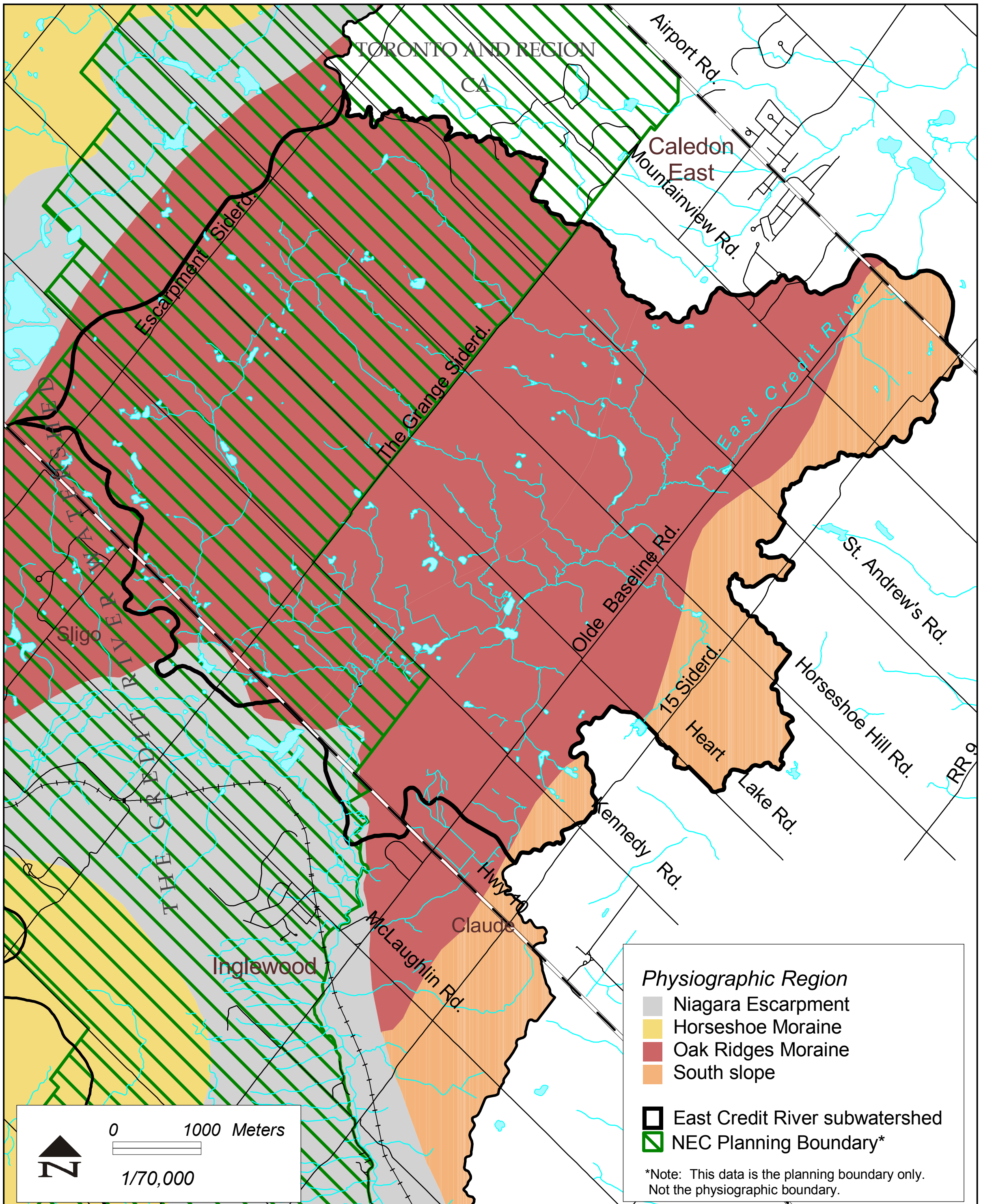

Figure 3.1.1: Physiographic Regions

Sources: Chapman, L.J. and D.F. Putnam, Map 2226, Physiography of the South Central Portion of Southern Ontario, 1972; Credit Valley Conservation, 1999; Ontario Ministry of Natural Resources, 1982.

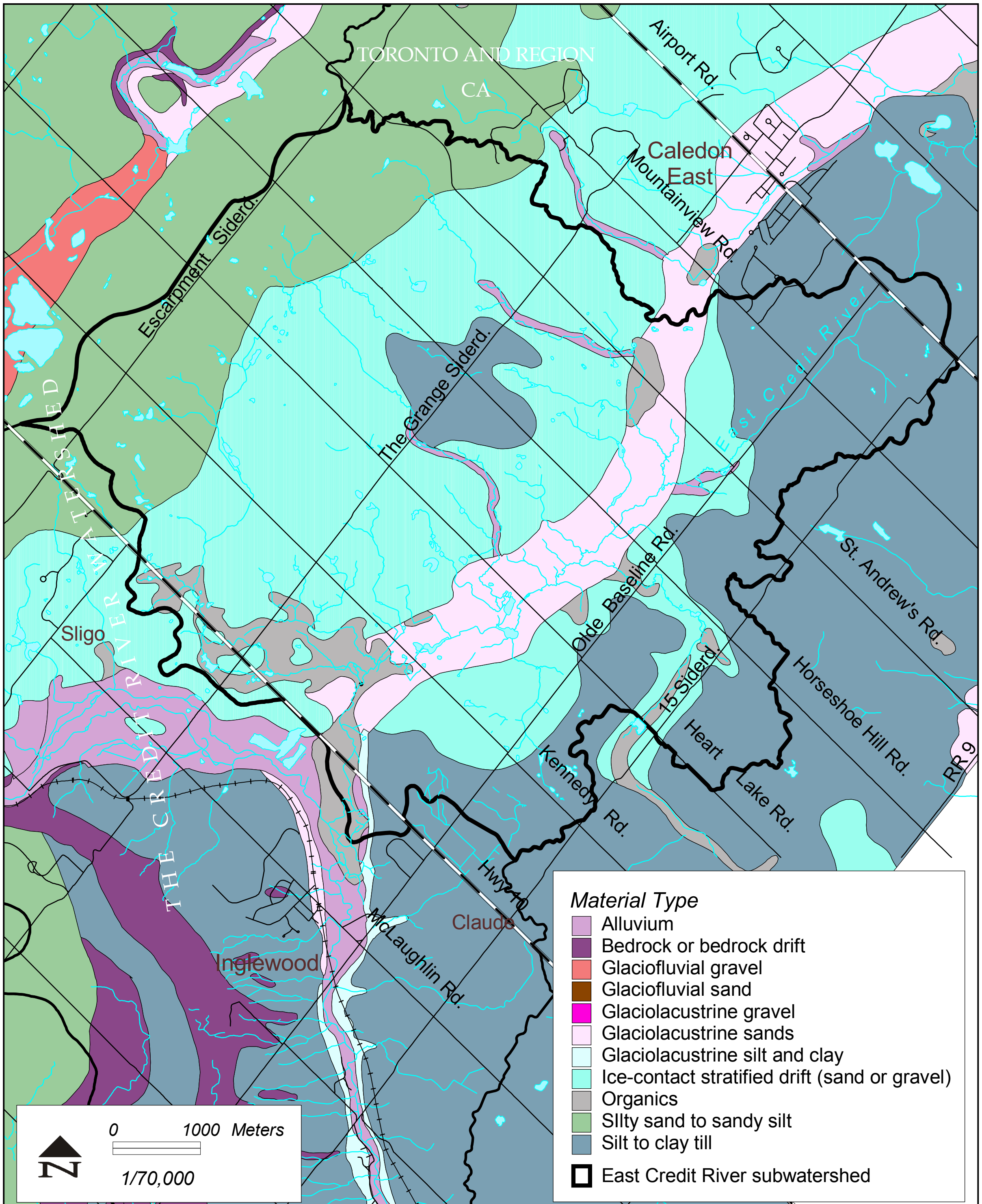

Figure 3.1.2: Surficial Geology

Sources:
White, O. and P. Karrow, Map 2275, Quaternary Geology, Bolton Area, 1965; Credit Valley Conservation, 1999; Ontario Ministry of Natural Resources, 1982

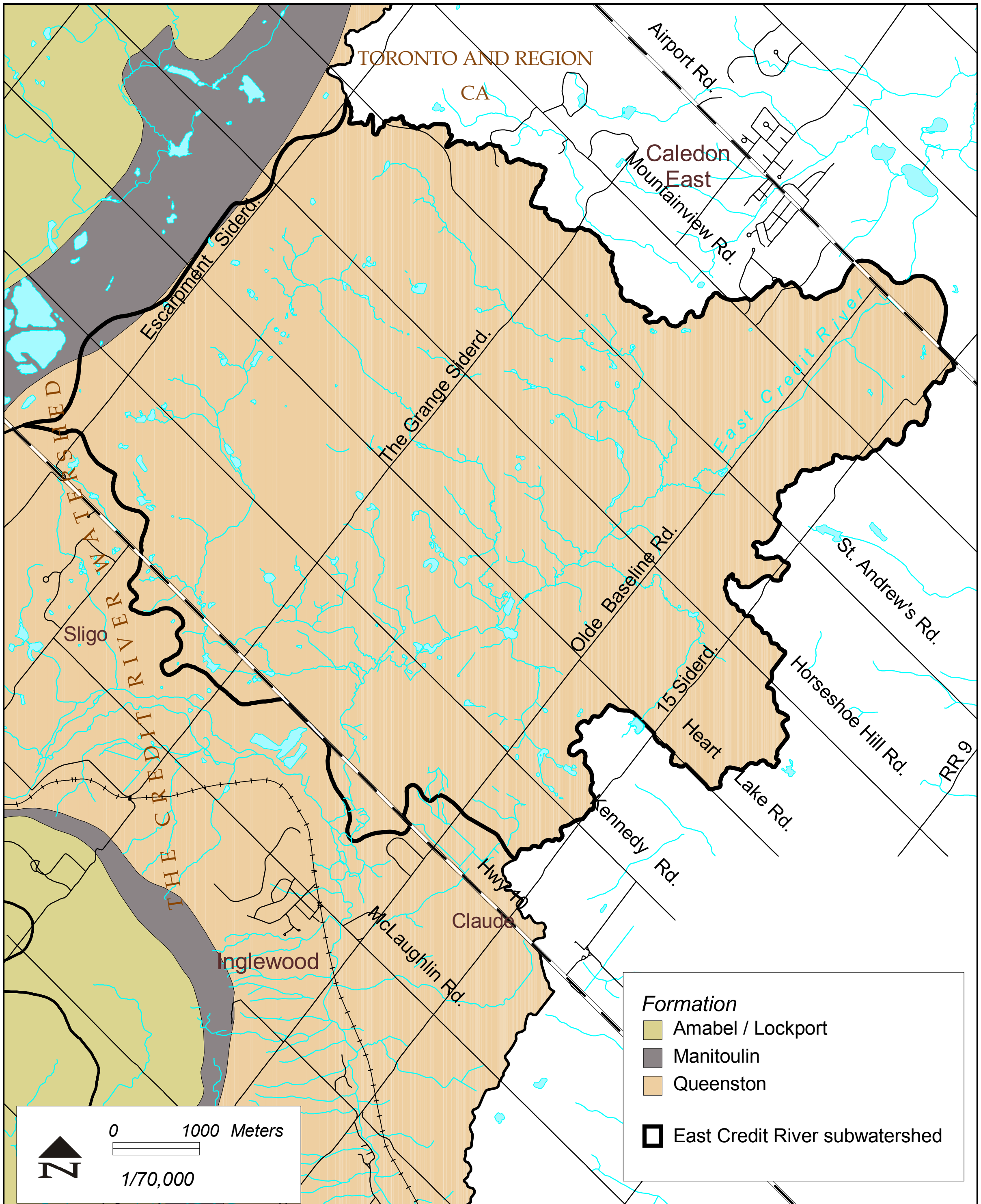

Figure 3.1.3: Bedrock Geology

Sources:
Bond, I.J. and P.G. Telford, Map 2338, Paleozoic Geology of Bolton, Ontario Division of Mines, 1976; Credit Valley Conservation, 1999; Ontario Ministry of Natural Resources, 1982

The South Slope Physiographic Region:

The South Slope physiographic region is defined as the area along the southern slope of the Oak Ridges Moraine and extends the length of the moraine from Durham Region in the east to the Niagara Escarpment in the west. The South Slope region within Subwatershed 13 includes the area immediately south of the Oak Ridges Moraine and makes up the southern portion of the study area. The South Slope is characterized as having a gently slope surface towards Lake Ontario, whereas, the Peel Plain is relatively flat.

The bedrock geology over the majority of the South Slope region, including Subwatershed 13 consists of red shale of the Queenston Formation. The Queenston Formation conformably overlies grey shales of the Georgian Bay Formation. The bedrock surface is overlain predominantly by low permeability red to brown silt to clay silt till belonging to the Halton Till sheet. These deposits range from approximately 3 to 15 m in thickness. The Halton Till sheet covers a large portion of the Credit River watershed below the Niagara Escarpment, including most of the South Slope and Peel Plain physiographic regions.

The Niagara Escarpment Physiographic Region:

The Niagara Escarpment is a prominent topographical feature that extends from the Niagara River near Niagara Falls to the Bruce Peninsula and then onto Manitoulin Island. Due to the preferential erosion of different rock types along the Escarpment, lands to the north and west of this feature are at a notably higher elevation than lands to the south. The physiographic region is defined essentially from the brow of the Escarpment corresponding to the crest of more resistant cap rock north and west encompassing an area where the overburden is very thin to absent and where dolostone bedrock and boulders are present. Within the study area; however, the Escarpment cap rocks are mantled by various thicknesses of ORM sediments. Therefore, within Subwatershed the area of the Niagara Escarpment is marked by a height of land, but the characteristic surficial features are masked by the overlying ORM deposits. The brow of the Niagara Escarpment within Subwatershed 13 approximately coincides with the northwestern boundary of subwatershed.

Geologically, the resistant cap rock of the Escarpment comprise dolostones of the Amabel Formation. This formation is underlain by rocks of the Clinton and Cataract Group (Fossil Hill Formation, Cabot Head Formation, Manitoulin Formation and Whirlpool Formation), which in turn are underlain by softer shales of the Queenston Formation. This differential erosion has resulted in prominent vertical cliffs, generally facing southeast, over much of the length of the Escarpment, although not in the study area. The Amabel Formation, which is the uppermost bedrock unit in this area, is characterized by numerous reefal bodies and is frequently fractured and karstic. These characteristics have resulted in a high primary and secondary permeability for the formation and, as a result, it is a very important aquifer for domestic water supply. As noted, the brow of the Escarpment coincides generally with the northwestern boundary of the subwatershed. As a result, most of the study area is actually underlain by Queenston Shale bedrock.

The Oak Ridges Moraine Physiographic Region:

The Oak Ridges Moraine is another significant topographical feature that extends from Lake Scugog in the east and extending west to the Niagara Escarpment for a total length of approximately 160 km. The moraine forms a west-east trending belt of undulating, kettle topography, that varies between 5 km and 20 km in width (Howard et al., 1996). The moraine forms the surface water divide between Lake Ontario and Georgian Bay and provides baseflow to numerous headwater streams along its length. Within the Credit River watershed, this physiographic region encompasses an area that extends from the Forks of the Credit in Subwatershed 20, northeast through Subwatershed 13 to the watershed divide. The ORM within the Credit River watershed coincides with the Caledon and Albion Hills and the Palgrave Moraine, as mapped by White (1975).

On a regional sense, the ORM has been the focus of much recent study due largely to its important groundwater resources and the threat to these resources from urban development. However, due to the extensive length and thickness of this feature, much work is still required to thoroughly understand the stratigraphy and depositional processes responsible for the moraine. The ORM is generally classified as an interlobate moraine and records sedimentation between two lobes of the Laurentide Ice Sheet during the last glaciation (approximately 13 Ka) (Howard et al., 1996?). The uppermost coarse-grained core deposits of the moraine, which are referred to as the Oak Ridges Moraine Aquifer Complex (ORAC), have been interpreted to be glaciolacustrine fan-delta and outwash deposits that accumulated in an interlobate lake (Howard et al., 1996).

In the 1990s, the Geological Survey of Canada (GSC) undertook an extensive regional study of ORM that has focused on understanding the three dimensional geological structure and the development of a conceptual geological model (Sharp et al., 2001). The geological model that was developed included six major hydrostratigraphic units within the overall three-dimensional framework. From youngest to oldest these hydrostratigraphic packages are: 1) bedrock; 2) lower sediments; 3) Newmarket Till; 4) channel sediments; 5) Oak Ridges Moraine sediments (equivalent to the ORAC unit of Howard et al., 1996); and 6) Halton Till (Lower sediments and ORM sediments form significant aquifers, whereas the Newmarket and Halton Till generally form aquitards (Sharp et al., 2001). Of particular interest in the GSC geological model is the role that channel sediments play in connecting the upper and lower aquifer systems. According to the model, these channel sediments are erosional features in the underlying Newmarket Till sheet and in some instances completely penetrated the till sheet providing a conduit between the ORAC unit and the lower sediments. The exact depositional processes responsible for the formation of the channel sediments is currently subject to some debate.

At present, there is not a great deal of readily available information about the geology of the Oak Ridges Moraine within the Credit River watershed. The Caledon and Albion Hills area comprises the most western section of the moraine where it meets the Niagara Escarpment near Inglewood and the Forks of the Credit. These features have been mapped as ice-contact stratified drift sand, gravel and locally silt deposits (White, 1975), which is interpreted to comprise the ORAC deposits described above. The Palgrave Moraine has been mapped at the very east end of Subwatershed 13. This moraine is a northeast-southwest trending ridge of hummocky topography approximately 5 km wide. At the surface of the moraine, deposits of Halton Till silts have been mapped. The till has been noted to be approximately 1 to 2 m in thickness and overlies stratified sands and gravels. This moraine was interpreted to be deposited by at the terminal limit of the Halton ice sheet.

Additional pertinent geological preliminary data regarding the Subwatershed 13 study area is available from CVC's ongoing work on a water budget analysis. A northwest-southeast cross-section through the subwatershed is presented in Figure 3.1.4. The cross-section shows the Niagara Escarpment to the northwest mantled by glacial sediments. Below the Escarpment, a subtle bedrock valley is present in the area of the East Credit River. Coarser grained outwash sand and gravel deposits are located beneath the East Credit River within this channel complex. Several till sheets are present in the cross-section, both above and below the coarser grained deposits. These may correspond to the Halton and Newmarket Till sheets, respectively but additional drilling and geophysics will be required to confirm this. CVC's interpolated bedrock surface through this area indicates that the channel trends in an east-northeast direction and extends the length of the study area beneath the Credit River. Overburden thicknesses within the study area are considerably thicker than elsewhere within the Credit River watershed, except in the area of the Orangeville Moraine to the northwest where thicknesses are similar. The overburden thicknesses within Subwatershed 13 range from about 15 m at the east end of the study area north of the meltwater channel to over 70 m at the Escarpment. The thicknesses within the meltwater channel associated with the East Credit River range from approximately 40 to 70 m. It should be noted, however, that these interpreted overburden thicknesses were based on a limited data set.

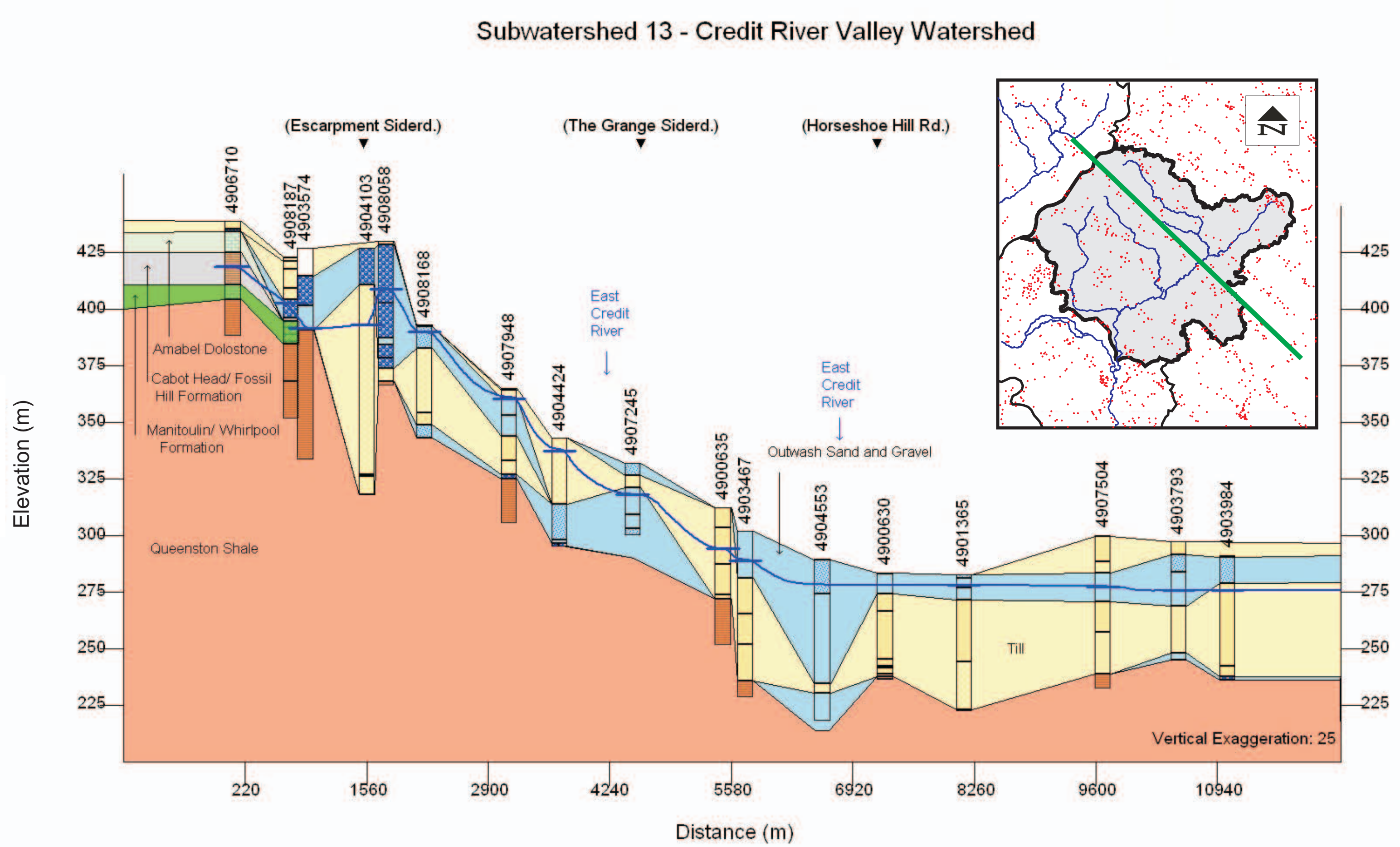

Figure 3.1.4: Northwest to Southeast Hydrostratigraphic Cross-section

Source: Credit Valley Conservation, 2002

Within the geological / physiographic setting, as summarized above, a number of generalizations have been made with respect to the hydrogeology of the study area, particularly significant recharge and discharge areas, as well as groundwater-surface water interactions, as follows:

- Within the ORM area, early work (Turner, 1977) noted that yields of groundwater were generally excellent and the potential for the development of high-capacity wells was good in most areas of the moraine. Sibul et al. (1977) recognized the role of the ORM in supplying baseflow to the headwater streams that source the tributaries of over 30 major rivers in the GTA.

- As noted by Sharp et al. (2001), there is considerable difficulty in developing a thorough understanding of the hydrogeology in the ORM due to its complex subsurface glacial deposits because aquifers and aquitards have varied regional extents and geometry and sedimentary facies can change rapidly.

- Recent work by Hunter and Associates (1996), indicates that the potentiometric surface on the Niagara Escarpment slopes down the Escarpment and recharges the ORM within the study area and adjacent south slope area. Throughflow continues towards the headwaters of Etobicoke Creek and Humber River. Mapping of groundwater levels in the overburden completed by the CVC as part of the Water Budget evaluation, indicate that the overburden groundwater flow direction in the area of the Escarpment is southeast towards the East Credit River and buried valley, but there is no throughflow component out of the watershed, as described by Hunter and Associates. According to CVC mapping the southeastern boundary of the subwatershed roughly coincides with a shallow groundwater divide and flow from both the Escarpment to the northwest and the southeast watershed boundary converge in the area of the East Credit River and the meltwater channel. Along the length of the meltwater channel and buried valley flow is to the southwest, out of the subwatershed to the Credit River valley.

- The groundwater levels in the overburden were noted to range from 395 m amsl on top of the Escarpment to approximately 270 m amsl at the confluence of the East Credit River with the Credit River.

- Groundwater levels in the bedrock deposits were also mapped by CVC as part of the water budget evaluation. Similar to flow in the overburden deposits, groundwater flow in bedrock is towards the southeast, down the Escarpment. In contrast to groundwater flow in the overburden, there is a significant component of flow in the bedrock that flows out of the watershed to the southeast. There does not appear to be a groundwater divide at the southeast end of the subwatershed. There is some convergence of flow on the buried channel feature, but only at the west end of the subwatershed near the confluence with the Credit River.

- Stream baseflow measurements have been collected for the East Credit River, near its confluence with the Credit River, as part of the CVC's watershed wide monitoring program. The results indicate that for flow normalized to the subwatershed area, the flow in the East Credit River is relatively low possibly indicating a low recharge rate or sub-surface transfers of groundwater either to another subwatershed or to another watershed. Based on the flow rate, the normalized flow rate was calculated to range form 160 mm/yr to 195 mm/yr, which is well below the average for the Credit River watershed. As illustrated by the cross-section presented in Figure 3.1.4, fine-grained deposits (Halton Till) are noted at surface and these may attribute to the low recharge rates. Alternatively, the cross-section illustrates the presence of the bedrock valley and deeper subsurface flow could be flowing out of the subwatershed via this feature.

- It is expected that due to the convergence of shallow overburden flow on the East Credit River that upward hydraulic gradients exist, however the stratigraphy is complex and this will require additional investigation.

- The subwatershed also has many wetland complexes and these are interpreted to be a result of relatively low permeability Halton Till deposits occurring at ground surface, as illustrated on the cross-section (Figure 3.1.4). The fine-grained nature of this unit would inhibit downward migration of surface water, thereby creating the wetlands.

In terms of groundwater supply for drinking water purposes, the significant aquifer within the watershed is the ORAC deposit, as described above. Unfortunately, as elsewhere on the ORM, the stratigraphy in the area is complex and not completely understood therefore a definitive assessment of the area from a groundwater resource assessment perspective has not yet been completed. Above the Escarpment, the Amabel Formation comprises a regionally significant aquifer. In addition to the these aquifer systems, some private residential wells may obtain groundwater from coarser grained facies of the Halton Till or the upper weathered 3 – 5 m of the Queenston Formation.

3.1.3 Groundwater Quality

Natural water quality within Subwatershed 13 is expected to vary, depending on the aquifer through which groundwater flows. As noted, the regionally significant aquifers within the subwatershed consist of the ORAC deposits associated with the ORM and, to a lesser extent, the Amabel dolostone formation above the Escarpment, which presumably discharges to the glacial sediments on the Escarpment face. Additional lower yielding aquifers that may be used for localized domestic water supply consist of the coarse grained facies of the Halton Till and the upper weathered portion of the Queenston Shale.

At present, there is not a great deal of readily available information regarding natural groundwater quality within the subwatershed. However, some regional information is available on the groundwater quality for the Amabel Formation and the ORAC deposits, as follows:

- Groundwater from the Amabel Formation is typically hard, with a resultant relatively high (alkaline) pH. The degree of mineralization varies depending upon the age of groundwater and the types of soluble minerals that occur along the flow path. Groundwater from the Amabel Formation is generally potable. Previous water quality sampling of the Amabel Formation completed by the MOE indicated that groundwater samples had high total dissolved solids (TDS) and elevated iron concentrations. The elevated iron concentrations have been attributed to the mineralogical makeup of the rock and not from any anthropogenic sources. Groundwater samples obtained by the MOE from bedrock wells within the Amabel did not have elevated nitrate concentrations, indicating that the bedrock had not been subject to bacterial contamination. Previous watershed-wide research has shown that chloride concentrations are variable. The occurrence of elevated chloride concentrations was attributed to road salting practices;

- Groundwater quality within the ORM aquifer complex is generally good to excellent (Intera Kenting, 1990). Groundwaters are hard and predominantly calcium bicarbonate in character (Sibul et al, 1977). Previous sampling of ORM waters has shown a different chemical signature related to age. Relatively young waters close to the recharge areas were noted to contain relatively low levels of sodium, chloride, fluoride and iodine. With increasing age (and distance along the flow pathline from a recharge area to discharge area), groundwater typically became increasing concentrated with sodium, chloride, fluoride and iodide and decreased in calcium concentration (Intera Keating, 1990). Unconfined aquifer sediments within the ORAC are susceptible to contamination. Commonly occurring contaminants in this area include elevated chlorides resulting from road salting practices, and elevated nitrate concentrations from both septic systems and agricultural activities. Due to the predominantly rural nature of the study area, impacts resulting from industrial activity are not expected to occur although there would be a small potential for gasoline related impacts from service stations or private fuel outlets (e.g., farm diesel tanks).

Potential Groundwater Impacts:

Potential anthropogenic impacts to groundwater quality could occur from either point sources or non-point sources of contamination. Point sources imply localized concentrated inputs of contaminants to the subsurface from a single specific source, such as a leaking underground storage tank (UST), whereas non-point sources represent more diffuse spreading of contaminants over a larger area, such as fertilizer spreading or bio-solid disposal. The presence of various potential point source and non-point sources of contamination will be addressed in the characterization report. In order to do this, the following types of databases and information sources will be consulted for the entire subwatershed:

- Database of waste receivers;
- Database of waste generators;
- Waste disposal sites inventory;
- Ontario PCB storage / disposal sites inventory;
- Coal Gasification sites inventory;
- Database of private and retail fuel storage tanks; and
- Biosolid Spreading Certificates of Approval.

The degree of impact to the groundwater resource from anthropogenic point or non-point sources of contamination will be influenced by the geological characteristics of the area in which the impact is occurring. In this regard, the subwatershed has several relatively distinct geological areas and hence the degree of protection to groundwater contamination is expected to vary, as discussed above.

3.1.4 Identification of Data Gaps

Much work has been completed in the last ten years or is underway at present to document the hydrogeological conditions of the Oak Ridges Moraine. However, due to the depth and lateral extent of this feature, much work is still required to more fully understand the detailed hydrogeology of the ORM, including the portion in the study area. The stratigraphy of the ORM is generally complex and the cross-section presented in Figure 3.1.4 illustrates this complexity. For example, it is not clear if the Newmarket Till is present in the study area. Therefore, more work is required to completely understand the hydrostratigraphy of the ORM in the study area.

In addition, the nature of groundwater flow at the Escarpment requires further study. It is known from other studies undertaken by the CVC along the Escarpment, that the Amabel Formation is a regionally significant aquifer and that a seepage face must exist at the Escarpment face. It is unclear then, why the flows normalized to catchment areas in the East Credit River are so low in comparison to many other reaches in the Credit River watershed. It is possible, that there may be some groundwater transfers out of the subwatershed, possibly via the groundwater channel. This requires further study. The relationship between the various stream sections and wetland areas to the hydrostratigraphic setting is also not fully understood and also requires further study.

Several tasks would aid in advancing the understanding of the hydrogeology of the subwatershed, as follows:

- The completion of two deep boreholes to bedrock in order to document the detailed stratigraphy at those locations would provide high quality stratigraphic details that could be used to correlate to surrounding MOE well records. Each of these boreholes should be completed as a monitoring well nest that could provide water level data on an ongoing basis as well as information on hydraulic gradients and hydraulic conductivity. Down-hole geophysics at each borehole location would aid in documenting the detailed hydrostratigraphy and could also be used as "type" logs to correlate to other, more regional studies being completed on the ORM;

- Collection of additional surface water level data and surface water flow data, as well as hydraulic gradient data from streambed piezometers at selected locations would aid in understanding groundwater-surface water interactions on both a local scale and a regional scale. This data would also aid in calibrating the numerical groundwater flow model discussed below; and

- Detailed numerical groundwater flow modelling of the subwatershed, based on a numerical model of the CVC watershed that was recently developed for the Water Budget evaluation and also for the Geological Model developed by the GSC. This should provide a detailed hydrostratigraphic model of the entire subwatershed and would enable delineation of linkages between various flow systems, such as those that may occur between the Amabel Formation and the buried valley features. Model calibration using available observations of groundwater levels, stream gauge baseflow data, spot flow baseflow data, areas of known surface water discharge or recharge and groundwater flow velocities will ensure that the numerical model developed adequately represents actual conditions.

3.2 HYDROLOGY

3.2.1 Background Information

Existing Studies

Three detailed studies have been conducted regarding the East Credit River (Subwatershed 13). In 1956 the Credit Valley Conservation Report summarized conditions along the East Credit River. In 1975, James F. MacLaren Limited conducted the Floodline Mapping Study for the East and West Branches of the Credit River, and in 1990, Triton Engineering conducted the Phase I Credit River Water Management Strategy.

Hydrologic Models

Three hydrologic models have been developed for Subwatershed 13. Philips Engineering developed a model in 1984 as part of the Federal / Provincial Flood Damage Reduction Program (FDRP) floodline mapping study for the entire Credit River watershed using the USDA's HYMO package. In 1990, Triton Engineering formulated a complete model of the entire Credit River watershed based on the Guelph All-Weather Storm Event Runoff model (GAWSER) package as part of the Phase I Credit River Water Management Strategy.

In 2000, Schroeter & Associates revised the existing Credit River watershed GAWSER model. The revised model of the Credit River watershed comprised 11 subwatersheds, including Subwatershed 13 (Little or East Credit River). The GAWSER model utilized the latest soil type / land cover information available in the CVC's GIS (Geographical Information System) database. The database was developed using Ontario Base Maps at a scale of 1:10,000. The revised East Credit River GAWSER model is divided into five subcatchment areas with a total drainage area of 50.9 km^2.

Topographic and planimetric data can be abstracted from maps and aerial photographs. In the spring of 1999, CVC had aerial photographs taken for the entire Subwatershed area. Six OBM map sheets with a scale of 1:10,000, and 5 m contour intervals are available for Subwatershed 13. CVC's Geographical Information System (GIS), which is based upon 1:10,000 scale mapping, utilizes the latest soil type, and land cover information available for the entire Credit River watershed and specifically Subwatershed 13.

3.2.2 Climatic Characteristics

The mean annual precipitation in the Credit River is about 850 mm, of which 15% appears as snowfall (125 cm in depth). The values are distributed in a fairly even pattern in a northwest to southeast direction with the greatest amounts occurring in the northern portions of the watershed. The mean annual evapotranspiration in the watershed is approximately 540 mm.

Long-term monitoring of meteorological quantities has occurred within and surrounding the Credit River watershed for more than 100 years. Historical data are primarily available from Environment Canada's Atmospheric Environment Service (AES) with additional data derived from CVC stations Figure 3.2.1. Table 3.2.1 and Figure 3.2.2 summarize stations within and adjacent to the Credit River watershed that can be used to derive detailed climatic information for Subwatershed 13. The climatic data abstracted from these stations can be used for simulating streamflow for Subwatershed 13.

Snow course data has been collected bimonthly in the Credit River Watershed for more than 20 years at five locations listed in Table 3.2.2. Each year the mean of the 10 points (both snow depth and equivalent water content) are collected for the period December 1st to April 15th, and are reported to the Ontario Ministry of Natural Resources as part of the province-wide network.

Table 3.2.1 Climate Stations

Station Name	Station Code	Owner	Available Period Of Record	Data Collected
Cataract	CVCA002	CVC	1988-1996	RGC
Above Erin	CVCA003	CVC	1988-1996	RG
Boston Mills	CVCA004	CVC	1988-1996	RG
Georgetown	6152691	AES	1960-1966	P,T
Georgetown WWTP	6152695	AES	1962-1996	P,T
Hillsburgh	6143465	AES	1981-1989	P,T
Blue Springs Creek IHD	6140818	AES	1966-1980	P,T,RG
Brampton MOE	6150916	AES	1962-1993	P,T
Fergus Shand Dam	6142400	AES	1960-1996	P,T,RG
Guelph Arboretum	6143069	AES	1975-1995	P,T,RG
Guelph OAC	6143083	AES	1960-1973	P,T,RG
Guelph Lake Dam	GRCA003	GRCA	1988-1996	P,T,RG
Hornby IHD	6153545	AES	1967-1978	P,T,RG,E
Milton Kelso	6155187	AES	1966-1987	P,T,RG
Shand Dam	GRCA001	GRCA	1988-1996	P,T,RG
Toronto Pearson Int'l A	6158733	AES	1960-1996	P,T,RG

Notes: P – daily precipitation (rain and snow)
T - daily maximum and minimum air temperature
RG - Recording raingauge (tipping bucket)
E - Pan evaporation estimates

Table 3.2.2 Credit River Watershed - Snow Course Sites

MNR No.	Snowcourse Name	Elevation M	Latitude	Longitude	Available Period of Record
1201	Belfountain	366	43 48	80 01	1960 -
1202	Monora (Orangeville)	427	43 56	80 06	1960 -

1203	Terra Cotta	343	43 43	79 57	1960 -
1204	Hillsburgh	480	43 48	80 10	1980 -
1205	Meadowvale	166	43 38	79 44	1980 -

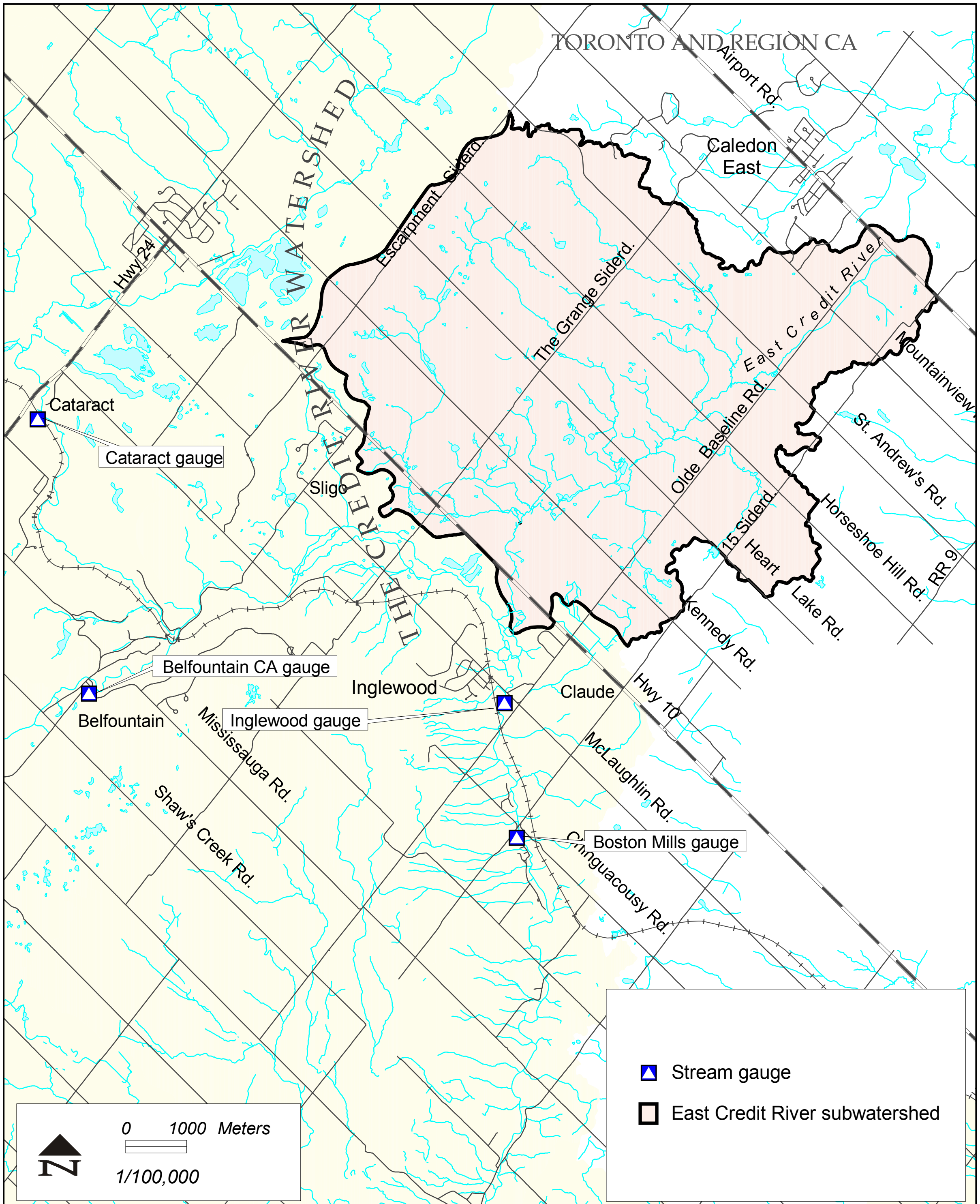

Figure 3.2.1: Stream Gauges Surrounding the East Credit River Subwatershed

Sources: Credit Valley Conservation, 2002; Ontario Ministry of Natural Resources, 1982.

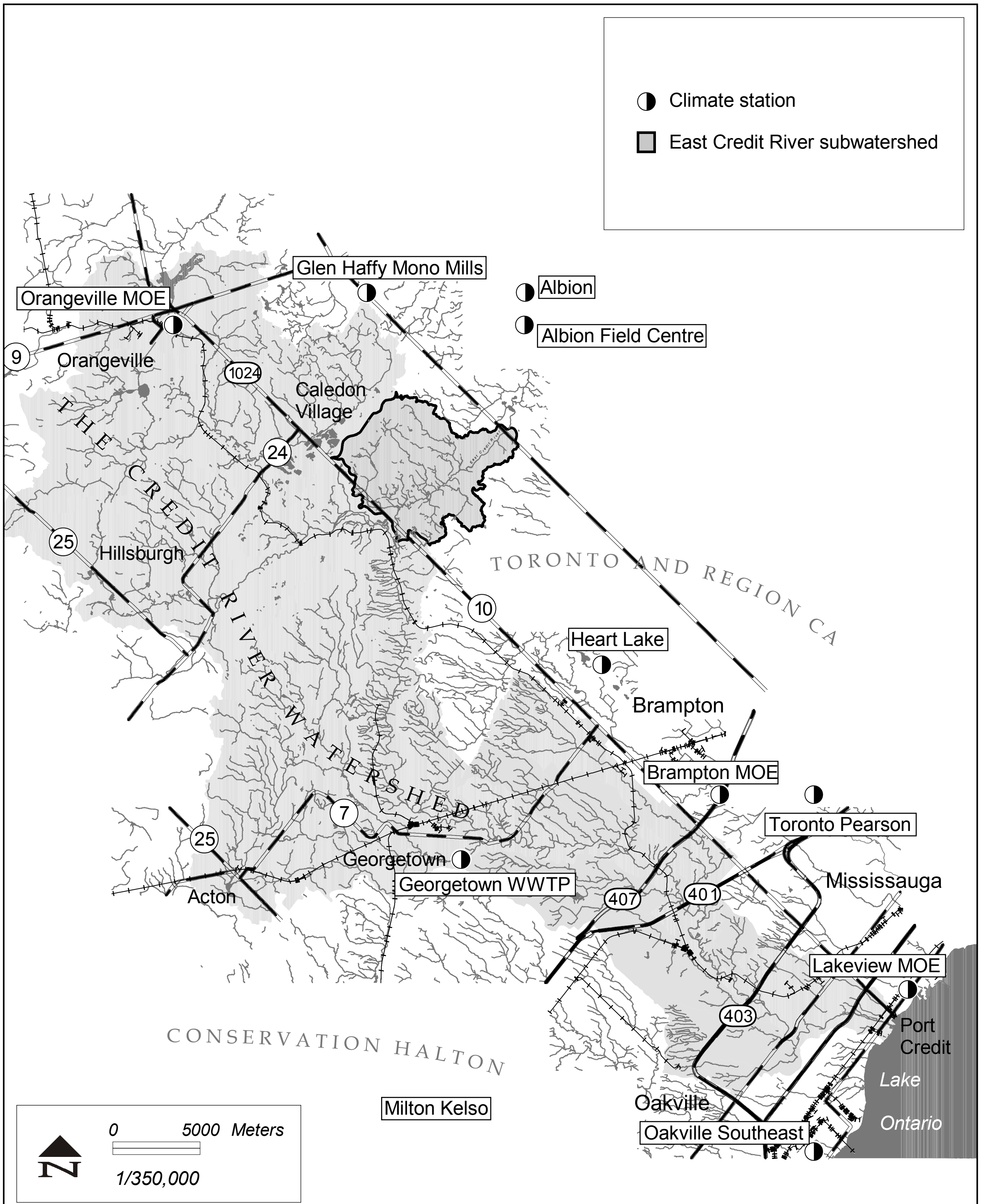

Figure 3.2.2: Climate Stations Surrounding the East Credit River

Sources: Atmospheric Environment Service, 1996; Ontario Ministry of Natural Resources, 1982.

3.2.3 Subwatershed Characteristics

Subwatershed 13 has a drainage area of 50.9 km^2 at it's confluence with the Credit River and is composed of a main branch with three major tributaries. Runoff is conveyed by the three roughly parallel tributaries in a northwest to southeast direction. The main branch conveys runoff in a northeast to southwest direction and is located along the southern limits of the Subwatershed.

3.2.4 Streamflow Characteristics

Long term streamflow monitoring has not been undertaken in the East Credit River watershed. Streamflow monitoring has been undertaken along the Credit River upstream and downstream of the confluence with the East Credit River. Table 3.2.3 sumarizes streamflow monitoring stations within the Credit River watershed. These stations can be used to abstract data for calibrating and verifying streamflow simulation models. The long term data recorded within the Credit River watershed is readily available for daily time steps. Strip charts must be discretized to obtain streamflow in smaller time steps.

Table 3.2.3 Streamflow Monitoring Stations

Station Name	Station Code	Owner	Available Period Of Record*	Drainage Area km^2
Credit River Near Orangeville	02HB013	WSC	1967 -	62.2
Credit River Alton Branch Above Alton	*02HB019*	*WSC*	*1983 -*	*59.5*
Credit River near Cataract	02HB001	WSC	1915-	205
Credit River Erin Branch above Erin	*02HB020*	*WSC*	*1983 -*	*32.3*
Credit River at Boston Mills	02HB018	WSC	1982-	402
Credit River West Branch at Norval	*02HB008*	*WSC*	*1960 -*	*127*
Credit River at Norval	02HB025	WSC	1988-	615
Credit River at Erindale	02HB002	WSC	1945 -	795

Notes : WSC - Water Survey of Canada

3.2.5 Data Gaps

Meteorological and streamflow data are not available for Subwatershed 13. Streamflow data, required impacts assessment, will be synthesized by the GAWSER computer program. Meteorologic data required for input will be transposed from adjacent watersheds.
A physically-based validated GAWSER model will synthesize the required streamflow data. The model will be validated using streamflow records from stations in the adjacent subwatersheds.

3.3 HYDRAULICS

3.3.1 Existing Studies & Mapping

The current floodplain mapping was conducted for the East and West Branches of the Credit River and was completed in 1975 by James F. MacLaren Limited. There are six photo based floodplain maps with a scale of 1"=200' and 5 ft contours. The six sheets extend along the entire length of the East Credit River. There have been no floodplain mapping studies for the East Branch of the Credit River, since the MacLaren Study.

3.3.2 Watercourse Characteristics

The East Credit River (Subwatershed 13) is a major tributary within the Credit River watershed of south central Ontario. Watersheds to the west of the East Credit River include the West Credit River and to the south the main branch of the Credit. To the east, is the West Humber River within the Humber River basin. Outflows from the East Credit River enter the Credit River near Inglewood (Highway 10).

The total drainage area of the watershed at the junction with the Credit River is approximately 50.9 km^2. This represents 8% percent of the Upper Credit River watershed above Norval, and 6% percent of the Credit River watershed discharging to Lake Ontario.

The main branch of the East Credit River is approximately 11 km in length, with an average channel slope of 1.5%. The watershed elevations vary from 437 m to 265 m. However, more than half the watershed is at an elevation below the 305 m contour, including all of the portion to the south of the main East Credit branch. The major tributaries, which drain from the north-west, originate along the face of the Niagara Escarpment and possess steep upper gradients and quick discharge characteristics.

The main channel lying in glacial spillways has a very flat gradient and wide flood plains, presenting considerable storage for peak flows. An extensive scrub-marshland area has developed at the confluence of the main branch and downstream of the tributaries.

There are no major urban centres within the watershed. However, to east of the Subwatershed is Caledon East and to the west is the Village of Inglewood.

3.3.3 Floodplain Characteristics

The six flood plain mapping sheets extend along the main branch of the East Credit River over a watercourse length of approximately 11 km. The main channel has a flat gradient with wide flood plains. The typical floodplain width is approximately 450 m, with Regulatory Flood depths of approximately 2-3 m.

3.3.4 Flood Damage Centres

Based on a preliminary investigation of the floodplain mapping by MacLaren Limited there appear to be no buildings within the Regulatory Floodplain.

3.3.5 Data Gaps

There are definite information gaps within the hydraulic data available for Subwatershed 13. There has only been one floodline mapping study conducted for the East Credit River. James F. MacLaren Limited conducted the study in 1975. Since1975, there have been no other hydraulic studies conducted for Subwatershed 13. Also, there are no hydraulic models for any of the major tributaries in Subwatershed 13.

3.4 TERRESTRIAL

CVC has recently mapped the East Credit River Subwatershed terrestrial system using the Ecological Land Classification for Southern Ontario (Lee, H. et al., 1998) and the Credit Watershed Natural Heritage Project Detailed Methodology (CVC, 1998). The Ecological Land Classification (ELC) was used to map and describe the upland and wetland systems. The Natural Heritage Project (NHP) Methodology outlines the methods used to characterize the land use matrix of the watershed. This ELC and Existing Land Use mapping was completed based on 1996 spring aerial photography. The data from these photographs was transferred to 1:10,000 Ontario Base Mapping and then digitized into a GIS or Geographic Information System (Arcview 3.1).

3.4.1 Upland System

The upland system includes forests, plantations, and cultural or successional “old field” communities. These communities were mapped to the Community Series level of the ELC for Southern Ontario (Figure 3.4.1). The Community Series is the finest level of the classification system that can be completed using aerial photography, without fieldwork. Community Series level mapping classifies upland communities as Deciduous Forest, Mixed Forest, Coniferous Forest, Deciduous Plantation, Mixed Plantation, Coniferous Plantation, Cultural Woodland, Cultural Savannah, Cultural Thicket, Cultural Meadow or Open Beach/Bar. According to the ELC mapping, the East Credit Subwatershed is dominated by cultural meadows while only 15.6% of this subwatershed is forested. This is only half of the goal of 30% forest coverage that has been recommended by the Ministry of Natural Resources and adopted by Credit Valley Conservation to maintain forest interior species and area sensitive species (MNR 1997).

To compliment the ELC natural community classifications, CVC developed Existing Land Use classifications to describe areas in the watershed that would not be considered natural. These communities consist of intensive and non-intensive agriculture, wet meadows, active and in-active aggregate, urban and rural development, manicured open space (parks, lawns and golf courses) and landfill (sanitary landfill sites and dumps). In terms of land use, agriculture dominates the East Credit subwatershed. Only 3.4% of the subwatershed is characterized as "urban" and 3.6% is characterized as rural. Studies show that in subwatersheds where urban land use is greater than 15%, fisheries are significantly degraded (Klein, 1979).

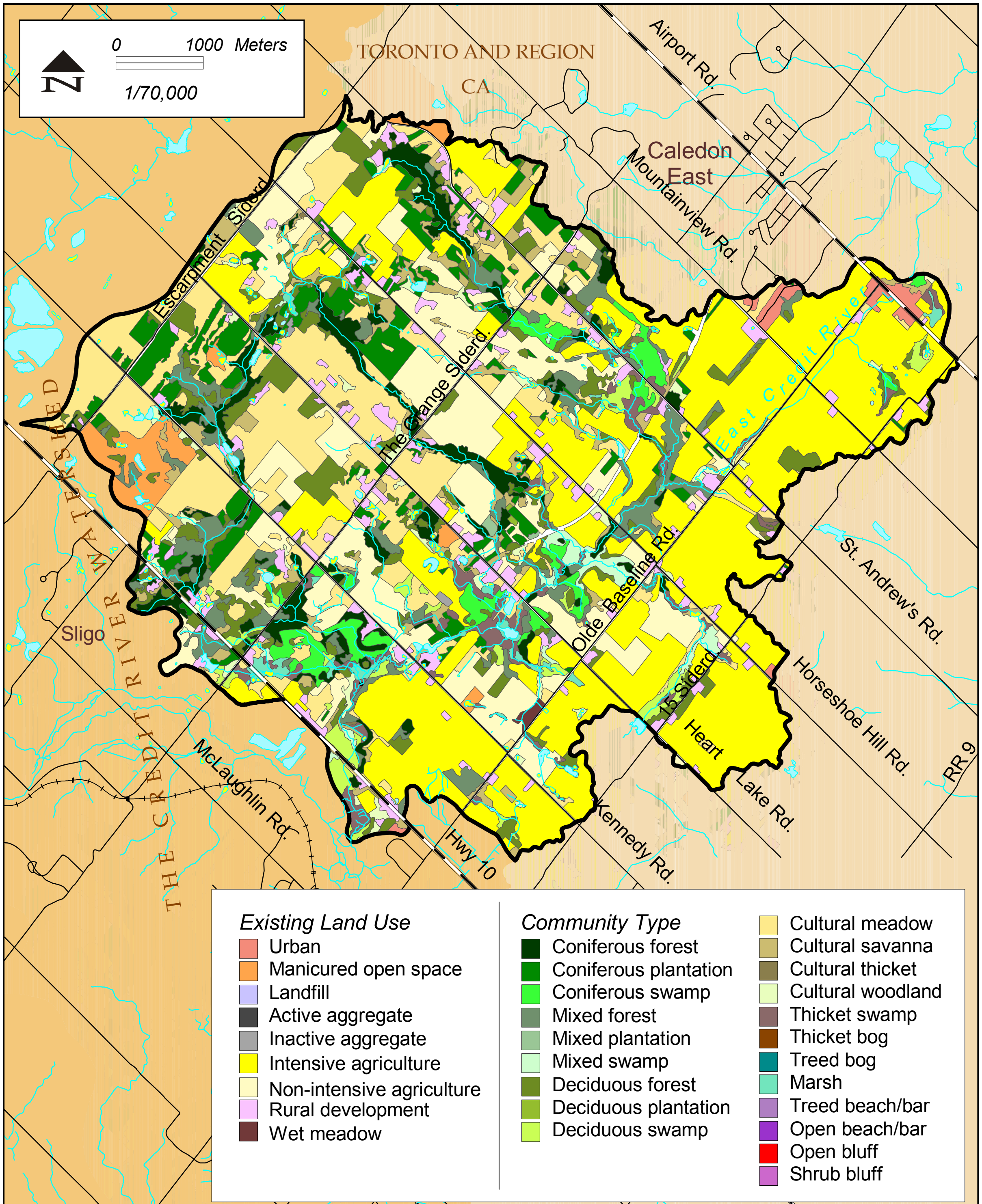

Figure 3.4.1: Ecological Land Classification and Existing Land Use

Sources: Credit Valley Conservation, 1996; Ontario Ministry of Natural Resources, 1982.

3.4.2 Wetland System

The wetland system is comprised of marshes, swamps, fens and bogs. Swamps are classified to the ELC Community Series level as Deciduous Swamp, Mixed Swamp, Coniferous Swamp or Thicket Swamp (Figure 3.4.1). Marshes are not mapped according to the Community Series level because it is difficult to determine the difference between Meadow Marsh and Shallow Marsh from aerial photography. Marshes are therefore just mapped to the ELC Community Class level as Marsh. Fens and Bogs are also difficult to interpret from aerial photography; therefore they are not mapped based on air photo interpretation. Fens and Bogs are mapped based on fieldwork, Ontario Wetland Evaluations, Environmental Impact Studies and other applicable studies. According to the ELC mapping, 6.3% of the East Credit subwatershed is classified as wetland.

The ELC mapping has been checked against the Wetland Evaluation mapping for discrepancies. These differences could include ELC wetlands that are not identified in the Wetland Evaluation mapping or cases where the ELC mapping identifies a community as upland whereas the Wetland Evaluation mapping identifies the community as wetland. In all cases discrepancies were double-checked in the air photos and corrections were made wherever possible. However, there are cases where no changes could be accurately made to the ELC mapping without field investigations. As a result, further adjustments to wetland boundaries will be made following this season's fieldwork. Further discussions with the OMNR will be required to deal with any formal changes to evaluated wetlands. The current ELC and Existing Land Use mapping identifies 310.49 hectares of wetland in the East Credit Subwatershed; whereas, the Wetland Evaluation System for Southern Ontario identifies 254.09 hectares of evaluated wetland. As a result, there are 56.4 hectares of potential and unevaluated wetland in the East Credit Subwatershed, identified through the ELC mapping. Consequently, there is a need to confirm the status of these potential and unevaluated wetlands, under the Wetland Evaluation System for Southern Ontario, and a field crew will carry out these evaluations during this summer's field season.

Four evaluated wetlands have been identified in the East Credit subwatershed. These include: Claude Swamp, the Little Credit River Wetland Complex, Caldwell Woods and Mono Road Wetland Complex.

3.4.3 Aquatic System – Watercourses, Lakes and Ponds

Current mapping of watercourses, lakes, and ponds are from the 1:10,000 Ontario Base Mapping. Past subwatershed studies have identified a significant number of inaccuracies and changes in the location and size of watercourses on the Ontario Base Mapping compared to the watercourses on the ground. Having accurate and up-to-date watercourse mapping is important for assessing, modeling and monitoring subwatershed health. Updates have been made to the Aquatic System component of the ELC and Existing Land Use mapping. These updates include previously unmapped lakes and ponds and sections of watercourses where there have been significant changes in the watercourse's size and location. Therefore, watercourses and on-line ponds have been updated using aerial photography and ground truthing and have been identified, classified and mapped according to the definitions in Table 3.4.1. Updated waterways and their classifications can be found in Figure 3.4.3. (Watercourses, Lakes and Ponds map)

Table 3.4.1 Definitions for Mapping Waterways Feature Description

Natural Waterways	
Classification	**Definition**
Watercourse	A watercourse is constituted when there is sufficient continuous flow of water to form and maintain a defined channel (with bed and banks) of a permanent, yet dynamic nature.
Intermittent or Ephemeral Watercourse	An intermittent or ephemeral watercourse is constituted when there is sufficient periodic flow of water to form and maintain a defined channel (with bed and banks) of a permanent, yet dynamic nature. These watercourses will generally flow with most rainfall events.
Watercourse Not Visible	Watercourse Not Visible refers to watercourses or intermittent watercourses where the exact location of the channel cannot be determined through air photo interpretation because they pass under the canopy of forests or swamps.
Wetland Flow	Wetland flow is formed when a watercourse dissipates as it enters a wetland. The water in these wetlands, flow through poorly defined channels, multiple braided channels, or outside a defined channel.
Swales	Swales are natural drainage courses without defined channels that contain intermittent or seasonally flowing water. These swales will generally only flow during large rainfall events or the snowmelt.
Modified Waterways	
Classification	**Definition**
On-line Ponds	Ponds are areas of still water lying in a natural or man-made depression. Can have either or both an in-flowing or out-flowing stream. Interrupting the normal flow of a watercourse with a dam can also create a pond.
Engineered Watercourse	Engineered Watercourses are any watercourses that have hardened banks and/or beds, including concrete lining, Gabion baskets, Armour stone or riprap. These watercourses have usually also been straightened or smoothed.
Agricultural Drain	Agricultural Drains are straightened and/or widened watercourses or constructed drainage course to drain wetlands and wet rural and agricultural land.
Roadside Ditch	Roadside Ditches are constructed watercourses created adjacent to roads to deal with their runoff related to rainfall and meltwater.
Lakes and Ponds	
Lake	Lakes are areas of still water, greater than 2 hectares, lying in a natural or man-made depression. Can be completely enclosed by land or can have either or both an in-flowing or out-flowing stream. Interrupting the normal flow of a watercourse with a dam can also create a lake. They are large enough to experience wave action.
Pond	Ponds are areas of still water, less than 2 hectares in size, lying in a natural or man-made depression. Can be completely enclosed by land or can have either or both an in-flowing or out-flowing stream. Interrupting the normal flow of a watercourse with a dam can also create a pond.

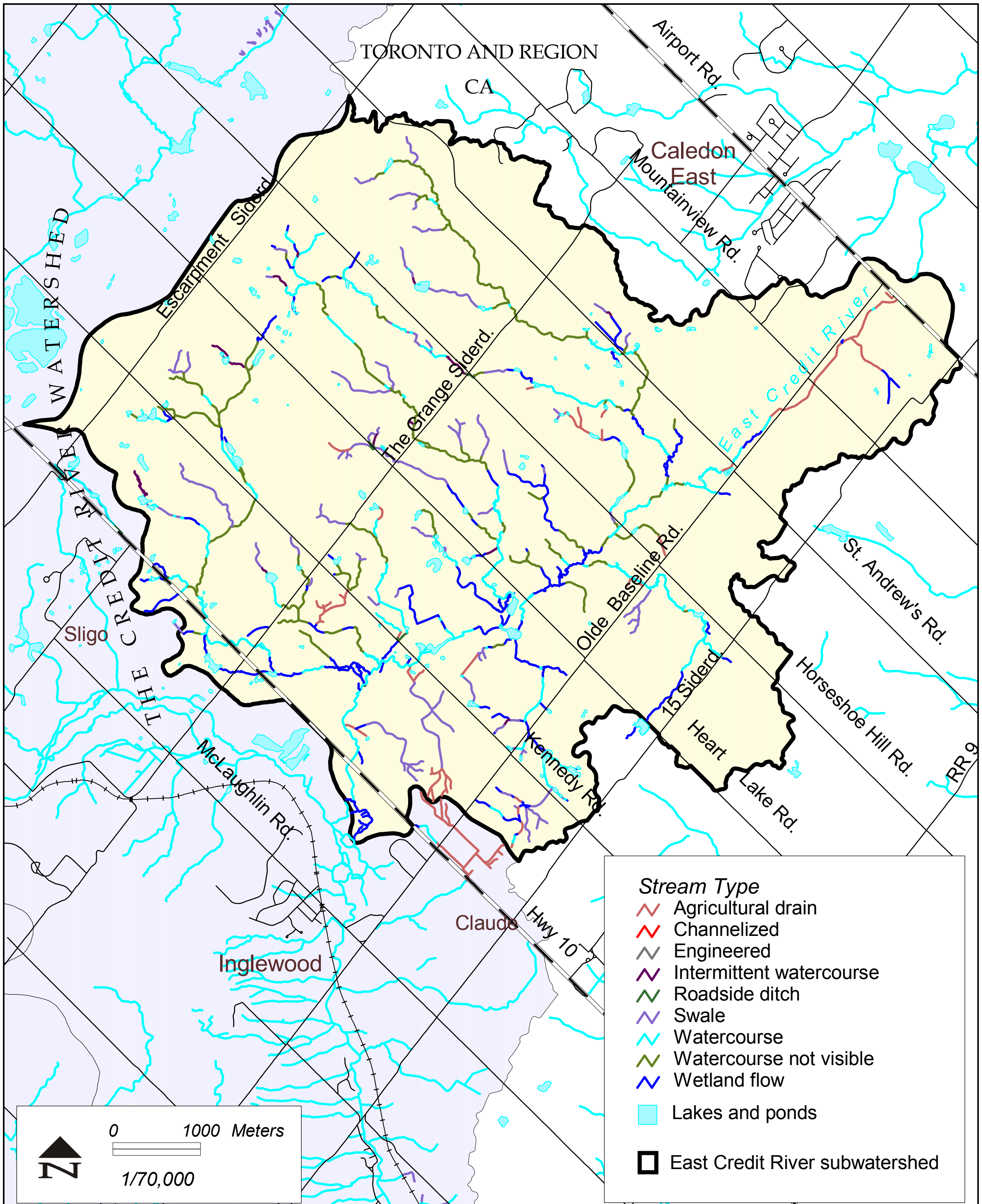

Figure 3.4.3: Watercourses, Lakes and Ponds

Sources: Credit Valley Conservation, 1999; Ontario Ministry of Natural Resources, 1982.

3.4.4 Evaluated Wetlands, ESAs, ANSIs

3.4.4.1 Evaluated Wetlands

There are wetlands that have been evaluated through the Provincial Wetland Evaluation System for Ontario - South of the Precambrian Shield. These wetlands are given a score based on a number of parameters that were developed to address all areas of wetland significance. The natural, socio-cultural, hydrological and geographical functions of the wetland to be evaluated are examined and a score is given to each section of criteria in the wetland evaluation process.

Provincially Significant Wetlands (Figure 3.4.4) are wetlands that have been evaluated, and determined to be provincially significant by the Ministry of Natural Resources. The Ministry of Natural Resources determines wetland significance based on the score assigned to the wetland through the Ontario Wetland Evaluation System. Wetlands that are not determined to be provincially significant by the Ministry of Natural Resources are considered to be important on a regional scale.

The locations of the following wetlands can be found in Figure 3.4.4. (Special features map)

Provincially Significant Wetlands (PSW)

Little Credit River Wetland Complex

This wetland complex spans 270.63 hectares of land extending through a large portion of the East Credit subwatershed and into Subwatershed 20, to the west. The Little Credit Wetland Complex contains the largest blocks of wetland in this subwatershed and is contained within the largest block of natural habitat in the East Credit. This wetland complex was formed by combining three existing evaluated wetlands, including; Inglewood Lowlands, Kilmanagh Swamp and the Little Credit River Lowlands. This wetland complex is made up of 42 separate wetland units, and is dominated by swamp and marsh vegetation communities.

There are no Provincially significant species listed for this location, but Purple Virgin’s Bower and Black Willow are both found in this complex, which are rare in the Credit River Watershed, Peel Region and the Greater Toronto Area (Kaiser, 2001).

The Little Credit River wetland complex includes two Environmentally Significant Areas (ESAs) and Proposed Environmentally Significant Areas (PESAs), namely Kilmanagh Swamp (ESA #49), Inglewood Lowlands Forests (ESA #50) and the Little Credit River Lowlands (PESA #25). They are dealt with in more detail in the Environmentally Significant Areas (ESAs) and Potentially Environmentally Significant Areas (PESAs) section of the report.

Regionally Significant Wetlands

There are three other evaluated wetlands located in the East Credit Subwatershed, which are considered to be Regionally Significant; Claude Swamp, Caldwell Woods and Mono Road Wetland complex.

Claude Swamp

Claude Swamp consists of 29 hectares of swamp and marsh. This wetland is hydrologically connected to surface water and other wetlands. Fish habitat has been recorded in this area, but its significance is not known. No significant flora or fauna was recorded for this site. This wetland was re-evaluated in 1997, but no additional fieldwork was carried out to complete this re-evaluation.

Caldwell Woods Wetland

The Caldwell Woods Wetland is 6.6 hectare swamp located on the Oak Ridges Moraine at the headwaters of Silver Creek in the East Credit Subwatershed. This wetland is a Non-Provincially significant wetland, which is dominated by yellow birch (*Betula alleghaniensis*) and Eastern white cedar (*Thuja occidentalis*). The Caldwell Woods Wetland and surrounding area were assessed under the Environmentally Significant Area (ESA) program and designated as a Potential ESA. This area is further discussed in the Environmentally Significant Areas section of this report.

Mono Road Wetland Complex

This wetland complex consists of 15 individual wetland communities covering 36.96 hectares of area, dominated by swamps but also containing some areas of marsh. This area is considered to be a distinct and important landscape feature in the East Credit Subwatershed, but due to the limited information available for this area, it is difficult to determine its significance in providing habitat for rare species and wildlife.

3.4.4.2 Environmentally Significant Areas (ESAs) and Potentially Environmentally Significant Areas (PESAs)

Environmentally Significant Areas (ESAs)

Environmentally Significant Areas (ESAs) are areas where ecosystem functions or features warrant special protection. Based on a report prepared by Ecologistics Ltd. for CVC in 1979, the Authority designated ESAs in 1984. To be designated, an area would have to meet one or several criteria, which reflected its ecological importance within the watershed. Also in 1984, CVC adopted a series of policies to aid in the protection of these features and their associated functions. The Town of Caledon and the Region of Peel have Official Plan Policies in place that require the protection of the designated ESAs.

The location of the following ESAs are illustrated in Figure 3.4.4. (Special Features Map)

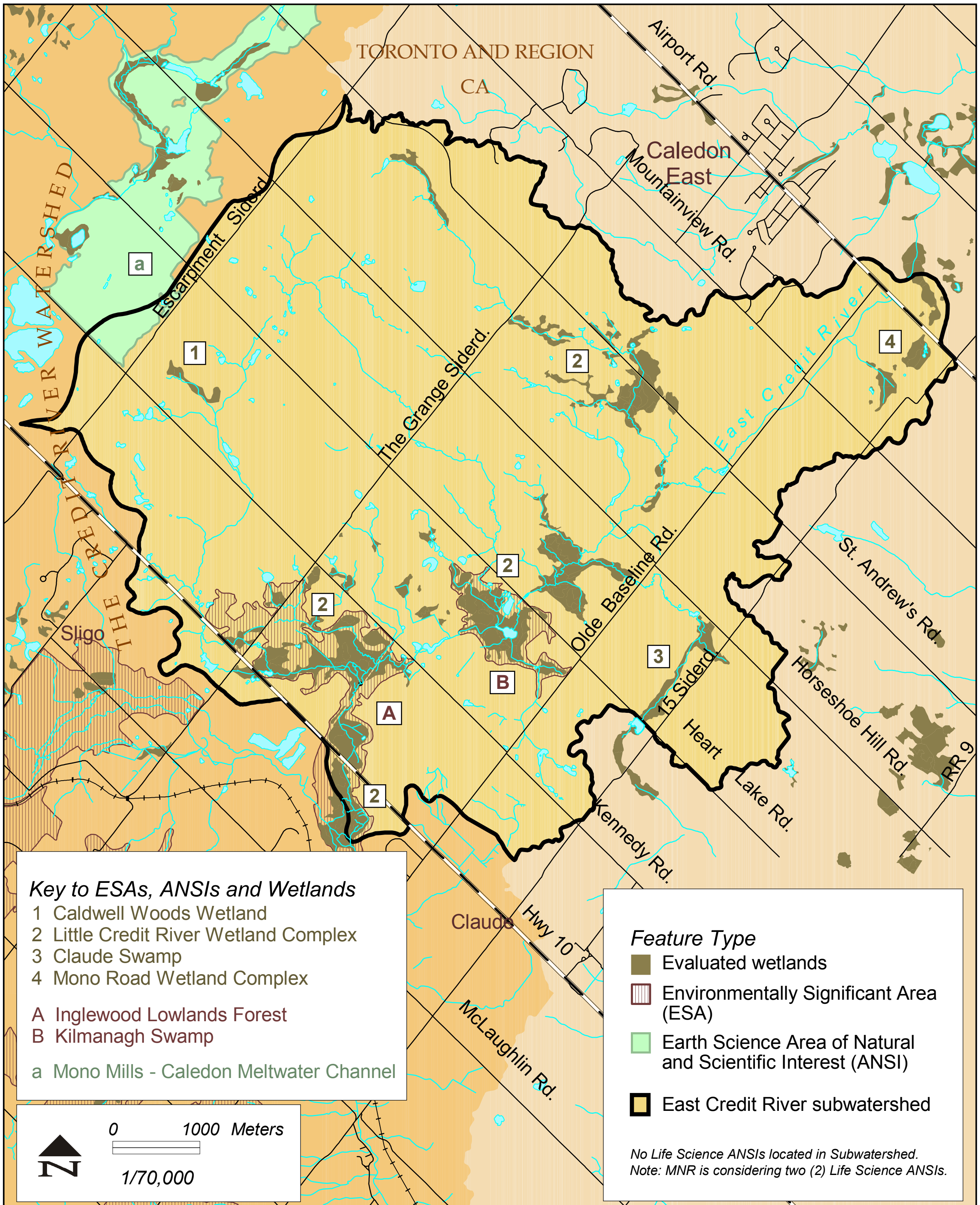

Figure 3.4.4: Environmentally Significant Areas, Evaluated Wetlands and Areas of Natural and Scientific Interest

Sources: Ontario Ministry of Natural Resources, 2001, 1982; Credit Valley Conservation, 1999.

Kilmanagh Swamp ESA #49

This ESA spans 68 hectares of natural area and is almost entirely contained within the CVC owned Warwick Property. This area is the only CVC owned land that falls completely within the Oak Ridges Moraine planning boundaries. All of the natural communities in this ESA are classified as wetlands. Kilmanagh Swamp contains both the East Credit River and two smaller tributaries, along with a number of on-line ponds. This ESA fulfills three of the 10 criteria used by Ecologistics to determine a natural area's significance in the CVC watershed. This ESA has been determined to be hydrologically/hydrogeologically significant, it contains rare or endangered species and provides habitat for rare species. This ESA falls within the Little Credit River wetland complex.

An extensive species list was collected for the Warwick property prior to CVC acquiring this area (Him, 1984). This list contains many species, including some regionally and locally rare plants and wildlife. The following Tables 3.4.2 and 3.4.3 list both bird and rare plant species that were recorded for the Warwick property. The bird species listed are designated as Credit Watershed Bird Species of Conservation Concern (Credit Valley Conservation, 1998).

Table 3.4.2 Rare Plant Species recorded in Kilmanagh Swamp

Species Common Name	**Rare in CVC/Peel***	**Rare in GTA***
Meadow horsetail	yes	yes
Bristly Sedge	yes	
Three-leaved False Solomon's-seal	yes	
Showy Lady's Slipper	yes	yes
Small Purple Fringed Orchid	yes	yes
Purple Clematis	yes	yes
Sicklepod	yes	yes
American Mountain Ash	yes	yes
Steeplebush	yes	yes
Marsh Blue Violet	yes	
Northern White Violet	yes	yes
Sundrops	yes	yes

(Source: Him, 1984), * (Kaiser, 2001)

Table 3.4.3 Bird Species of Conservation Concern recorded in Kilmanagh Swamp

Species Common Name	**Breeding (B), Suitable Habitat (SH) or Observed (OB)**
Great Blue Heron	OB
Turkey Vulture	OB
Killdeer	OB
Ruffed Grouse	B
Pileated Woodpecker	OB
Hairy Woodpecker	OB
Gray Catbird	OB
Veery	B
Black-and-white warbler	OB
Yellow-rumped Warbler	SH

(Source: Him, 1984)

Inglewood Lowland Forests ESA #50

This wetland ESA consists of 65 hectares around both the convergence of the Little Credit and Silver Creek tributaries, and the main Credit with the Little Credit. Much of this area is contained in the Ken Whillans Resource Management Area and is owned by CVC. The Caledon Trailway system runs through the center of this ESA. This ESA is also part of the Little Credit River wetland complex, and provides significant winter cover for wildlife as well as fish spawning and rearing habitat. This ESA fulfills three of the 10 criteria used by Ecologistics to determine a natural area's significance in the CVC watershed. This ESA has been determined to be hydrologically/hydrogeologically significant, it contains rare or endangered species and provides habitat for rare species.

Potentially Environmentally Significant Areas (PESAs)

Within the East Credit subwatershed, there are a number of Potential Environmentally Significant Areas (PESAs) as determined by CVC. The Town of Caledon and the Region of Peel require an evaluation of potential ESAs prior to any land use decisions being made, and following a review of this information designated ESAs are protected.

The Little Credit River Lowlands PESA falls within the Little Credit River Wetland Complex and the wetland portion of Caldwell Woods PESA is contained within the Caldwell Woods wetland. They are however, still worthy of mention in the ESA section of this report. Many of the areas contain significant numbers of locally rare plant species or birds designated by CVC as Bird Species of Conservation Concern. There were some species recorded in these sites that are not currently recognized as species occurring in the Credit River watershed. Some of these species are potentially significant and must be re-confirmed through field work.

Caldwell Woods (PESA #26)

This area falls almost entirely within the Niagara Escarpment Plan Area, and a large portion is classed as Escarpment Natural Area. The following Tables 3.4.4 and 3.4.5 list both bird and rare plant species that were recorded as part of the Proposed Environmentally Significant Area study for Caldwell Woods (PESA #26) (Ecologistics Ltd., 1979). The bird species listed are designated as Credit Watershed Bird Species of Conservation Concern (Credit Valley Conservation. 1998).

Table 3.4.4 Rare Plant Species recorded in Caldwell Woods

Species Common Name	**Rare in CVC/Peel***	**Rare in GTA***
Bog Laurel	yes	yes
Black Spruce	yes	yes
One-flowered Wintergreen	yes	yes
Showy Lady's Slipper	yes	yes
3 Leaved False Solomon's Seal	yes	yes
Canada Waterleaf	yes	yes

(Source: ESA Report, Ecologistics Limited, 1979), * (Kaiser, 2001)

Table 3.4.5 Bird Species of Conservation Concern recorded in Caldwell Woods

Species Common Name	**Breeding (B) or Observed (OB)**
Green Heron	B
Nashville Warbler	B
Ovenbird	B
Northern Waterthrush	B
Mourning Warbler	B
Common Grackle	B
Turkey Vulture	OB
Northern Harrier	OB
Yellow-billed Cuckoo	OB
Belted Kingfisher	OB
Hairy Woodpecker	OB
Eastern Kingbird	OB
Least Flycatcher	OB
Eastern Wood-pewee	OB
Bank Swallow	OB
Barn Swallow	OB
Cliff Swallow	OB
Wood Thrush	OB
Veery	OB

Warbling Vireo	OB
Chestnut-sided Warbler	OB
Ruffed Grouse	OB
Gray Catbird	OB
Brown Thrasher	OB

(Source: ESA Report, Ecologistics Limited, 1979)

Little Credit River Lowlands (PESA #25)

The Little Credit River Lowlands covers 430 hectares of land and is considered to be a valley related site. This PESA falls completely within the flood line and fill-line mapping completed by CVC and one third of the area is within the Niagara Escarpment Commission's jurisdiction. Two thirds of this PESA has the East Credit River running through it. This PESA falls within the Little Credit River wetland complex.

3.4.4.3 Areas of Natural and Scientific Interest (ANSI)

There are two types of ANSIs: Life Science and Earth Science. Life Science ANSIs are significant representative segments of Ontario's biodiversity and natural landscapes including specific types of forests, valleys and wetlands, their native plants and animals, and their supporting environments (MNR, 1997). Earth Science ANSIs consist of some of the most significant representative examples of bedrock, fossil and landform record of Ontario, and including some examples of ongoing geological processes (MNR, 1997).

There is one Earth Science Area of Natural and Scientific Interest in the East Credit Subwatershed. Only a portion of this ANSI is contained within Subwatershed 13, along the northern boundary.

Mono Mills – Caledon Meltwater Channels ANSI

The Mono Mills-Caledon Meltwater ANSI is located about 6km southeast of the village of Mono Mills and is characterized by an ice-contact complex of three intersecting moraines and associated meltwater channels in the Caledon area (Cowell and Woems 1976). This area is unusual in that the channels drain both northward and southward. The meltwater channels are directed by the three moraines that intersect in the ANSI, including the Paris, Gibraltar and Singhampton moraines and by the Niagara Escarpment, which is partially buried in this area. The Mono Mills-Caledon meltwater channel is a provincially significant geological site because it represents a complex ice-contact environment adjacent to a buried portion of the Niagara Escarpment. It provides excellent representation of the two associated meltwater channels in Caledon and Mono Mills, and is a good example of buried Niagara Escarpment that has been exposed by glacial ice movements and meltwater flow. Some of the most significant features contained in this ANSI include kettle lakes that were formed by glacial meltwater. To the north of the East Credit subwatershed, in the Caledon Creek Subwatershed, this ANSI contains the provincially significant, Star Wetland Complex.

ANSIs are mapped based on information provided by the Ministry of Natural Resources (Figure 3.4.4). (Special Features Map)

3.4.5 Identification of Data Gaps

The following tasks will be completed to address any data gaps as part of the East Credit Subwatershed Study.

- Naturalist Clubs (e.g. Upper Credit Field Naturalists) and other community groups (e.g. Caledon Countryside Alliance) offer a wealth of knowledge and experience to such a study. Therefore, every effort will be made to encourage participation by these groups.

- Reconnaissance fieldwork is required to confirm the Ecological Land Classification and Existing Land Use mapping.

- Detailed community data will be collected through fieldwork to classify a number of significant natural areas according to the Ecological Land Classification for Southern Ontario.

- Ontario's Ministry of Natural Resources needs to be contacted to obtain the latest mapping and status of evaluated wetlands.

- Fieldwork using the Wetland Evaluation System for Ontario - South of the Precambrian Shield will be completed for areas in the subwatershed showing discrepancies between Evaluated Wetland and ELC mapping and other areas that may be wetland.

- Steep valley slopes will be mapped to define the physical boundaries of the well-defined valley system.

- Landscape and watershed scale corridors will be mapped and assessed.

- Terrestrial communities shall be assessed to determine their relative significance in the East Credit Subwatershed based on fieldwork and existing data.

- Forest Bird Monitoring and Roadside Amphibian Call Counts will be carried out to develop a better understanding of the wildlife and their habitats in the East Credit Subwatershed.

- ANSIs in the area are currently under review. Forks of the Credit ANSI, which currently falls outside of the subwatershed study area, is being reviewed by the Ministry of Natural Resources for proposed expansion. This could extend the eastern boundary of the ANSI into the East Credit Subwatershed.

- An ANSI at the southern end of the East Credit subwatershed exists in some older versions of the ANSI mapping, but does not appear in current mapping or documentation. This discrepancy needs to be reviewed.

- A previous report (Stream Survey), which documented conditions of the riparian zone, must be reviewed: Little Credit River Assessment (1985).

- Oak Ridges Moraine
  The East Credit River subwatershed contains a large portion of the Oak Ridges Moraine falling within the Credit River watershed. The East Credit subwatershed contains the point where the Niagara Escarpment abuts the Oak Ridges Moraine. The significance of the Oak Ridges Moraine to the terrestrial ecosystem will be addressed in the next phase of the East Credit Subwatershed Study.

3.5 STREAM GEOMORPHOLOGY

3.5.1 Background Information

Investigation of stream morphology began by collecting and reviewing background and historical information to identify channel characteristics (e.g. sinuosity, gradient, and surficial geology) and historical changes (e.g. land-use change). Sources identified for this study include:

- topographic mapping (1:20,000)
- surficial geologic mapping (1:50,000; Russell and White, 1997)
- land-use mapping (1:20,000)
- historic air photos (1954, 1978, and 2001)

Background information assisted with delineating reaches. Reaches are lengths of channel ranging from several hundred meters to several kilometers, with relatively homogeneous characteristics including geology, land-use, and valley form. Methods used for reach delineation followed those outlined by PARISH Geomorphic Ltd. (2001). Reach characteristics were then defined (i.e. sinuosity and gradient) and reaches were grouped together in a matrix to determine similarity. Three field sites (Figure 3.5.1) were then selected from this matrix to best represent each category and ensure that the variation within the basin was represented and redundancy was avoided. Furthermore, site selection required the identification of private landowners that prohibited access to their property. A fourth site from the CVC watershed monitoring program was also utilized.

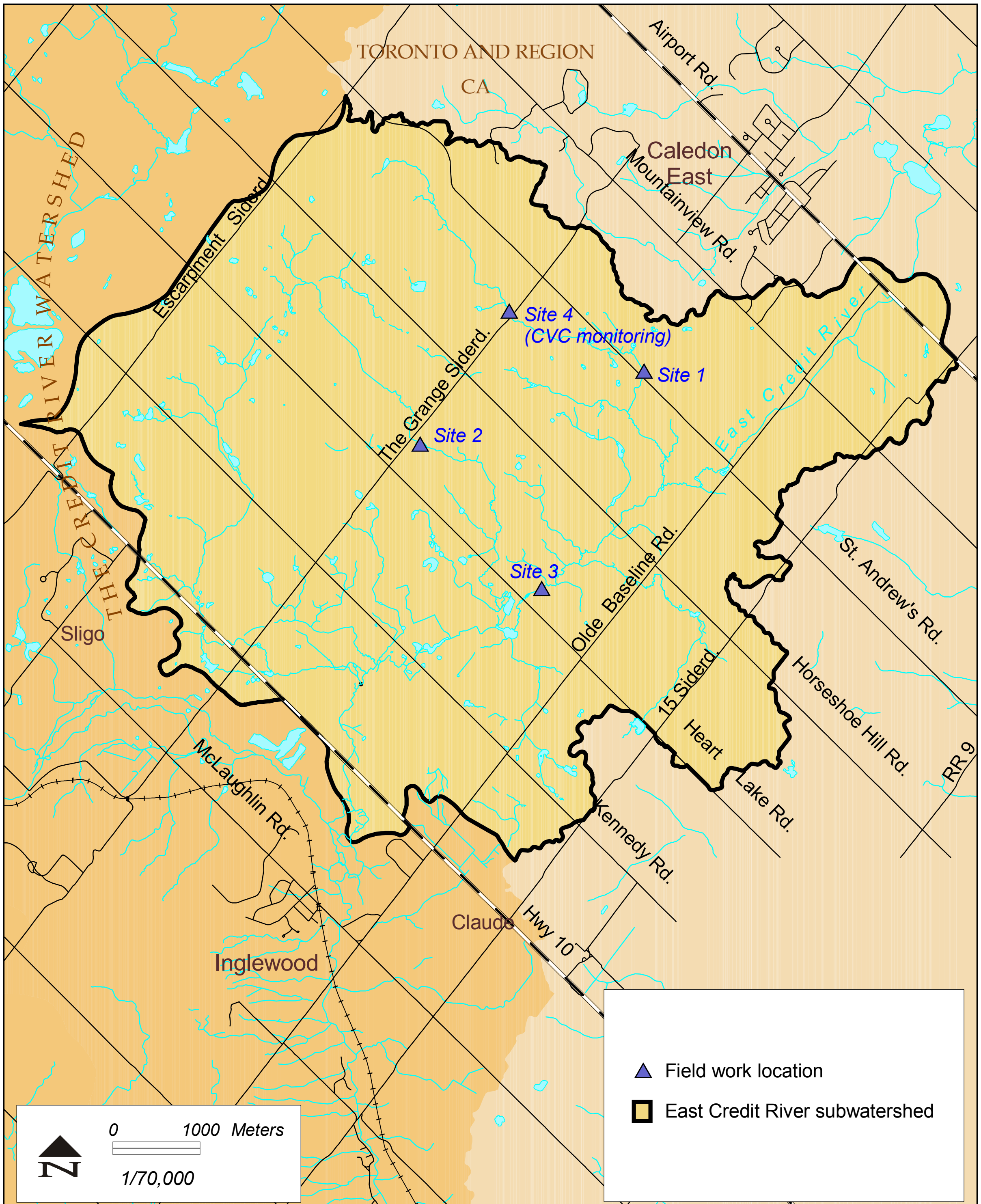

Figure 3.5.1: Location of Detailed Field Work Reaches within Subwatershed 13

Sources: Credit Valley Conservation, 2001; Ontario Ministry of Natural Resources, 1982.

3.5.2 Preliminary Interpretation of Existing Data

To provide an initial understanding of channel processes and stability, rapid channel assessments (e.g. RSAT and RGA) were completed at road crossings and along the rail trail. Further insight into existing channel condition was gained from the four sites where detailed data was collected. Collected data consisted of measures of bank characteristics, substrate material, and channel form (Table 3.5.1). A survey of the site was completed to determine the energy gradient which was used for quantitative assessment of bankfull flow characteristics at each site.

The downstream portion of the main channel is relatively low lying and flows into several lakes and wetlands. Portions of the channel flow over sand and gravel material providing an abundance of fine to coarse sand to the channel. Completion of rapid assessments within this area identified the downstream end as transitional due to indicators of deposition and widening. Several beaver dams were located along the lower main channel, interrupting continuous channel flow and sediment transport. The low energy environment was confirmed by analysis of a detailed site (Site 3) located upstream of Heart Lake Road.

At Site 3 (Heart Lake) the channel flowed through a low-lying alder thicket, with a saturated and hummocky floodplain. The channel had access to the floodplain allowing higher flows to spill over the banks thereby limiting the stream energy during flows greater than bankfull. Bank erosion was minimal (Table 3.5.1) and banks were composed predominantly of silt and organic material. Channel morphology was defined though the bed was covered with a thick layer of fine sediment (D_{50} = 0.0013 cm) and organic material. Thick deposits of fine sediment and a relatively low erosion potential (Table 3.5.2) suggest deposition as the dominant process.

Table 3.5.1 Geomorphological parameters measured at the surveyed sites through Subwatershed 13.

Parameter	Site 1 St. Andrew's	Site 2 Grange	Site 3 Heart Lake	Site 4 CVC Monitoring
Drainage area (km^2)	5 (approx.)	3 (approx.)	23 (approx.)	3.51
Average bankfull width (m)	3.77	3.74	5.84	3.63
Average bankfull depth (m)	0.40	0.39	0.39	0.42
Bankfull gradient (%)	0.32	0.83	0.32	1.1
Substrate D_{50} (cm)	0.0098	0.45	0.0013	0.52
Substrate D_{84} (cm)	0.0878	2.43	0.0115	1.21
Percent of banks undercut (%)	45	65	5	35
Dominant bank material	silt, clay	silt, medium sand	silt, clay, very fine-medium sand	silty sand, sand silt, sandy muck

Table 3.5.2 Bankfull discharge and channel flow characteristics at each of the four field sites in Subwatershed 13.

Parameter	Site 1 St. Andrew's	Site 2 Grange	Site 3 Heart Lake	Site 4 CVC Monit.
Bankfull discharge (m^3/s)	1.45	1.92	2.55	2.37
Bankfull velocity (m/s)	0.96	1.31	1.12	1.55
Tractive force (N/m^2)	12.56	72.69	12.24	45.73
Critical shear stress of substrate (N/m^2)	0.18	4.31	0.18	4.79
Permissible velocity (m/s)	0.21	0.64	0.55	0.66
Erosion potential (N/ms)	11.4	35.9	13.5	63.5
Stream power (W/m)	45.5	156.2	80.0	258.1
Stream power per unit width (W/m^2)	12.1	41.7	13.7	71.1

The upstream end of the main channel was identified as "stable" with localized increases in gradient and contact with valley walls providing pockets of instability (i.e. erosion). This portion of the basin was represented by Site 1 (St. Andrew's). Site 1 was characterized by low banks (0.7 m) with minimal protection provided by vegetation cover and roots. Silt and clay were the dominant bank material (Table 3.5.1) providing a degree of resistance to erosion. The channel was relatively narrow (Width/depth ratio = 9.52) allowing a larger portion of the energy to be exerted on the banks. Bank erosion was moderate with 45 % of the surveyed banks being undercut an average of 12 cm. Sediment being transported by the channel was dominated by fine material (D_{50} = 0.0098 cm) provided from upstream reaches flowing over alluvial material.

The northwest tributaries originate in silty sand to sandy silt material and flow over a wide variety of materials including stratified drift (sand and gravel), alluvium, and organic deposits at their downstream confluence. The gradient is moderate to high for most of these tributaries, decreasing rapidly near the confluence with the main channel. Rapid assessment identified these tributaries as transitional due to indicators of degradation and widening. Two detailed field sites represented these tributaries, Site 2 (Grange) flows over alluvium and contacts silt/clay till while Site 4 (CVC Monitoring) does not have any silt/clay contact.

Site 2 (Grange) was characterized by a relatively narrow channel that was entrenched resulting in high flows being confined to the channel. Bankfull gradient was particularly high (Table 3.5.1) at this site providing enough energy (Table 3.5.2) to transport coarse substrate material (sand and gravel) provided from upstream. Banks were composed of silt and clay providing some protection against erosion. Several constructed and natural drops in the channel indicate that the upstream portion of this reach is degradational (e.g. incising).

At the CVC monitoring site (Site 4), the upstream portion of the channel flows through a cedar forest underlain by alluvium. Substrate material was slightly finer than at Site 2.

The high bankfull gradient and narrow channel suggests that this reach is also a higher energy environment. However, the channel does not appear entrenched allowing larger flows to access the surrounding floodplain reducing the amount of bank and bed erosion.

Tributaries flowing from the southeast side of the basin have lower gradients and many have poorly developed morphology. These channels originate in silt and clay till flowing over similar materials as the northwest tributaries before joining the main channel.

3.5.3 Identification of Data Gaps

Data collected during detailed field work has been summarized and analysis is being completed. A field check of flows at each site during higher flows (March 1, 2002) indicate that bankfull flow calculations may require further refinement due to bankfull gradients and roughness elements at each site. Refinement of bankfull discharge estimates will allow for more insight into sediment transport and depositional processes. Preliminary reach delineation requires confirmation and a detailed review of historical air photos will provide migration rates and insight into disturbance along each reach.

3.6 WATER QUALITY

For the purposes of this study, water quality will be defined as the chemical, microbiological and physical condition of water. The water quality conditions of a watercourse can be used, in concert with many other indicators such as habitat features and flow regime, to evaluate the overall ecological health of a watercourse. This section will provide an introduction to indicators of water quality, describe the water quality data CVC has collected to-date in the East Credit River subwatershed and make recommendations where more data is required to characterize the water quality conditions.

3.6.1 Existing Information and Data

This section presents the existing data for the East Credit River subwatershed and based on these data, a preliminary assessment of water quality conditions in the subwatershed is discussed in the following section. As part of CVC's Water Quality Strategy, the CVC has developed watershed-wide Parameters of Concern, which include nitrate, phosphorus, metals (copper and aluminum), water temperature, *E. coli* and chlorides. These parameters represent a good starting point as they were identified based on watershed-scale issues and will be expanded to include other parameters that may be significant for the East Credit River and its tributaries, on a subwatershed scale. Table 3.6.1 presents the typical suite of parameters measured for in-stream water quality and summarizes the possible sources of these parameters, concerns relating to these parameters and the data that CVC currently has collected with regard to these parameters. The water quality parameters that are marked in bold represent those on the CVC's Parameters of Concern list.

Table 3.6.1 Water quality parameters measured in the East Credit River

Parameters	Category	Potential Sources	Concerns	Time Period
• Total Ammonia • Total Kjeldahl Nitrogen (TKN) • Phosphate Phosphorus • Total Phosphorus • Nitrate • Nitrite	Nutrient-related	• Urban Runoff • Rural Runoff • Agricultural Runoff • STP effluent • Septic systems • Aquatic plants	• Ammonia, nitrite and potentially nitrate may be toxic to aquatic biota. • Nitrate also has a Drinking Water Standard • Elevated levels of nitrate, ammonium, and both forms of phosphorus may stimulate aquatic plant growth, which may lead to an unhealthy dissolved oxygen regime for aquatic biota. • TKN can be used to determine the amount of Organic-N in a water body. • Ammonia can exert an oxygen demand similar to BOD	June 1998 to Sept 1998 Jan 2002
• Calcium • Magnesium • Alkalinity • Hardness • pH	Major minerals and related parameters	• Groundwater discharges	• 'hard' water decreases the toxicity of many metals but may require softening for water supplies • higher alkalinity values indicate a higher capacity of the water body to buffer pH changes	June 1998 to Sept 1998 for pH June 2001 for pH Jan 2002 for all
• Biological Oxygen Demand (BOD) • Chemical Oxygen Demand (COD) • Dissolved Oxygen (DO)	Oxygen Related	• Urban Runoff • Rural Runoff • Agricultural Runoff • STP effluent	• sufficient levels of DO are required by most aquatic biota • materials with high BOD and COD can deplete DO levels	June 1998 to Sept 1998 for BOD and DO June 2001 for DO Jan 2002 for all

Parameters	**Category**	**Potential Sources**	**Concerns**	**Time Period**
• Water Temperature • Particulate Residue (Suspended Solids – SS) • Filtered Residue (Dissolved Solids) • Conductivity • Chlorides	Physical and related parameters	• Urban Runoff • Rural Runoff • Agricultural Runoff • STP effluent • Road salting • Septic systems	• SS can damage fish habitat by clogging up spawning areas • both too high and too low water temperatures can be harmful to fish • increased filtered residue and/or conductivity (a measure of dissolved solids) may indicate increases in chlorides or other ions	June 1998 to Sept 1998 for water temperature and conductivity June 2001 for water temperature and conductivity Jan 2002
• **Aluminum** • Barium • Berylium • Cadmium • Chromium • Cobalt • **Copper** • Iron • Lead • Manganese • Molybdenum • Nickel • Strontium • Titanium • Vanadium • Zinc	Trace Metals	• Urban Runoff • STP effluent • Rural Runoff • Erosion of clay soils (which can contain Aluminum, Manganese and Iron oxides)	• acute and chronic toxicity to aquatic biota • buildup in the food chain from elevated levels in aquatic biota.	Jan 2002 for all
• Escherichia coli (E. coli) • Pseudomonas Aeruginosa • Fecal Streptococcus	Bacteriological	• Urban Runoff • Rural Runoff • Agricultural Runoff • STP effluent • Septic systems	• Although not typically directly harmful to aquatic biota, high levels of bacteria can indicate organic pollution • *E. coli* is used as an indicator for pathogenic bacteria that can cause respiration and gastro-intestinal illnesses in humans	Jan 2002 for all

To date, very little water chemistry data has been collected in the East Credit River and its tributaries. CVC currently has four sources of data:

- Basic water chemistry, including nutrients and oxygen demanding substances (i.e. BOD) and a diurnal dissolved oxygen data collected on the East Credit River at Highway 10 for the Inglewood Village study in 1998
- Spot measurements for dissolved oxygen, conductivity, pH and water temperature as part of the macroinvertebrate monitoring program
- Diurnal data for dissolved oxygen, conductivity, pH and temperature collected in 2001 on the East Credit River at the Caledon Rail Trail
- Nutrients, metals, bacteriological, oxygen demanding substances and other relevant water chemistry parameters collected on the East Credit River at Highway 10 in January of 2002.

Figure 3.6.1 shows the locations of the water quality stations where the majority of data has been collected on the East Credit River (at the Rail Trail and Highway10) and the data is presented in Appendix C.

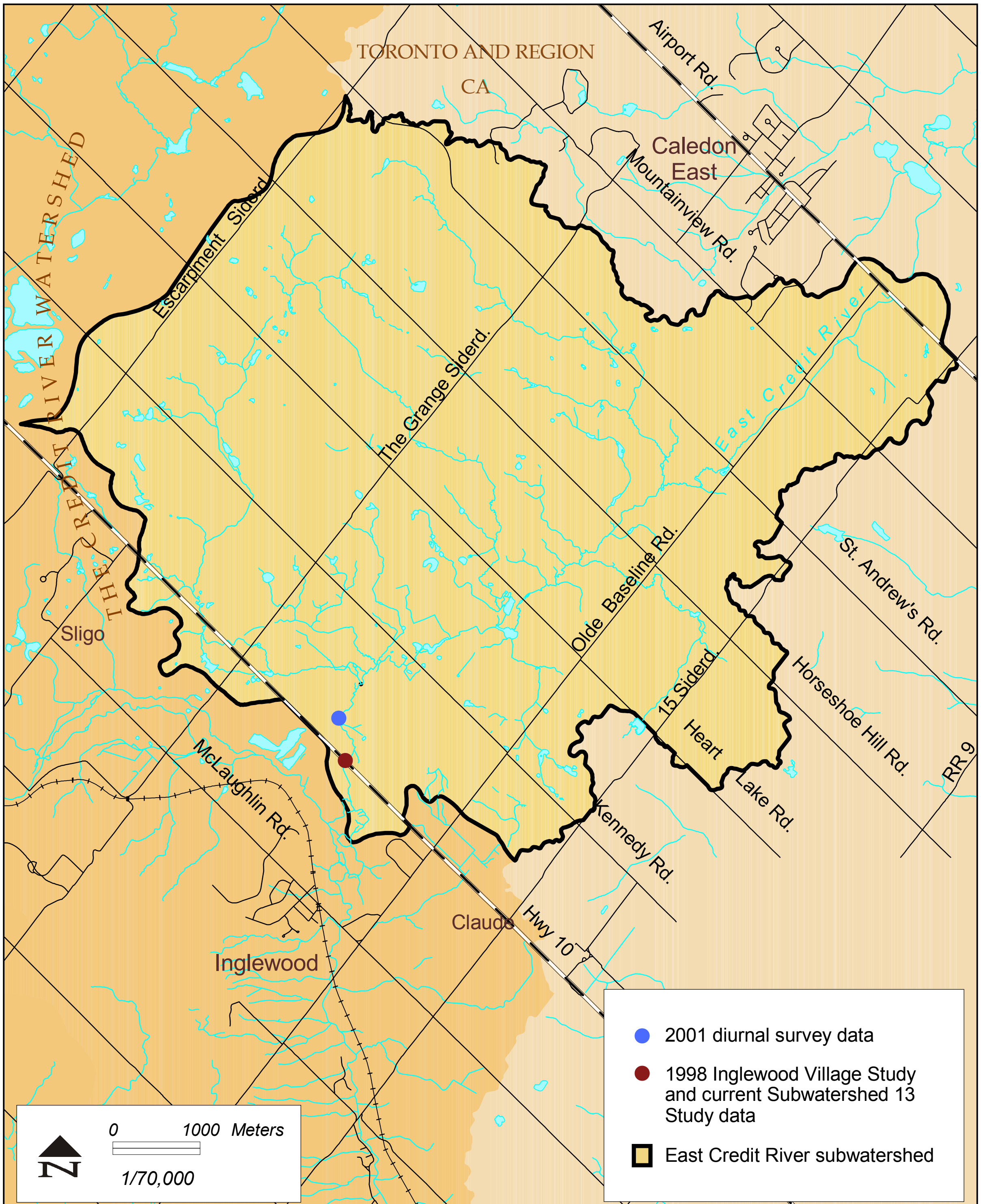

Figure 3.6.1: Locations of Currently Available Water Quality Data

Sources: Credit Valley Conservation, 2001; Ontario Ministry of Natural Resources, 1982.

east credit SUBWATERSHED

3.6.2 Preliminary Interpretation of Existing Data

There is currently not sufficient data to determine water quality conditions in the East Credit River subwatershed but some discussion on the water quality data collected to-date is provided below. These discussions are preliminary in nature and the overall conclusions may change once more data has been collected and evaluated.

Nutrients

Water quality parameters related to nutrients include any of the phosphorus and nitrogen species. High nutrient levels in a watercourse can cause excessive aquatic plant growth, which in turn can lead to low night time dissolved oxygen levels due to photosynthetic and respiration processes. Plants require daylight to photosynthesize, a process which produces oxygen, but plants also respire, a process which consumes oxygen, 24 hours a day. Therefore, during the night, dissolved oxygen levels can drop significantly and can be potentially harmful to aquatic biota, such as macroinvertebrate and fish species. Since phosphorus is typically the limiting nutrient to aquatic plant growth, there is a Provincial Water Quality Objective (PWQO) (MOE, Reprint 1999) for total phosphorus (30 μg/L) that was set to minimize the potential for excessive aquatic plant growth in rivers and streams.

In addition, the un-ionized ammonia, nitrite and nitrate have the potential to be directly toxic to aquatic biota. Un-ionized ammonia has a PWQO (MOE, Reprint 1999) of 20 μg/L and nitrite has a Canadian Water Quality Guideline (CWQG) (CCME, 2000) of 60 μg/L. The fraction of un-ionized ammonia (from total ammonia) is a function of pH and water temperature and is based on the equations provided in MOE's Water Management, Policies and Provincial Water Quality Objectives (PWQOs) (Reprint, 1999).

A Drinking Water Standard (MOE, 2001) has been developed for nitrate and has been set at 10 mg/L to protect infants from methaemoglobinaemia (blue baby syndrome). However, concentrations of nitrate as low as 2.5 mg/L have been shown to have negative health impacts on some species of fish egg and fry and some amphibian species (Rouse et al., 1999). Based on these and other studies, Environment Canada is looking at a guideline for nitrate of 2.9 mg/L (Environment Canada, 2001) but this guideline is still under review. Until this guideline has been approved and is deemed acceptable from CVC's perspective, it is CVC's practice to request that all groundwater upwellings (which have the potential to support fish spawning) and watercourses have nitrate levels less than 2.5 mg/L.

The nutrients and pH results collected to date on the East Credit River at Highway 10 are presented in Table 3.6.2. Nitrate and un-ionized ammonia appear to be well under levels that could pose a threat to aquatic biota at this location on the East Credit River. The 1998 results for phosphorus indicate that levels are above the PWQO however the one sample taken in January 2002 was below the PWQO. The data collected to-date does not provide enough information to characterize the nutrient levels in the East Credit subwatershed. Additional water quality sampling locations and frequency are needed to further investigate the levels of these parameters at this location and others in the subwatershed.

Table 3.6.2 East Credit River at Highway 10 results from 1998 Inglewood Village Study compared to January 2002 results

Parameter	Units	Average from Hwy 10 (June to Sept 1998)	Results from Hwy 10 (Jan 2002)	Standard	Source of Standard
(Nitrate+Nitrite)-N	mg/L	0.18	0.64	2.5	Literature
Un-ionized ammonia	μg/L	1.1	1.0	20	PWQO
Total Phosphorus	μg/L	80	19	30	PWQO
TKN	mg/L	0.60	0.30	NA	NA
pH	units	7.80	7.94	6.5 to 8.5	PWQO
BOD	mg/L			NA	NA

Oxygen-related

Like humans, fish require sufficient levels of dissolved oxygen (DO) in the water to maintain respiration processes. The PWQO for DO states that a minimum level of 5 mg/L is required to maintain a healthy coldwater fishery and 4 mg/L for a warmwater fishery. As part of the aquatics (fisheries) components of this study, warmwater and coldwater designations may be confirmed for different reaches of the East Credit River but the current designation for the East Credit River is for a coldwater fishery. Dissolved oxygen is also expressed as percent saturation, which is the ratio of the measured dissolved oxygen to the saturated dissolved oxygen level, at the measured water temperature. The saturated level is the hypothetical condition where the oxygen in the water is in equilibrium with the oxygen in the air and where there are no oxygen consuming or producing processes in the water. If dissolved oxygen levels are below saturation, then oxygen is being consumed at greater rates than it is being produced or mixed back in through re-aeration. Alternatively, if dissolved oxygen levels are above saturation, then oxygen is being produced at greater rates than it is being consumed, typically when photosynthesis is occurring. For coldwater fisheries, the oxygen levels should be above 54% to 63% saturation, depending on the water temperature.

Due to the diurnal fluctuations in dissolved oxygen, 24-hr sampling is required to capture the changes in this parameter. Two surveys in 1998 were conducted from sunrise to sunset on the East Credit River at Highway 10 and one survey was conducted over 9 days on the East Credit River at the Rail Trail using a remote water quality instrument, which recorded measurements of dissolved oxygen, water temperature, pH and conductivity every 30 minutes. Table 3.6.3 shows the maximum and minimum DO values for these three surveys. The Highway 10 site appears to have higher DO values compared to the Rail Trail site which cannot be explained by temperature differences alone, since the June 1998 survey had comparable water and air temperatures to the 2001 survey. However, both sites need to be sampled simultaneously to confirm this observation. Also, it should be noted that although the Highway 10 location is less than 1 km downstream of the Rail Trail location, there are a number of riffles (which re-aerate the water) between these two sites which may, in part, explain the higher DO values at the downstream location.

Table 3.6.3 Maximum and minimum dissolved oxygen levels for the East Credit River

	June 24, 1998 at Highway 10	August 13, 1998 at Highway 10	June 27 to July 4, 2001 at the Rail Trail
Maximum (mg/L)	8.0	8.4	6.40
Minimum (mg/L)	6.7	7.1	3.57

Figures 3.6.2 and 3.6.3 show the dissolved oxygen levels and percent saturation values for the 9-day survey in 2001. The lowest dissolved oxygen level (3.57 mg/L) and percent saturation value (41%), which occurred on July 1st, 2001 on 7:30 am, are lower than both the coldwater and warmwater PWQOs for dissolved oxygen. Both figures indicate a diurnal fluctuation, where the lowest DO value occur around sunrise however the percent saturation figure also shows that the DO levels were always below saturation, indicating constantly high oxygen consumption processes and/or low re-aeration rates. Both conditions are plausible since the sediment observed in this reach is made up of fine organic matter, which consumes oxygen as it decomposes (SOD – sediment oxygen demand), and the upstream reaches are slow moving and flow through a wetland area. High in-stream concentrations of BOD (biological oxygen demand) and NOD (nitrogenous oxygen demand) can also deplete oxygen levels although the preliminary results indicate relatively low nitrogen and BOD values (see Table 3.6.1 above) through this reach. Additional locations and frequency of data collect is needed to further describe the dissolved oxygen regime through these reaches and other reaches in the subwatershed.

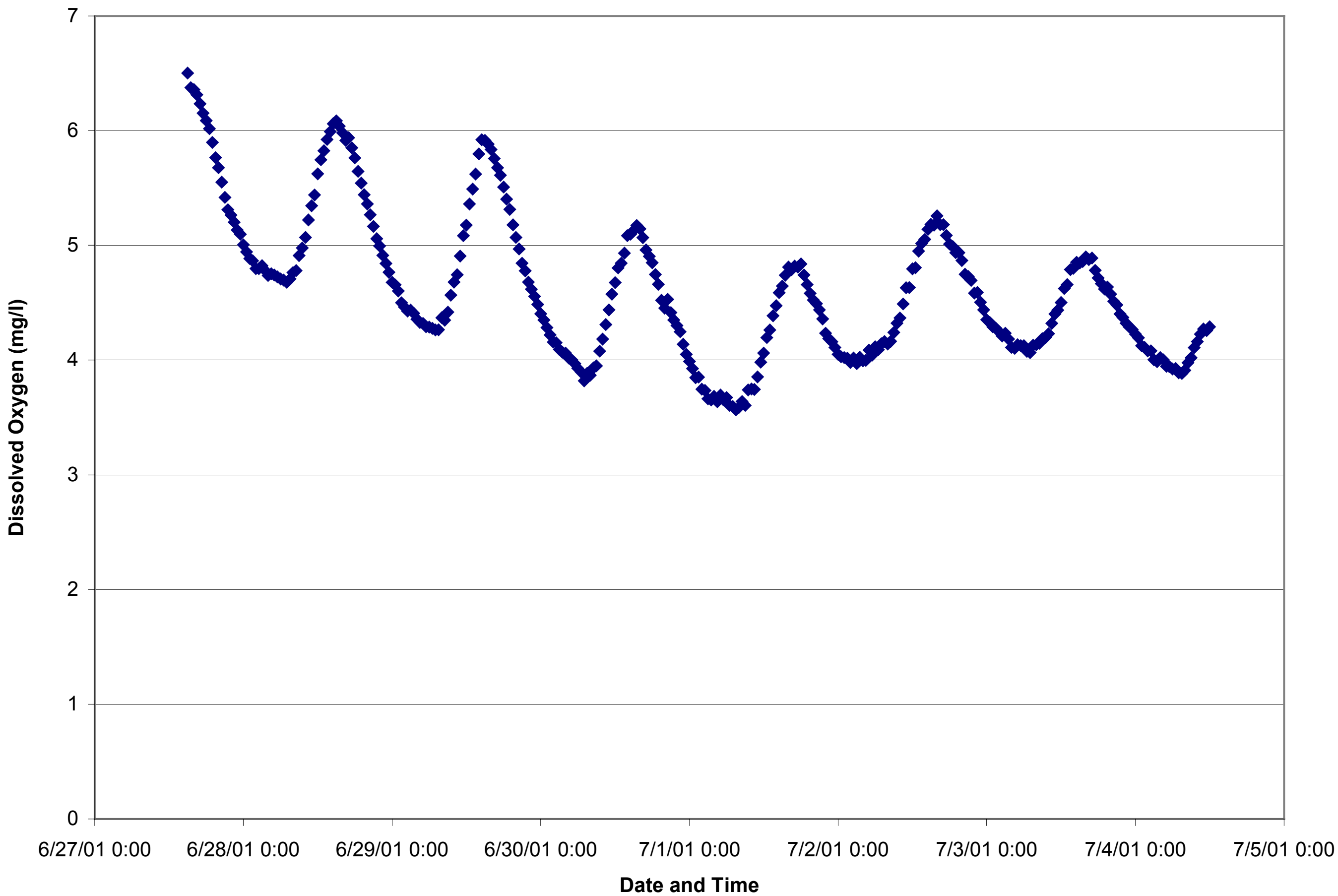

Figure 3.6.2: Dissolved oxygen levels from June 27th, 2001 to July 5th, 2001 on the East Credit River at the Caledon Rail Trail

CVC
CREDIT VALLEY CONSERVATION

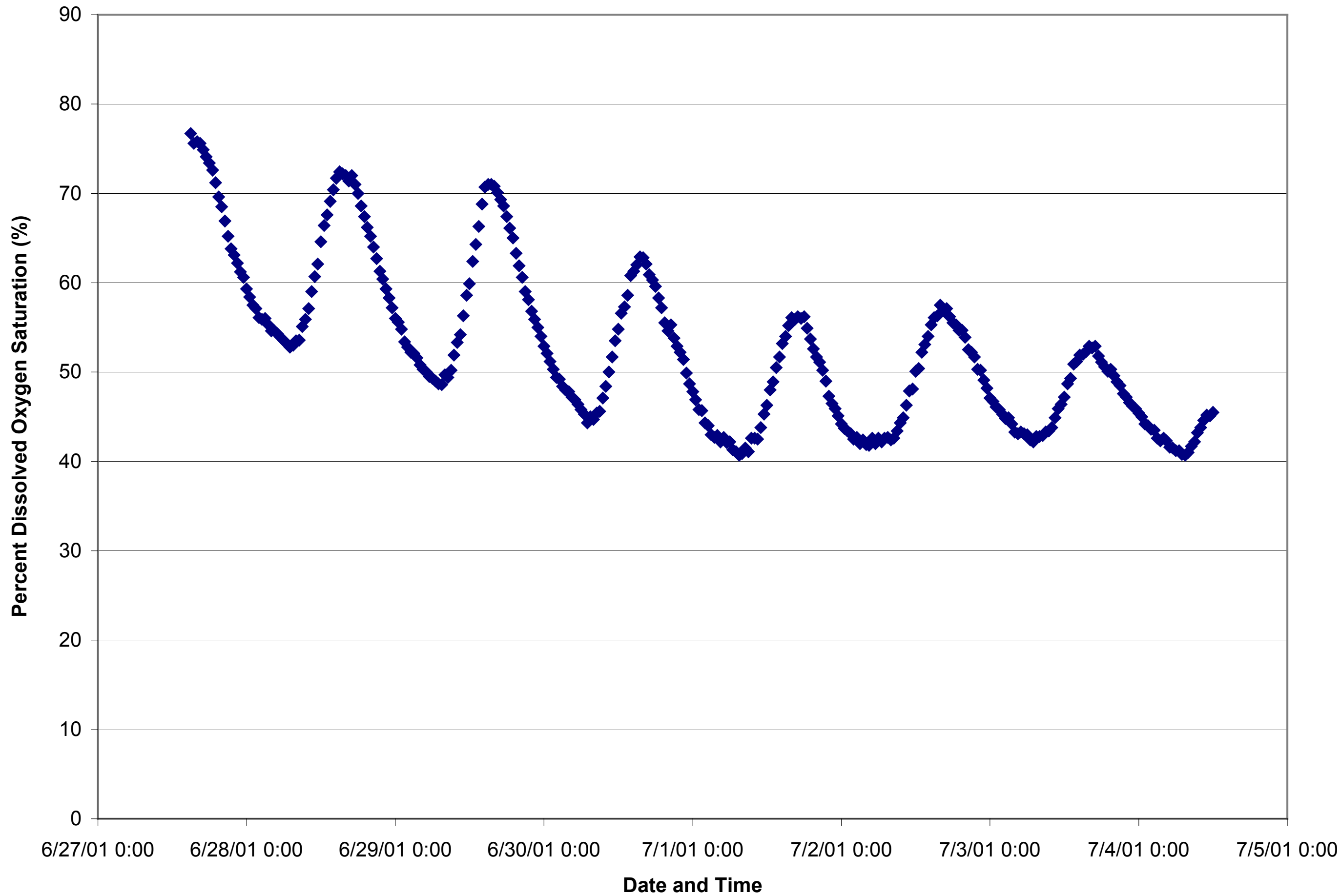

Figure 3.6.3: Percent dissolved oxygen saturation from June 27th, 2001 to July 5th, 2001 on the East Credit River at the Caledon Rail Trail

CREDIT VALLEY CONSERVATION

There is also a PWQO range for pH of 6.5 to 8.5. Dissolved oxygen and pH can be indirectly related in that the pH often decreases as the oxygen levels decrease since more carbon dioxide is being produced through respiration processes. As more carbon dioxide is produced, there is a greater amount of carbonic acid formed, lowering the pH. Conversely, as carbon dioxide is removed during photosynthesis, pH values increase during daylight hours. The observed values from 1998 and January 2002 show that the East Credit River is well within the acceptable range of the PWQO. The diurnal survey presented in Figure 3.6.4 shows the fluctuations of pH which are within the expected range based on the observed DO fluctuations. In general, the observed pH in the East Credit River is lower compared to other watercourses in the Credit River watershed. This may be, in part, due to the low dissolved oxygen observed at this location. Additional locations and increased frequency for sampling are required to determine the pH conditions throughout the subwatershed.

Water temperature

A healthy water temperature regime is critical for fisheries and other aquatic biota, such as macroinvertebrates. Increased water temperatures in the summer cause dissolved oxygen levels to decrease while at the same time can increase the metabolic rate of the fish. Coldwater species of fish are particularly sensitive to changes in water temperature. In the summer, water temperature may increase from thermal pollution such as warmer runoff water, decreases in cooler groundwater upwellings, and ponds, which increase the area of surface water contact with the air. In the winter, groundwater upwellings help to maintain ice-free conditions in areas where fish spawn. Without these upwellings, air temperatures below freezing would cause the watercourse to freeze over and potentially kill over wintering eggs. A maximum temperature of 20^{o}C was recommended to protect a native coldwater fishery and 23^{o}C was recommended to protect a self-sustaining coldwater fishery in the Credit River Management Plan (Beak Consultants, 1992). In addition, changes to water temperatures significantly impact biological and chemical reaction rates, which can control processes such as nitrification (conversion of ammonia to nitrate), denitrification (conversion of nitrate to nitrogen gas), and oxygen demanding rates. Temperature also affects physical processes of reaeration and oxygen saturation levels; higher temperatures have lower oxygen saturation levels, while reaeration rate is increased.

Table 3.6.4 presents the maximum and minimum water temperatures from the 3 diurnal surveys in 1998 and 2001. The maximum and minimum air temperatures recorded at Environment Canada's climate station in Orangeville are included in parenthesis for comparison.

Table 3.6.4 Maximum and minimum water and air temperatures for the East Credit River

	June 24, 1998 at Highway 10	August 13, 1998 at Highway 10	June 27 to July 4, 2001 at the Rail Trail
Maximum (oC)	24.8 (31)	21 (26)	26.23 (29.5)
Minimum (oC)	19 (17.5)	16.5 (9)	16.75 (6)

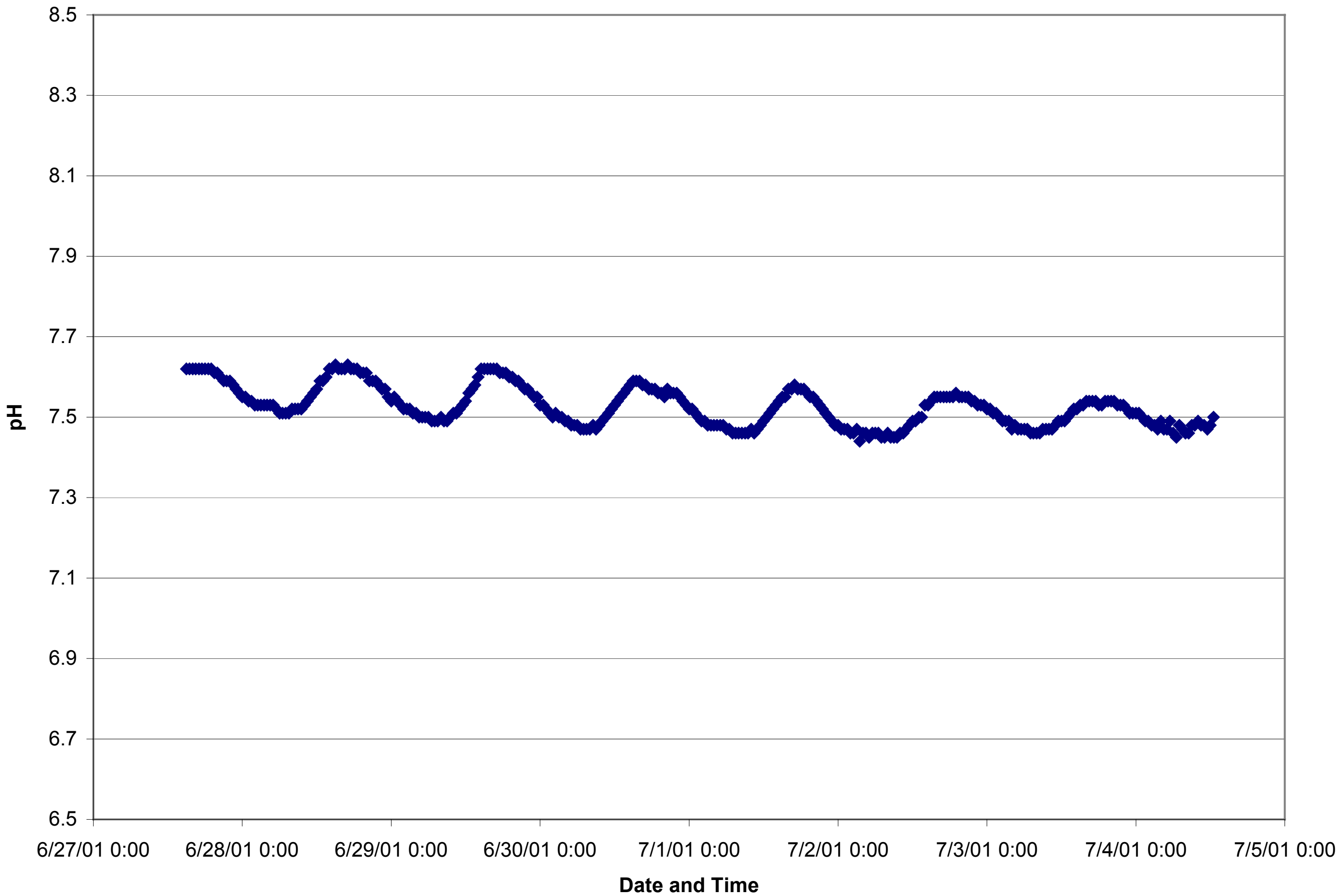

Figure 3.6.4: pH levels from June 27th, 2001 to July 5th, 2001 on the East Credit River at the Caledon Rail Trail

The maximum temperatures are significantly above the 20^oC recommended to protect a native coldwater fishery and sometimes above the 23^oC recommended to protect a self-sustaining coldwater fishery (Beak Consultants, 1992). Figure 3.6.5 shows the water temperatures of the East Credit River from June 27 until July 4, 2001 with the daily maximum and minimum temperatures at Environment Canada's climate station in Orangeville. Of particular interest is that the maximum water temperatures from the 2001 diurnal survey (at the Rail Trail) sometimes did not occur until 8 or 8:30 pm, much later than what is typically expected for peak temperatures (typically around 5pm). This could be due to the slow moving reaches upstream of the sampling location, which would create a longer lag time in receiving the warmest water temperatures of the day.

Additional temperature information is needed to assess the temperature regime for upstream reaches of the main branch and tributaries, which are likely to have a cooler temperature regime. It should be noted that the typical time period (5pm to 6pm) for the Rapid Temperature Assessment may need to be expanded to include later times.

Suspended solids

Although there is no PWQO for suspended solids, it is recognized that high levels can clog critical spawning areas for fish, increase sediment oxygen demand (SOD) which can deplete DO levels, and results in poor water clarity for recreational uses. Parameters that can adsorb/attach to suspended solids, such as phosphorus, metals and bacteria, can increase when suspended solid levels increase. The CWQG for suspended solids suggests that during clear flow conditions suspended solids levels should not increase from anthropogenic activities to over 25 mg/L of background levels for a 24-hr period and 5 mg/L for period of longer-term exposure (24-hr to 30 d). Currently, there has been only one measurement of suspended solids in January 2002, which was 1 mg/L at the Highway 10 location. This value would be considered low however additional data is needed to determine the conditions at other locations and during higher flow events.

Conductivity and chlorides

Conductivity is a measurement of the ability of water to conduct an electrical current. Because the electrical current is transported by the ions in the water, the conductivity increases as the concentration of ions increase. Conductivity is therefore a gross measurement of the levels of dissolved solids in the water. The major ions that may be contributing to conductivity in the East Credit River include chlorides (Cl^-), nitrates (NO_3^-), carbonate (CO_3^{-2}), bicarbonate (HCO_3^-), sulphate (SO_4^{-2}), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+) and sodium (Na^+). These ions can all be found naturally in watercourses and high levels in some parameters, such as calcium and magnesium, can indicate high groundwater contributions. However increases in other ions, such as nitrate (as discussed in the nutrient section), sodium and chloride may be related to human activity.

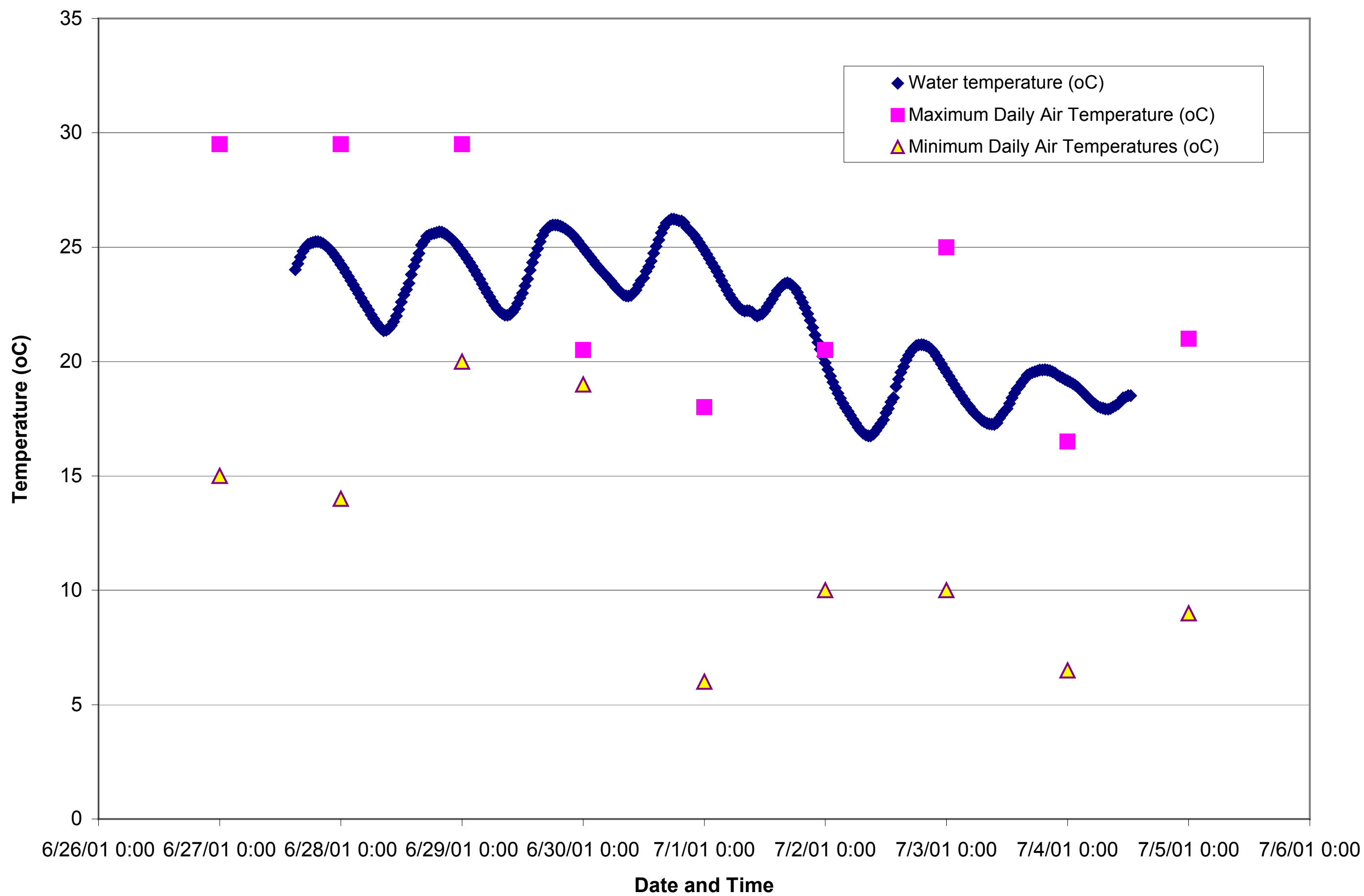

Figure 3.6.5: Water temperatures from June 27th, 2001 to July 5th, 2001 on the East Credit River at the Caledon Rail Trail (with daily maximum and minimum air temperatures from Environment Canada's climate station at Orangeville)

CVC
CREDIT VALLEY CONSERVATION

During the 2001 diurnal survey, conductivity measurements were recorded in the range of 473 to 505 uS/cm, as can be seen in Figure 3.6.6. Some of the fluctuations observed in Figure 3.6.6 may be due to evapouration of water causing slight increases in conductivity and rainfall events, which tend to decrease conductivity since groundwater tends to have a higher conductivity (from dissolved minerals) than surface runoff. There were a number of small rain events during the survey period that may be responsible for the occasional rise and fall in conductivity.

One of the contributors to conductivity, chloride, is becoming a concern since increasing trends for chlorides are observed for most stations in the Credit River watershed (CVC et al., 2000) and in many other watersheds in Ontario (Bowen and Hinton, 1998). Chlorides may originate from road salt, used for de-icing in the winter (typically NaCl) or as a dust suppressant in the summer ($CaCl_2$) or from treated wastewater effluent. Because the East Credit River subwatershed is mainly rural in nature, the majority of the chlorides are likely to come from road salt. Chloride is a highly soluble and mobile ion in ground and surface waters since it does not biodegrade, volatize, easily precipitate or significantly adsorb onto minerals. Only one chloride measurement has been taken on the East Credit River at Highway 10 (January 2000), which indicated relatively low chloride levels (38 mg/L compared to the drinking water objective of 250 mg/L) however further data is needed to determine the spatial and seasonal variability in this parameter.

Environment Canada has proposed to add road salt to its federal 'toxic substance' list based on its impacts to a variety of different environmental receptors (Environment and Health Canada, 2000) and since chlorides are a good representative of road salt in this area, additional chloride measurements should be taken. Furthermore, it is likely that most chlorides originate from sodium chloride and although there is no PWQO for sodium, the aesthetic objective for sodium in drinking water is 200 mg/L (MOE, 2001), which represents a level where some people may taste a 'salty' taste. In addition, the local Medical Officer of Health should be notified when the sodium concentration in drinking water exceeds 20 mg/L so that this information may be communicated to local physicians for their use with patients on sodium-restricted diets.

Metals

The primary concern for metals is their toxicity to aquatic biota. High metal levels are typically associated with urban development and metal mining activities but they can also be high due to naturally occurring metals in the soils and bedrock. The January sampling results show that the East Credit River have relatively low metal levels when compared to existing Provincial Water Quality Objectives (PWQOs) (MOE, Reprint 1999). The only metal that was slightly over its PWQO was zinc, which was then below the PWQO when the sample was re-analyzed for routine quality control procedures. Even though the rural nature of the subwatershed would typically imply that metals levels should be low, one grab sample is not sufficient to confirm this. Additional sampling throughout the season at this site will be required to make a better assessment of the metals levels for the subwatershed.

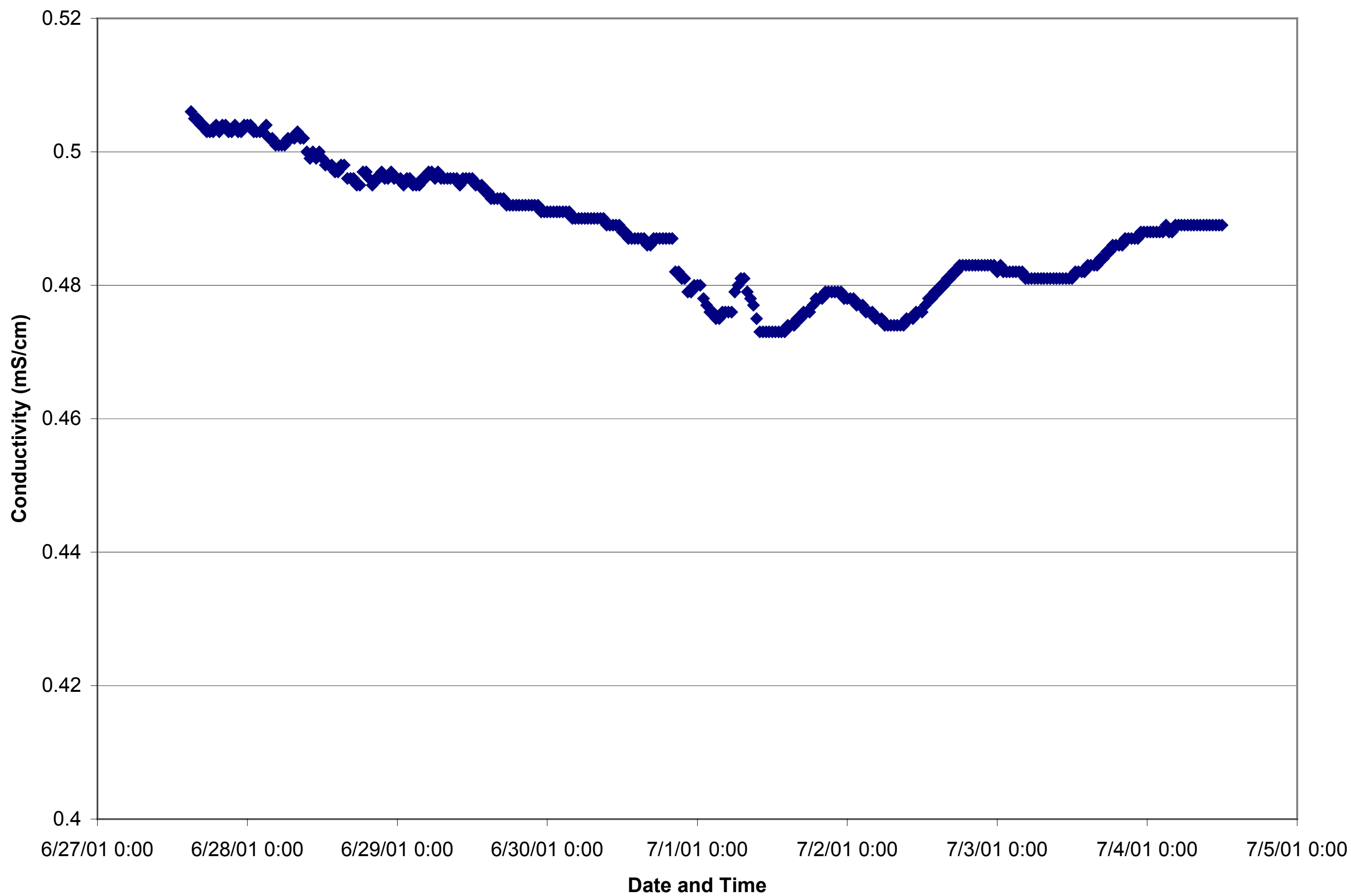

Figure 3.6.6: Conductivity from June 27th, 2001 to July 5th, 2001 on the East Credit River at the Caledon Rail Trail

CVC
CREDIT VALLEY CONSERVATION

Bacteriological

Although no surface water in Ontario should be considered safe to drink, bacteria sampling in surface waters can determine the risk to human health for recreational uses of the water. *E. coli* is used as an indicator bacteria for the potential presence of pathogenic bacteria that can cause gastrointestinal and respiratory illnesses. The PWQO for *E. coli* is 100 counts/100 ml and is for recreational uses of the water such as swimming.

The results from the January 2002 bacteriological sampling, as shown in Table 3.6.5, indicate low bacteria levels at Highway 10. Although the results for *E. coli* are over the Drinking Water Standard (MOE, 2001) of 0 counts(which applies to treated drinking water), the more appropriate criteria is the PWQO for recreational contact level of 100 counts/100 ml. The January 2002 results (at 18 counts/100 ml) are well below this criteria. However additional data is needed to determine conditions in other reaches and seasonal trends. In general, bacteria levels tend to increase during the warmer months due to increased runoff of bacteriological containing material (i.e. manure, wildlife waste, etc.).

Table 3.6.5 Bacteriological results from East Credit River at Highway 10 (Jan 2002)

Parameter	Value	Units
E. coli	18	counts/100 ml
Fecal Streptococcus	48	counts/100 ml
Pseudomonas aeruginosa	Not detected	colony forming units/ml

3.6.3 Identification of Data Gaps

Due to the paucity of long-term data in the East Credit subwatershed, a greater water quality sampling effort is required to augment the existing water quality data. The following field program has been recommended to fill in the spatial and seasonal gaps and to provide a larger base of data from which to draw conclusions on water quality conditions in the subwatershed:

1. All the parameters listed in Table 3.6.1 will be sampled or measured once a month from January to September 2002 at the Highway 10 station to capture the water quality conditions at the downstream end of the subwatershed.
2. Nutrients, oxygen demanding material, suspended solids, *E. coli*, chloride, pH, dissolved oxygen, and conductivity will be sampled or measured twice a month from May to September 2002 at up to16 stations, to be located as close as possible (dependent on access and landowner permission) to the downstream end of the subcatchments identified for the study. Ideally, some of the sample runs will characterize wet weather conditions of high runoff.
3. Two diurnal surveys for dissolved oxygen, water temperature, pH and conductivity in late June (to capture the high aquatic plant growth period) and late August (to capture the low flow period) will be conducted.

4. At least one rapid temperature assessment to capture maximum in-stream temperatures will be conducted after 3 days of hot weather (daily maximums should be around 30^{o}C) without rain.

Once the additional data collected above has been incorporated with the existing data, the water quality conditions with the subwatershed can be characterized for the Phase I portion of the study and integrated with other disciplines such as fisheries and macroinvertebrates.

3.7 MACROINVERTEBRATES

Macroinvertebrate (the 'bugs' that inhabit streams, lakes and rivers) community structure can indicate the ecological health of an aquatic system. Through the food chain, macroinvertebrates are directly linked to fish and a change in their community can act as an early indicator of potential change in a fish community. Biological communities reflect overall ecological integrity (i.e., chemical, physical, and biological integrity) and therefore biological surveys can directly address the goal of monitoring for the protection and enhancement of biological diversity and productivity. The advantages of using biological surveys include (Barbour et al., 1999):

- Biological communities integrate the effects of different stressors and thus provide a broad measure of their aggregate impact.
- Communities integrate the stresses over time and provide an ecological measure of fluctuating environmental conditions.
- Routine monitoring of biological communities can be relatively inexpensive, particularly when compared to the cost of assessing toxic pollutants, either chemically or with toxicity tests.
- The status of biological communities is of direct interest to the public as a measure of a pollution free environment.
- Where criteria for specific ambient impacts do not exist (e.g., nonpoint-source impacts that degrade habitat), biological communities may be the only practical means of evaluation.

Some advantages of using macroinvertebrates in biological surveys are (Barbour et al., 1999):

- Macroinvertebrate assemblages are good indicators of localized conditions.
- Because many benthic macroinvertebrates have limited migration patterns or a sessile mode of life, they are particularly well suited for assessing site-specific impacts.
- Macroinvertebrates integrate the effects of short-term environmental variations. Most species have a complex life cycle of approximately one year or more. Sensitive life stages will respond quickly to stress; the overall community will respond more slowly.
- Degraded conditions can often be detected by an experienced biologist with only a cursory examination of the benthic macroinvertebrate assemblage.

- Macro-invertebrates are relatively easy to identify to family; many "intolerant" taxa can be identified to lower taxonomic levels with ease.
- Benthic macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects.
- Sampling is relatively easy, requires few people and inexpensive gear, and has minimal detrimental effect on the resident biota.
- Benthic macroinvertebrates serve as a primary food source for fish, including many recreationally and commercially important species.
- Benthic macroinvertebrates are abundant in most streams. Many small streams (1st and 2nd order), which naturally support a diverse macroinvertebrate fauna, only support a limited fish fauna.

3.7.1 Existing Information and Data

The East Credit River subwatershed has been studied several times since the 1950s. The Ontario Department of Planning and Development (ODPD) collected the most extensive benthic community data from 12 stations within Subwatershed 13 in 1954 (ODPD, 1956). Reed (1968) repeated the ODPD survey in 1965. In 1999-2001, staff from Credit Valley Conservation sampled benthic macroinvertebrates at four locations.

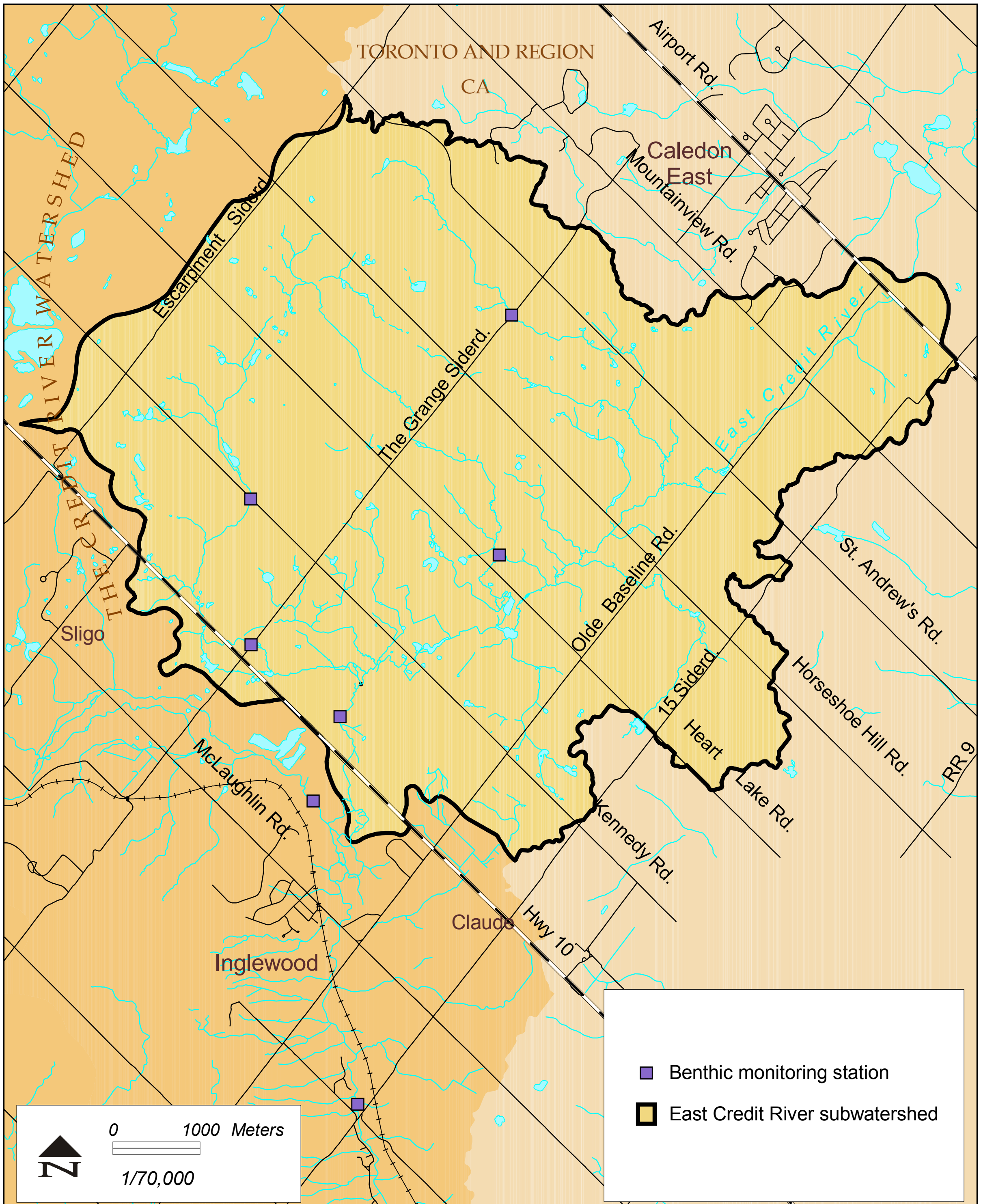

Figure 3.7.1: Long-term Macroinvertebrate Monitoring Stations from CVC's Integrated Monitoring Program

Sources: Credit Valley Conservation, 2001; Ontario Ministry of Natural Resources, 1982.

3.7.2 Preliminary Interpretation of Existing Data

Benthic communities in Subwatershed 13 indicate that water and habitat qualities have been and currently are in good condition. On the basis of Hallam (1959), Martin (1984) classified two stream reaches (including the main stem) as cold water, and one as marginal cold water. Martin determined that this subwatershed had undergone little change in quality and surrounding land uses between 1965 and 1984, and was still a cold water system.

The most recent benthic data for the East Credit River subwatershed are those collected by Credit Valley Conservation as part of routine monitoring in 1999-2001. Those samples were collected using a travelling kick methodology, and were identified to lowest practical levels at four stations (see map Fig. 3.7.1):

- Station 12, on the East Credit River tributary west of St. Andrew's Road, upstream of the Grange Sideroad;
- Station 15, on the East Credit River tributary north of the Grange Sideroad, downstream of Kennedy Road;
- Station 13, on the East Credit River tributary east of Highway 10, upstream of the Grange Sideroad; and,
- Rail Trail Station, on the main stem of the East Credit River north of Highway 10.

The resulting data indicate that the benthic community is presently in good condition. With the exception of Station 12 in 2000, Shannon's diversity (H') has been above 3 for all sites in each year studied. Two of the sites (Stations 15 and "Rail Trail") have had H' diversity values above 4 in each year studied. H' diversity values typically range between 0 and 4, but have no theoretical maximum. Values < 1 are usually associated with impaired communities, while values > 3 are usually associated with unimpaired communities (Wilm and Dorris, 1968). The numbers of taxa per site have also been high (average of 30+ taxa) reflecting relatively good water and habitat quality. Each site surveyed by CVC has had a full assortment of animals including mayflies, stoneflies and caddisflies (i.e., those that are generally considered sensitive), other insects, plus Mollusca and Crustacea. Pollution tolerant forms (e.g., oligochaete worms, chironomids) are generally not as abundant as they would be predicted to be if there were significant water quality issues.

None of the existing studies has reported invertebrate species that are considered threatened, endangered, or otherwise at risk

3.7.3 Identification of Data Gaps

All of the older (1954, 1965) data are outdated, and are therefore of limited use to the present study.

The recent data collected by CVC can be used to characterize current conditions. However, the data are somewhat limited spatially, with several tributaries to the East Credit River not represented. It is recommended that additional samples be collected within each of the major subcatchments of subwatershed 13 using methods similar to those used by CVC. Samples should be collected during the summer, when benthic communities reflect limiting conditions (Barton, 1996).

3.8 AQUATICS

3.8.1 Introduction

The protection and enhancement of fish communities has been clearly identified in the Credit River Water Management Strategy, several Subwatershed Plans and the Credit River Fisheries Management Plan. Some of the advantages of using fish as indicators includes: widespread distribution in all waters (including intermittent streams and wetlands), ease of capture and identification, available literature on life histories and sensitivities, and the occupation of a variety of trophic levels. Fish flesh can also be tested for various contaminant levels that bioaccumulate through the food chain. People can relate to statements on fish community conditions and their direct value for food and recreation. It is also important to note that there are legislative requirements to protect and assess impacts to fish habitat under the Federal Fisheries Act.

Fish communities can serve as integrative indicators of the health of any watershed ecosystem as Figure 3.8.1 illustrates based on a model developed for Credit River Integrated Monitoring Program. Generally fish species can be specialized and intolerant of culturally derived stresses, such as those affecting the hydrological cycle including urbanization, sewage treatment and water taking. Other species are more generalized in their habits and can tolerate many stresses. These species often displace other species as degradation occurs. Fish community measurements of species diversity, numbers or biomass density and the known sensitivities of species present are required in order to assess habitat conditions. These habitat conditions are created and maintained by natural processes related to water quality, flow conditions and the resulting physical or geomorphological features.

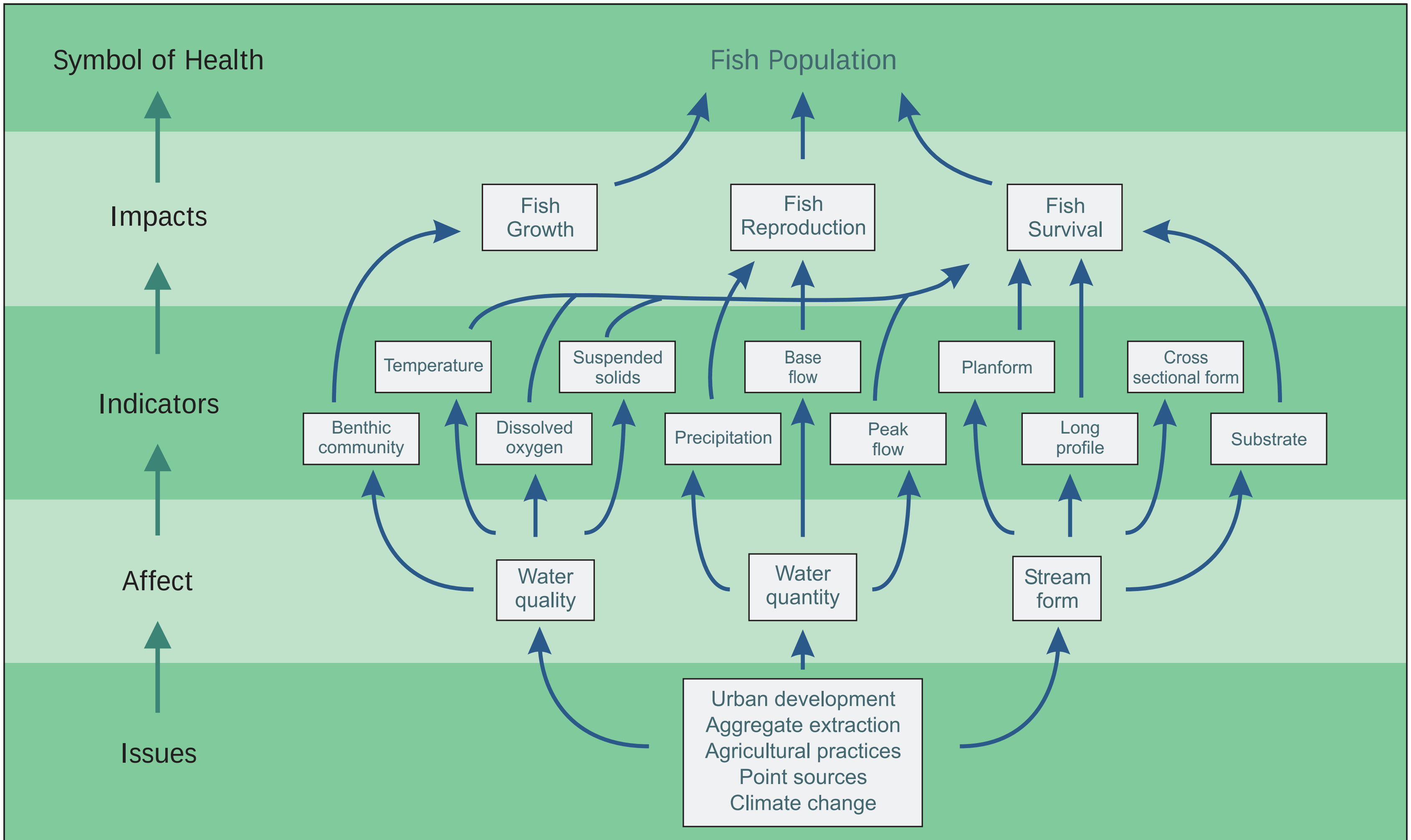

Figure 3.8.1: Conceptual Impact Model

Source: Credit Valley Conservation, 2000

The objective of this study component is to characterize the fish communities of the East Credit Subwatershed. The sensitivity of the fishery, including the physical and chemical habitat requirements, needs to be understood in order to prevent, mitigate or rehabilitate any degradation. The information will provide baseline monitoring data and the ability to model impact predictions. The information can also be used to compare fish community health to that of the rest of the Credit Watershed or even other planning jurisdictions along the Oak Ridges Moraine.

3.8.2 Fish Communities

Over 30 fish collection records on file since the 1980's were compiled and are summarized in Figure 3.8.2. Each station is identified with the year of collection as many sites have been sampled repeatedly. About 12 different sites have been sampled and they are relatively evenly distributed across the subwatershed and between the main branch and tributaries. Sampling to date does permit generalized extrapolations of fish communities and habitats throughout the subwatershed. Additional sampling at about 6 sites in 2002 is proposed to provide some better overlap and integration with other disciplines. One half of these sites will provide information on 3 new tributaries not sampled previously. Proposed sampling sites are included in Figure 3.8.2. Also shown is the designation of each sample site as a cold or warmwater habitat.

Coldwater sites are best indicated by the presence of brook trout or mottled sculpin. Brown trout are slightly more temperature tolerant and may indicate transitional or mixed waters. Brown trout were introduced to the Credit River and have fully naturalized as a wild population in the Forks area to as far downstream as Georgetown. Brook trout also inhabit the Forks area and are native upstream of the Cataract Falls and in colder tributaries, including the East Credit. Brown trout have access from the main Credit River up the East Credit as far as the first dam just upstream of Kennedy Road. Warmwater sites are often more productive and can harbor the richest diversity of species except in intermittent streams or other stressful conditions where very tolerant species such as blacknose dace, creek chub and brook stickleback often dominate. Many other minnow species, some of which are considered habitat specialists and water quality sensitive species are common to small warmwater streams. Species such as sunfish and catfish could be more associated with wetlands and ponds throughout the subwatershed. Coolwater species such as darters and hog suckers are also found in the East Credit. The total number of species found at each sampling site is also indicated in Figure 3.8.2.

Table 3.8.1 presents a total of 25 species found in the East Credit and their corresponding Index of Biotic Integrity (IBI) values as further documented in Credit Valley Conservation (2000). A modified IBI methodology was adopted in order to analyze more quantitative data collected annually for about 40 stations across the Credit River watershed. Such biomass data (total weight of all and each species) in terms of fish density in grams per square meter are statistically comparable between stations and over time for long term monitoring purposes. In the fisheries component of the CVC Integrated Watershed Monitoring Program the East Credit stations, one small tributary and one on the main branch, are highlighted in Figure 3.8.3 in context with other stations watershed wide. It is suggested that the East Credit has fair biological integrity on the lower main branch in 2001. Previous years data showed slightly healthier results when a few more brown trout were sampled at this location. The tributary sample was rated in good health and would be typical of pristine coldwater conditions for a small tributary. Raw data for these biomass stations are provided in Appendix A.

Generally the most important “indicator” species found in the East Credit is the native brook trout that is highly dependant on groundwater inputs to maintain water temperaturesin its preferred range below 20^{C}. In addition, groundwater upwelling areas are sought out to deposit eggs in excavated nests known as redds in the late fall. Groundwater upwellings are responsible for incubating and preventing these eggs from freezing all winter long until hatching occurs in the spring.

The Credit River Fisheries Management Plan (CRFMP) has designated the East Credit at a regional scale as a coldwater tributary that corresponds with the majority of sampling sites. This designation provides guidance for management decisions at a watershed scale that can be refined at a subwatershed scale. The coldwater fish communities of the East Credit will dictate most management activities given the assumption this is the most sensitive fishery at least in terms of groundwater contributions and water quality. Restoration goals often first give consideration to coldwater habitats. Nevertheless, warmwater communities, particularly those associated with Provincially Significant Wetlands found throughout the subwatershed, may also have to be given specific consideration.

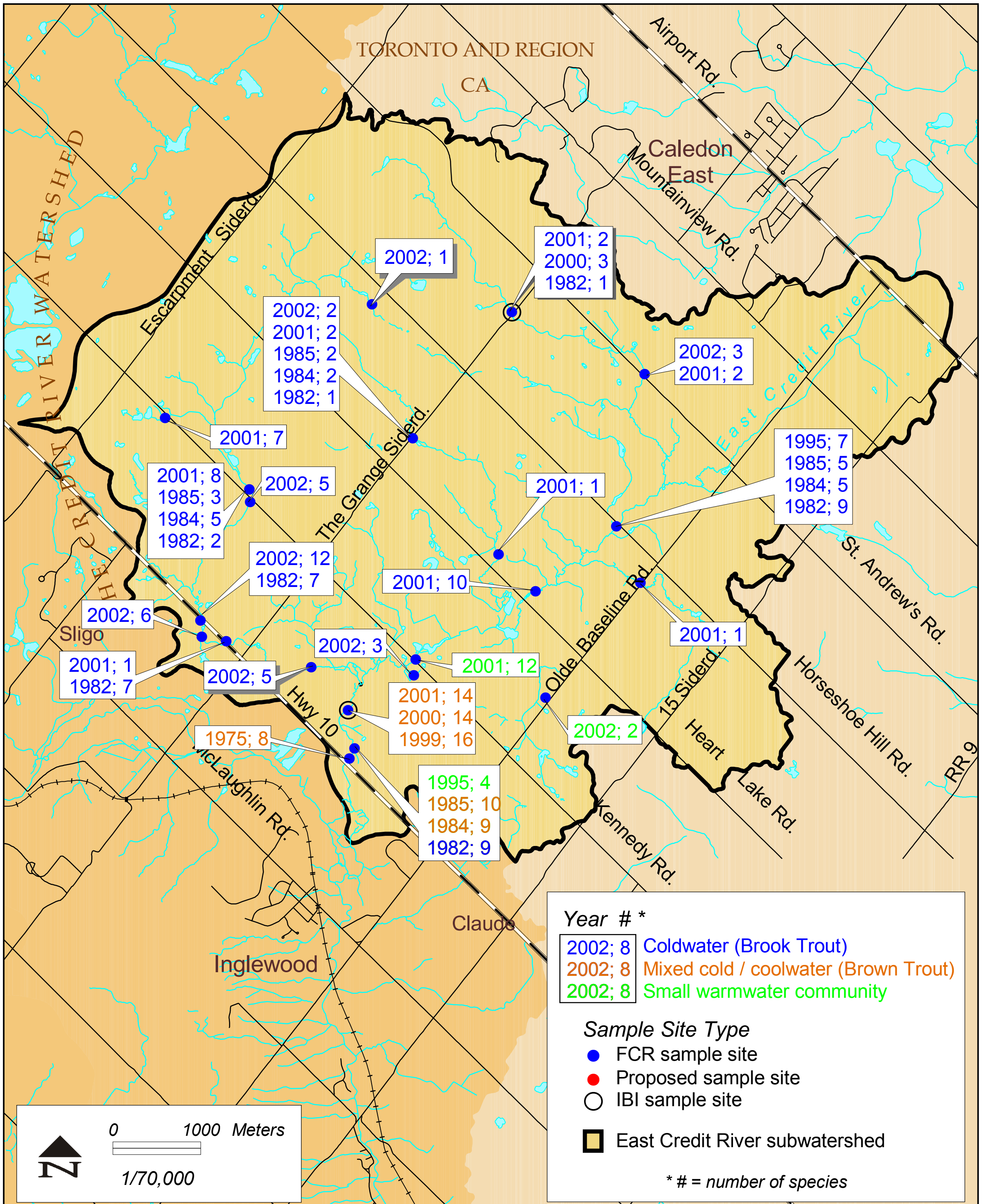

Figure 3.8.2: Fish Collection Records for the East Credit Subwatershed

Sources: Credit Valley Conservation, 2001; Ontario Ministry of Natural Resources, 1982.

Table 3.8.1 Index of Biotic Integrity Metric Scores for Fishes of the East Credit Subwatershed.

Species	Index of Biotic Integrity Final Metrics Score	Rare/Uncommon Native ++ Native/Endemic Or fully Naturalized + Stocked 0 Exotic/Pest/ Lentic escapees -	Omnivore/ Detrivore – Filter/Herbe-vore 0 Insectivore+ Carnivore ++	Simple Litho-Philic Spawner+ Other silt tolerant breeders-	Intolerant Species + Tolerant Species -	Specilaist + (benthic, mid-water, coldwater, bogs and late maturing) Generalist Species –
Brown trout	3	+	++		+	+
Brook trout	3	+	++		++	+
Central mudminnow	2	+	+	-	-	+
White sucker	1	+	-	+	-	+
Northern hog sucker	3	+	+	+	+	+
Northern redbelly dace	2	+			+	+
Pearl Dace	2	+	+	-		+
Brassy minnow	1	+		-		+
Common shiner	1	+	+			-
Golden Shiner	-1	+		-	-	
Bluntnose minnow	1	+	-	-	--	-
Fathead minnow	1	+	-	-	--	-
Blacknose dace	1	+	+	+	-	-
Longnose dace	3	+	+	+		+
Creek chub	2	+	+		-	-
Brown bullhead	1	+		-	--	-
Brook stickleback	1	+	+	-	-	+
Pumpkinseed sunfish	1	+	+	-		-
Rock Bass	3	+	++	-		+
Rainbow darter	3	+	+	+	+	+
Iowa darter	3	+	+	-	+	+
Fantail darter	3	+	+	+		+
Johnny darter	3	+	+	-		+
Mottled sculpin	3	+	+	-	+	++
American brook lamprey	3	+			+	+

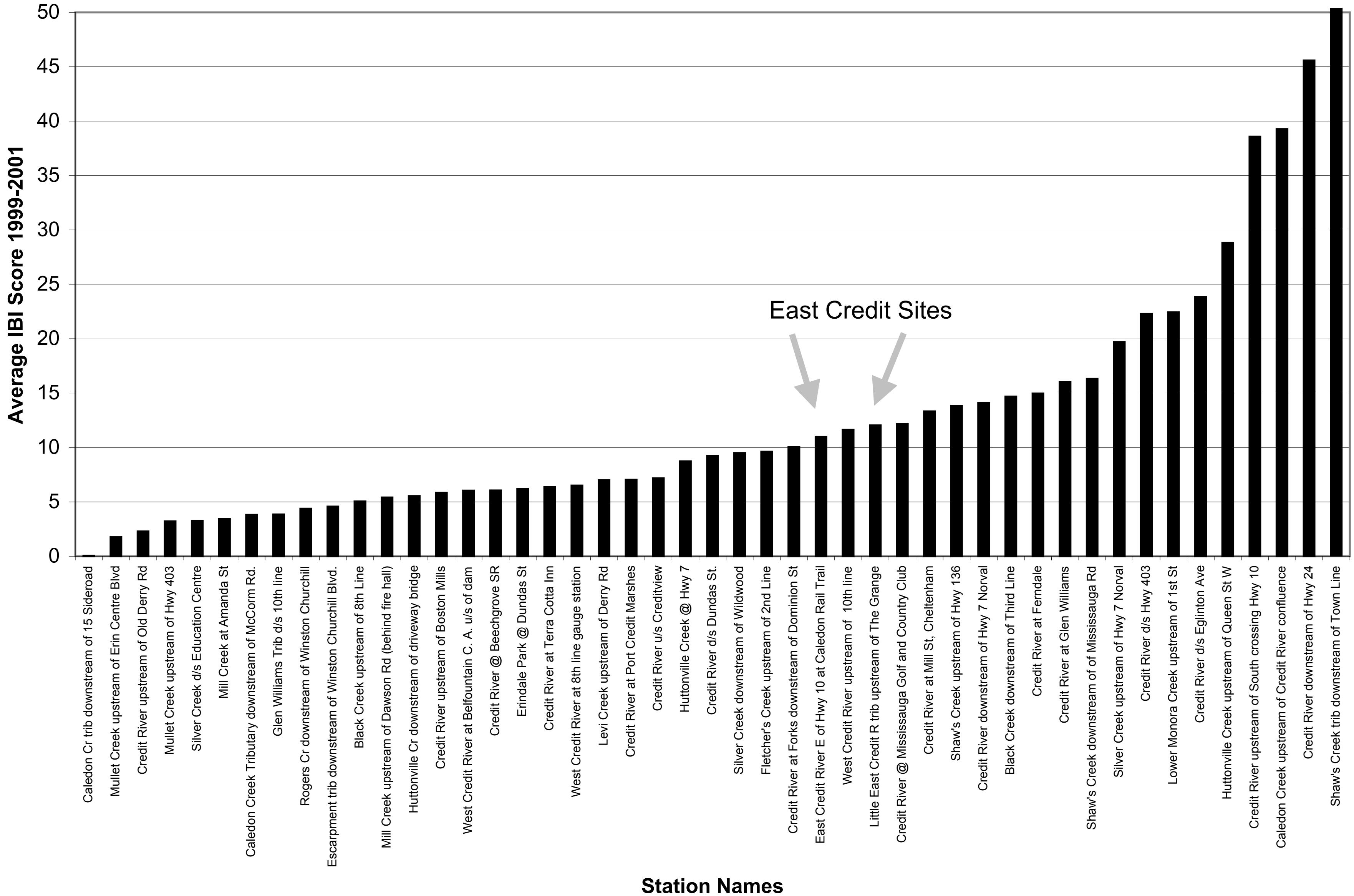

Figure 3.8.3 : Credit River Watershed Fish Index of Biotic Integrity Station Results

3.8.3 Spawning Habitats

Given the sensitivity and importance of groundwater to coldwater fisheries, the documentation of brook (and brown) trout spawning redds are useful in protecting such critical habitats. (These same areas are also used as summer thermal refugia.) Spawning surveys are also valuable in identifying major groundwater discharge areas for other purposes related to the hydrogeological component of this subwatershed study. Figure 3.8.4 illustrates the distribution of trout redds identified in 2001 along only the lower reaches of the main channel and portions of the Silver Creek tributary.

A few earlier spawning survey attempts were made in previous years but it was suspected that redds were extremely difficult to identify due to the dominance of sand substrates. Gravel substrates, although preferred are not as necessary as good groundwater upwellings. In gravels a depression created by the fish is more visible, especially because algae covered surfaces are turned over leaving a brighter patch with a gradation of fines to coarser gravels outside and downstream of the depression. Algae does not colonize sand as well and is not stable enough to hold a depression. Sand is more mobile and will “mask” over itself quickly especially after small storm events. It was highly suspected trout were spawning in some of these areas given adults in breeding colours were observed, as well as, many young-of-the-year trout.

Given the timing of this phase of study and that the next spawning season is in November, further data will not be available for this phase of the Subwatershed Study. Future efforts should be directed to areas where young brook trout populations have been sampled. Relative abundance of young trout were assessed from the fish collection records to suggest areas of high, moderate and low spawning potential on Figure 3.8.4. Other priority areas should also be surveyed based on the hydrogeological information presented in this study that suggests significant discharge areas. Any areas identified with potential impacts from urban development, other land use changes or water taking would also be requested to conduct spawning surveys. It should be noted that spawning areas are often restricted to relatively short reaches and represent critical habitats where wide ranging populations may congregate for reproduction and survival. These areas are the most stringently protected under the Federal Fisheries Act.

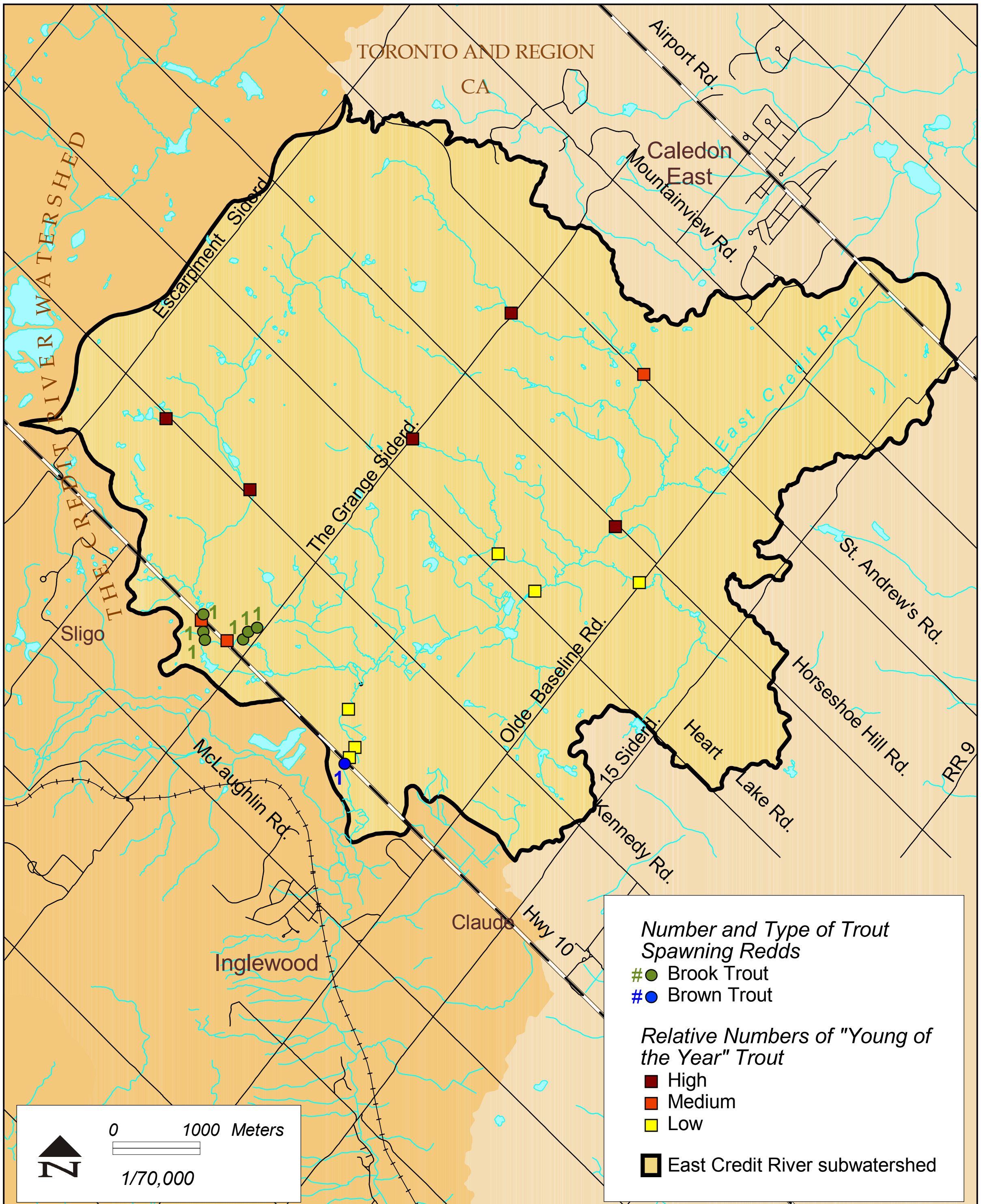

Figure 3.8.4: Trout Spawning Habitats of the East Credit Subwatershed

Sources: Credit Valley Conservation, 2001; Ontario Ministry of Natural Resources, 1982.

3.8.4 Fish Habitat

Formal fish habitat surveys using a standard descriptive MNR protocol were carried out in 1983 and 1985 along the main branch from the Credit River confluence upstream and along the portion parallel to St. Andrew's Road, for a distance of over 13 km. Data collected included bank stability, stream canopy, substrate size, pool/riffle/run/flat morphology, instream cover and riparian land use. Summaries by percentage values for consecutive reaches are available as well as an overall summary in Galamb and Samiec (1985). This data should be considered and integrated with the geomorphological and terrestrial components of this study.

Generally the report highlights the following descriptions.

- There are some areas of bank erosion associated with cattle access to the stream.
- Rubble riffles are scarce (1% in lower reaches, 10% in upper). Runs were also scarce (6%) upstream of the abandoned CNR tracks.
- Flats (slow and shallow) dominated stream morphology (44 – 64%) and reflect a generally low gradient stream.
- Pools were estimated at 15% surface area in lower reaches and 24% in the upper reaches.
- Sand dominates the substrates of the East Credit with silts in many slow / backwater areas. Gravels were more common in the headwaters.
- Undercut banks and boulders were rare, but logs and trees provided sufficient cover.
- Riparian land use was described generally as being well treed but stream canopy cover (shade) seems to be highly variable.
- Large areas of pasture and ponds have degraded some stream conditions.
- Stream temperatures peaked at 19.5 C with average temperatures around 13 C. Water temperatures were generally 3 to 4 C cooler than air temperatures.
- Tree planting was not highly recommended from a temperature perspective but research into dissolved oxygen was, given the lack of riffles.

It should be noted that observations made since this survey recorded the dominance and ecological values of wetland habitats along the stream. These may not represent ideal trout stream habitats but are naturally valuable for many other functions. A formal wetland evaluation is available on file. Also a number of beaver dams and associated activities have been reported by landowners and anglers. Temperature problems have been identified with some more recent data and could be related to on-line ponds, beaver dams and extensive wetland areas.

3.8.5 Summary

In general, the East Credit subwatershed supports a coldwater fish community. Quantitative fish community data rates the health of the system as generally good in terms of an Index of Biotic Integrity applied across the Credit River watershed. Some warmwater reaches were are also known and may be more common in wetland habitats found throughout the watershed. Only a few critical spawning areas have been located for brook trout to date but there is lots of indication of brook trout reproduction throughout the subwatershed. Limitations to fish production seem to relate to agricultural areas, on-line ponds and the lack of riffles.

3.8.6 Data Gaps

- Conduct fish samples on specified tributary reaches.
- Continue more quantitative fish biomass sampling at the two long term monitoring stations and consider establishing any new sites in cooperation with other disciplines or known areas of potential impact.
- Conduct additional spawning surveys in priority areas as suggested to identify critical habitats dependent on groundwater.
- Integrate on-going research and results with other study components.

3.9 ENVIRONMENTAL PLANNING

The planning component will assist in addressing the requirements of provincial legislation and regional and local planning documents during the preparation of the subwatershed plan. This component will also develop specific environmental policies for lands within the East Credit subwatershed. This component will also have input into the Phase 1 Characterization Report, which is due in the Fall of 2002.

The two major provincial planning components in the East Credit are the Niagara Escarpment Plan and the Oak Ridges Moraine Conservation Act; the regional planning component consists of the Region of Peel Official Plan (OP), and the local planning component is the Town of Caledon OP. The Region of Peel and Town of Caledon OP's will be discussed further in the Phase 1 Report.

The Niagara Escarpment Planning and Development Act (approved by the Ontario Legislature in June 1973) establishes the legislative mandate for the preparation and implementation of the Niagara Escarpment Plan, and a development control process through the review of Development Permit Applications. The Niagara Escarpment Plan provides a planning framework including objectives, designations and policies. The purpose of the Plan is "To provide for the maintenance of the Niagara Escarpment and land in its vicinity substantially as a continuous natural environment and to ensure only such development occurs as is compatible with that natural environment." (Section 2)

The Oak Ridges Moraine Conservation Act (passed December 13, 2001) included the establishment of a regulation for the Oak Ridges Moraine Conservation Plan (ORMCP finalized April 22, 2002). This is an ecologically based plan established by the Province to direct land use and resource management within the Oak Ridges Moraine. All municipalities on the Moraine must conform to this new policy, and the Plan has achieved a level of protection for the Moraine that is greater than the level of protection provided by the current planning regime. Other than the areas of agriculture, wayside pits and mineral aggregate extraction, municipal OP policies may be more restrictive than the new ORMCP.

Section 9(1) of the ORM Conservation Act requires the three Regions (Peel, York and Durham) to prepare and adopt an official plan amendment to implement the Conservation Plan within a twelve month timeframe (by April 22, 2003). Lower tier municipalities have eighteen months within which to bring their OP’s and zoning by-laws into conformity (October 22, 2003).

A staff working group was established and involves the Region of Peel, the Town of Caledon, Credit Valley Conservation (CVC) and the Toronto and Region Conservation Authority (TRCA). This group has been meeting regularly since May 2002 to discuss general issues and approaches to meeting the Provincial requirements, liase with Councilors and the Ministry of Municipal Affairs and Housing (MMAH), develop a coordinated work plan, tackle how to best deal with development proposals, and to create long-term implementation tools and procedures.

Although the Oak Ridges Moraine and the Niagara Escarpment overlap in the area of Subwatershed 13 it was determined by the Province that the two Provincial plans would not overlap, therefore, the Niagara Escarpment Plan is in effect within the Niagara Escarpment Plan Area.

4.0 LANDSCAPE FEATURES WITH RELATED PLANNING RE: LEGISLATION

The Niagara Escarpment and Oak Ridges Moraine form the foundation of the natural heritage and greenspace systems in south-central Ontario. The strategic location of these two landscape features will continue to influence the form and function of the Greater Toronto Area (GTA) into the future.

4.1 OAK RIDGES MORAINE

The Oak Ridges Moraine (herein referred to as the Moraine) is an important part of the GTA landscape and is connected to broader ecological systems, such as the Niagara Escarpment. It is a distinct landform feature, performing essential ecological functions including the provision and maintenance of groundwater resources and natural habitat.

It extends 160 kilometres, from the Niagara Escarpment in the west (in the Town of Caledon), to Trenton in the east, and varies in width from 3 to 23 kilometres. It functions as the drainage divide between Lake Ontario to the south, and Lake Simcoe and the Kawartha Lakes to the north.

Oak Ridges Moraine Conservation Plan Highlights

Land Use Designations

The Conservation Plan divides the Moraine in four land use designations, including:

- **Natural Core Areas** – protect lands with the greatest concentrations of key natural heritage features. Existing uses are permitted with very restricted new resource management, agricultural, home businesses, low intensity recreational, transportation, and utility uses.

- **Natural Linkage Areas** – protect critical natural and open space linkages. Only uses include those permitted under Natural Core Areas and some aggregate resource operations.

- **Countryside Areas** – provide an agricultural and rural transition. Prime agricultural areas and natural features are protected. Most typical agricultural and other rural uses are permitted. Within Countryside Areas, Rural Settlements are identified. Some lot creation and development is permitted in the Rural Settlements and the Palgrave Estates Residential Community.

- **Settlement Areas** – a range of existing communities, urban uses, and development is allowed as set out in municipal official plans.

Within the East Credit the percent land use by area is designated as follows (according to current ORMCP mapping which is undergoing updates): 18.5% Natural Core Area, 10.7% Natural Linkage Area, 6.5% Countryside Area, 1.4% Settlement Area.

Key Natural Heritage and Hydrologically Sensitive Features

Within any of the land use designations identified above, there could also be areas/features identified by the Conservation Plan as Key *Natural Heritage Features* (wetlands; habitat of endangered, rare, and threatened species; fish habitat; life science ANSI's; significant valleylands; significant woodlands; significant wildlife habitat; and sand barrens, savannahs, and tallgrass prairies, note: significant still needs to be defined by the Province) and/or *Hydrologically Sensitive Features* (streams, wetlands, kettle lakes, seepage areas, and springs). In these features (and their associated vegetation protection zones), development and site alteration are prohibited, except forest, fish, and wildlife management; conservation and flood or erosion control projects; transportation/infrastructure/utilities if there is a need and there are no reasonable alternatives; and low intensity recreational uses.

Water- related Plans

The Conservation Plan requires every upper and single tier municipality to begin preparing a watershed plan, a water budget, and conservation plan on or before April 22, 2003, for every watershed whose streams originate within a municipality's jurisdiction. These watershed plans are to be completed on or before April 22, 2007. On or after April 23, 2007, major development is prohibited unless the watershed plan has been completed, the major development conforms to the watershed plan, and the water budget and conservation plan demonstrate that the water supply is sustainable.

4.2 NIAGARA ESCARPMENT

The Niagara Escarpment is a unique linear feature that extends from Queenston on the Niagara River to Tobermory on the Bruce Peninsula. The Ecarpment is characterized by a combination of geological, geomorphological and ecological features. The Escarpment traverses the northerly half of the East Credit Subwatershed and is mantled by the Oakridges Moraine as well as a small portion of the Paris Moraine across the northerly width of the study area. North and East of the subwatershed boundary, the Niagara Escarpment turns in a northerly direction.

The area of the Niagara Escarpment Plan consists of the following seven land use designations (descriptions are summaries of Plan objectives; for complete description, land use permitted uses and limitations you must consult the Official NEC Plan):

- **Escarpment Natural Areas** – maintain lands that are the most significant natural and scenic areas of the Escarpment (including stream valleys, wetlands and related significant natural areas), which contain important plant and animal habitats, geological features and cultural heritage features. Compatible recreation, conservation and educational activities are also encouraged.

- **Escarpment Protection Areas** - maintain and enhance the open landscape character of Escarpment features, provide a buffer to prominent Escarpment features, maintain natural areas of regional significance and cultural heritage features, while encouraging agriculture, forestry and recreation. These areas are important because of their visual prominence and their environmental significance.

- **Escarpment Rural Area** – maintain portions of the Escarpment and lands in its vicinity that provide a buffer to the more ecologically sensitive areas of the Escarpment. Important to maintain scenic value, maintain the open landscape character by encouraging the conservation of the traditional cultural landscape and cultural heritage features, encouraging agriculture and forestry while providing for compatible rural land uses.

- **Minor Urban Centre** - includes rural settlements, villages and hamlets that are distributed throughout the area of the Plan. Maintain and enhance existing rural settlements, provide concentration points for development and growth in rural areas and ensure that development and growth can be accommodated and serviced in an environmentally sustainable way

- **Urban Area** - identifies Urban Areas in which the Escarpment and closely related lands are located. To minimize the impact and further encroachment of urban growth on the Escarpment environment.

- **Escarpment Recreation Area** - areas of existing or potential recreational development associated with the Escarpment, including ski centers and seasonal lakeshore cottage dwellings. To ensure that future recreational development is compatible with cultural and natural heritage values, and minimizes any adverse effects of recreational activities on the Escarpment environment.

- **Mineral Resource Extraction Area** - includes pits and quarries licensed pursuant to the *Aggregate Resources Act* and areas where mineral resource extraction may be permitted subject to the policies of this Plan. To minimize the impact of mineral extraction operations on the Escarpment environment and provide for areas where new pits and quarries may be established.

The lands within the East Credit Subwatershed are currently designated (percent land use of subwatershed) as 7.0% Escarpment Natural Area, 14.6% Escarpment Protection Area, 22.4% Escarpment Rural Area and 0.4% Mineral Resource Extraction Area. There is no area designated under Minor Urban Centre, Urban Area or Escarpment Recreation Area within the subwatershed boundaries. The NEC Plan is currently under review and the Draft 2001 mapping may result in slight changes to land use designation areas: 15.0% Escarpment Protection, 21.9% Escarpment Rural and 0.5% Mineral Resource Extraction Area.

5.0 ADAPTIVE ENVIRONMENTAL APPROACH

5.1 PURPOSE OF AEM

Adaptive Environmental Management (AEM) can be defined as *an approach to environmental management aimed at improving understanding of the ecosystems being managed, the institutions charged with their management, and the coupling of the two* (Gunderson et al 1995). This concept is particularly suitable to subwatershed planning since it recognizes that ecosystems are by their nature complex and in a state of constant evolution. We therefore start by learning about the functional relationships between key environmental features, develop predictions on the response of these features as to management interventions, and recognize the uncertainty that underlies resource management issues.

AEM is a learning tool, and is just which it claims to be – adaptive. Although there are principles and guidelines that are common in the field of environmental management, they must be altered, or adapted to each specific scenario. The premise of AEM is that goals must be clearly defined, and a model developed, such as a subwatershed framework, in order for the ecological system to be understood. AEM is a planned adaptive approach to learning and can be summarized in terms of its major principles, primary tools and generic process. Table 5.1.1 summarizes the generic approach to AEM.

Table 5.1.1 Generic Approach to AEM

PRINCIPLES	TOOLS	PROCESS
Continuous and Deliberate Learning	Modeling	Define Boundaries
Formal Experimentation	Teamwork	Identify Uncertainties
Expect Surprise	Experimental Design	Generate Hypothesis
Systems Approach		Design Experiments
Management ⇔ Research		Implement
		Monitor

(*Adapted from Ohlson 1996*)

In utilizing the AEM approach, it is important that clearly defined and measurable goals and objectives are identified. The selection of indicators of health that are simply, cost effectively and easily measured is necessary if this approach is to be successful in these times of dwindling resources. It is important to note that the views of the public are incorporated into the process, and AEM is not only used to deal with technical issues.

5.2 Generalized Subwatershed Approach

The following section describes the framework used for watershed management and watershed planning by CVC; this process has been applied to each subwatershed within the CVC watershed. The process has four main stages, as described below and illustrated in Figure 5.2.1. This sequence is usually started due to one or more triggers, which may arise from proposals for large-scale urban development, plans to extract gravel or concerns over the loss of fish species, for example.

- **Planning** – *developing watershed, subwatershed or other watershed-based environmental plans*

Subwatershed planning (including the Subwatershed 13 Study for the East Credit River) can include several steps: a background report of existing data and identifying data gaps; characterization report to characterize the system, set goals and objectives; predictions exercise to compare potential changes and impacts; and creating an implementation report to identify potential targets, and proposing future management plans.

- **Implementation** – *Implementing the programs, policies or projects that arise from watershed, subwatershed or other watershed-based environmental plans*

Subwatershed plan implementation can take action on many different levels, potentially involving many agencies, organizations, and individuals. The time span for implementation will vary from small projects over a few weeks to large-scale engineering works that require decades. The costs involved with these works will vary along with technology, expertise and human resources required to complete them. Most plans will include regulatory/government approaches, incentives, education programs, and have varying layers of public involvement. To be effective, implementation plans need to clearly identify actions, targets, agencies responsible, timelines and costs.

- **Monitoring and Reporting** – *assessing whether plan goals, objectives and targets are being met and periodically communicating the results to decision-makers and the public*

Monitoring the progress towards goals, objectives and targets, along with reporting/ communicating that information to the public, are fundamentally important elements of sound watershed management. Monitoring can provide the means to determine if we are achieving what we have set out to do. Due to the complex nature of (sub)watersheds effective monitoring can be quite extensive, looking at stresses, conditions and responses of the ecosystem.

- **Reviewing, Evaluation and Updating** – *periodically reviewing watershed management plans themselves to see if changes are needed and then altering targets, plans or actions as required*

Every five to ten years it is important to review existing (sub)watershed studies to determine if they need to be updated due to changing environmental conditions, new land use pressures or changing public attitudes. These plans cannot remain static but must respond to lessons, both positive and negative, learned throughout the process.

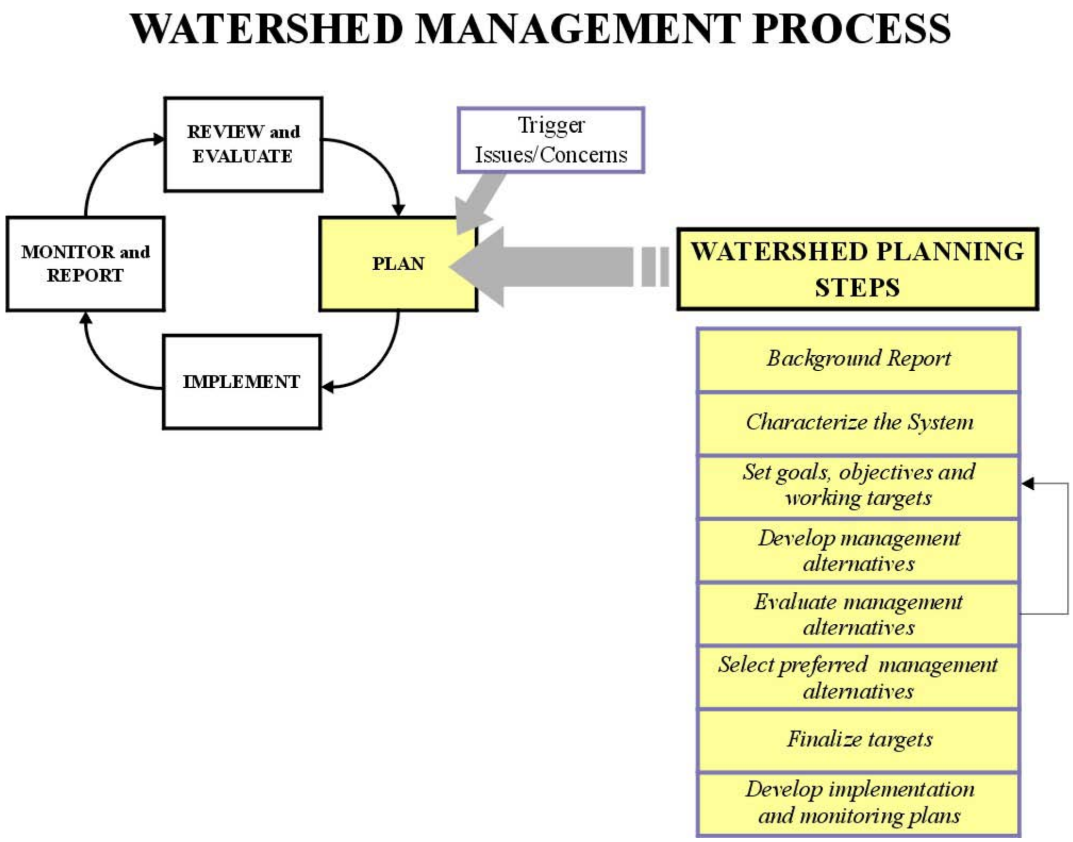

Figure 5.2.1 Watershed Management Process

6.0 NEXT STEPS

This report discusses the existing information and data for the East Credit Subwatershed Study Area. It identifies data gaps and proposes a plan for work to be completed as part of the Characterization Report.

A Phase 1: Characterization Report will be generated as a result of this work in the Fall of 2002. This report will describe the environmental resources, identify functions and linkages between the resources and identify any gaps in knowledge and understanding. A second Focus Group Meeting and a public Open House will follow in late fall/early winter 2002. A Phase 3: Implementation Report will follow in 2003, to define objectives and management options.

REFERENCES

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Barton, D.R. 1996. The use of percent model affinity to assess the effects of agriculture on benthic invertebrate communities in headwater streams of southern Ontario, Canada. Freshwater Biology, 36:397-410.

Beak Consultants, Aquafor Engineering Limited and Donald G. Weatherbe Associates Inc. (1992) Credit River Water Management Strategy Phase II.

Bowen, G. S. and M. J. Hinton. 1998. The Temporal and Spatial Impacts of Road Salt on Stream Draining the Greater Toronto Area. Groundwater in a Watershed Context Proceedings. Burlington, Ontario, pp. 303-309.

Brown, D.M, G.A. McKay and L.J. Chapman. 1974. The Climate of Southern Ontario. Climatological Studies Number 5, Environment Canada, Atmospheric Environment Services, En57-7/5.

Burkart, M.B., H.R. Whiteley, H.O. Schroeter, and D.R. Donald. 1991. Snow depth/area relationships for various landscape units in southwestern Ontario. Proceedings of the 48th Annual Meeting of the Eastern Snow Conference, pp. 51-65.

Canadian Council of Ministers of the Environment. 1999. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.

Chapman, L.J. and D.F. Putnam. 1984. Physiography of Southern Ontario. Third Edition, Ontario Geological Survey Special Volume 2, Ontario Ministry of Natural Resources.

Credit River Fisheries Management Plan (unpublised draft 2001). Ministry of Natural Resources and Credit Valley Conservation.

Credit Valley Conservation, (Him, W). 1984. A Biological Inventory of Warwick Conservation Area. Credit Valley Conservation. Meadowvale, Ontario.

Credit Valley Conservation. 1995. Credit Watershed: Environmentally Significant Area Update Report. Credit Valley Conservation. Meadowvale, Ontario.

Credit Valley Conservation. April 1998. "Credit Watershed Natural Heritage Project Detailed Methodology: Identifying, Mapping and Colletcing Field Data at Watershed and Subwatershed Scales, Version 3". Credit Valley Conservation. Meadowvale, Ontario.

Credit Valley Conservation. 2000. A methodology for assessing the biological integrity of fish communities of the Credit River watershed.

Credit Valley Conservation. Environmentally Significant Areas (ESA's) in the Credit River Watershed. (Report to The Chairman and Members of the Executive Committee). 22 p.

Credit Valley Conservation. n.d. E.S.A. File #50 for Inglewood Lowland Forests. Credit Valley Conservation. Meadowvale, Ontario.

Credit Valley Conservation. n.d. E.S.A. File #49 for Kilmanagh Swamp. Credit Valley Conservation. Meadowvale, Ontario.

Credit Valley Conservation. n.d. P.E.S.A. File #25 for Little Credit River Lowlands. Credit Valley Conservation. Meadowvale, Ontario.

Credit Valley Conservation. n.d. Wetland Evaluation File for Little Credit River Wetland Complex. Credit Valley Conservation. Meadowvale, Ontario.

Credit Valley Conservation. n.d. Wetland Evaluation File for Claude Swamp. Credit Valley Conservation. Meadowvale, Ontario.

Credit Valley Conservation. n.d. Wetland Evaluation File for Caldwell Woods Wetland. Credit Valley Conservation. Meadowvale, Ontario.

Credit Valley Conservation. n.d. Credit Valley Conservation Authority Property – Land Inventory. Credit Valley Conservation. Meadowvale, Ontario.

Credit Valley Conservation. 1998. Credit Watershed Natural Heritage Project – Bird Species of Conservation Concern. Unpublished document available through CVC.

Credit Valley Conservation, Totten Sims Hubicki Associates, Donald G. Weatherbe and Associates, EBNFLO Environmental, D.W. Draper and Associates, Schroeter and Associates, Blackport Hydrogeology. 2000. Water Quality Strategy: Phase I Report (Draft).

Department of Planning Development, 1956. Credit Valley Conservation Report.

Ecologistics Limited. 1979. Credit River Watershed Environmentally Significant Areas. 207p.

Environment Canada. 2001. Poster on Proposed Canadian Water Quality Guideline for Nitrate, National Guideline and Standards office.

Environment Canada and Health Canada. 2000. Priority Substance List Assessment Report: Road Salts, Draft for Comments.

Galamb and Samiec. 1985. Little Credit River Assessment. Credit Valley Conservation Authority.

Hallam, J.C. 1959. Habitat and associated fauna of four species of fish in Ontario streams. Journal of the Fisheries Research Board of Canada 16:147-173.

Hare, F.K. and M.K. Thomas. 1979. Climate Canada, 2nd Ed. John Wiley and Sons.

Howard, W.F., N. Eyles, P.J. Smart, J.I. Boyce, R.E. Gerber, S.L. Salvatori, and M. Doughty. The Oak Ridges Moraine of Southern Ontario: A Ground-water Resource at Risk. Geoscience Canada, Vol. 22, No. 3, pp. 101-120.

Hunter and Associates. 1996. Technical Report – Hydrogeological Evaluation of the Oak Ridges Moraine Area. Prepared for: Oak Ridges Moraine Technical Working Committee.

Intera Kenting. 1990. The Hydrogeological Significance Of The Oak Ridges Moraine. Report prepared for: Greater Toronto Area Greenlands Strategy.

Kaiser, J. March 2001. The Vascular Plant Flora of the Region of Peel and the Credit River Watershed. Prepared for Credit Valley Conservation, The Regional Municipality of Peel and Toronto and Region Conservation Authority. 34p.

Klein, R.D. 1979. “Urbanization and Stream Quality Impairment”. Water Resources Bulletin. Vol. 15, No. 4, pp. 948-962.

Kor, P.S.G. 1993. An Earth Science Inventory and Evaluation of the Mono Mills-Caledon Meltwater Channels Area of Natural and Scientific Interest. Ontario Ministry of Natural Resources, Southern Region, Aurora; Open File Geological Report 9302, 25p.

Lee, H. T., W.D. Bakowsky, J. Riley, J. Bowles, M. Puddister, P. Uhlig, and S. McMurray. 1998. “Ecological Land Classification for Southern Ontario-First Approximation and its Application”. Ont. Min. Natur. Resour., Southcentral Region, Science Development and Transfer Branch.

Ohlson, D. 1996. An Introduction to Adaptive Management and Decision Analysis: Opportunities for the Greater Vancouver Water District Watershed Management Division. School of Community and Regional Planning, University of British Columbia. 33p

Martin, D.K. 1984. The fishes of the Credit River, cultural effects in recent decades. M.Sc. Thesis, Department of Zoology and the Institute for Environmental Studies, University of Toronto.

Ministry of the Environment. 2001. Ontario Drinking Standards.

Ministry of the Environment. (Reprint) 1999. Water Management: Policies, Guidelines and Provincial Water Quality Objectives.

Ontario Department of Planning and Development (ODPD). 1956. Credit Valley Conservation Report. ODPD, Toronto.

Ontario Ministry of Natural Resources (OMNR). 1984. Water Quantity Resources of Ontario. OMNR Publication No. 5932, Queen's Park, Toronto, Ontario.

Parish Geomorphic Ltd. 2001. Geomorphological protocols for subwatershed studies. Submitted to: Regional Municipality of Ottawa-Carleton.

Reed, D.J. 1968. A resurvey of the fishes of the Credit River. M.Sc. Thesis, Department of Zoology, University of Toronto.

Rouse, J.D., C.A. Bishop and J. Struger . 1999. Nitrogen Pollution: An Assessment of Its Threat to Amphibian Survival Environmental Health Perspectives Volume 107, Number 10, pp. 799-803.

Russell, H.A.J. and O.L. White. 1997. Surficial geology of the Boulton area, NTS 30M/13, southern Ontario; Geological Survey of Canada, Open File 3299, Scale 1:50,000.

Schroeter & Associates, 1999. Technical Appendix: Hydrology. Submitted to Environmental Water Resources Group, as part of the Caledon Creek and Credit River Subwatershed Study (Subwatersheds 16 and 18).

Schroeter, H.O. and H.R. Whiteley. 1986. Distribution of snow cover as influenced by landscape units in southwestern Ontario. Proceedings of the 43rd Annual Meeting of the Eastern Snow Conference, pp. 32-44.

Schroeter, H.O. 1988. An operational snow accumulation-ablation model for areal distribution of shallow emphemeral snowpacks. Ph.D. Thesis, School of Engineering, University of Guelph.

Sibul, U., K.T. Wang and D. Vallery. 1977. Groundwater Resources of the Duffins Creek – Rouge River Drainage Basins: Ontario Ministry of Environment Water Resources Report 8, 109 p.

Sharp, D.R., M.J. Hinton and H.A.J. Russel. 199?. Groundwater Resources in the Oak Ridges Moraine, Greater Toronto Area.. Printed from the Oak Ridges Moraine Web site (http://sts.gsc.nrcan.gc.ca/page1/envir/orm/orm.htm).

Triton Engineering Services Limited. 1992. Credit River Water Management Strategy Phase I. 75 p.

Turner, M.E. 1977. Oak Ridges Moraine, Major Aquifers in Ontario Series. Ontario Ministry of Environment, Hydrogeological Map 782.

Wilm, J.L and T.C. Dorris. 1968. Biological parameters for water quality criteria. Bioscience 18:477-481.

White O.L. 1975. Quaternary Geology of the Bolton Area. Ontario Division of Mines Geological Report 117.

APPENDIX A

APPENDIX A: Fisheries

A METHODOLOGY FOR ASSESSING THE BIOLOGICAL INTEGRITY OF FISH COMMUNITIES OF THE CREDIT RIVER WATERSHED

Robert J. Morris, M.Sc. Credit Valley Conservation

Introduction

The Index of Biotic Integrity (IBI) is the best known approach for compiling fish community data and interpreting it as an index of stream health. The IBI includes a range of geographically derived multimetric indices based on biological measures that can diagnose chemical, physical and biological impacts including cumulative effects at a watershed scale. It is used as a tool for making comparisons and for predictive or monitoring purposes in the "Adaptive Management" of water resources promoted by Credit Valley Conservation. Most research of the IBI is based on Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities, a compilation of over 25 papers edited by Simon, Thomas P. (1999).

"The Index of Biotic Integrity incorporates fish assemblage attributes (called metrics) that reflect predominant anthropogenic effects on streams (Karr et al., 1986). Each IBI metric describes a particular taxonomic, trophic, reproductive, or tolerance feature of the assemblage (e.g. number of darter species, proportion of individuals as top carnivores, proportion of lithophilous spawners, proportion as members of tolerant species). An IBI score represents comparisons between metric values at a sample site and those expected under conditions least affected by anthropogenic disturbance. These expectations serve as a predetermined criteria that are used as standards of comparison for scoring individual IBI metrics; hereafter referred to as "metric criteria." If an observed metric value closely matches its criterion value, then the metric is assigned an arbitrary numeric score. If observed value differs moderately from its criterion, then the metric is assigned a lower score. If the observed value differs greatly from its criterion (a condition reflecting high anthropogenic disturbance), then the metric is assigned the lowest score (tyically 1). The IBI score for a site is simply the sum of these metric scores; a high score represents fish-assemblage attributes similar to those of a least disturbed assemblage, i.e., high biotic integrity." (Smogar and Angermeier 1999)

Metrics usually selected to measure fish community attributes include:

- Number of species and/or native species
- Number of trout and/or age classes
- Number of darter and sculpin species
- Number of sucker, sunfish species
- Number of minnow species
- Number of intolerant and/or tolerant species
- Number of sensitive species

- Number of benthic specialists and/or water column species
- Percent or number of simple lithophils

Percent omnivores, insectivores, carnivores
Percent large individuals by size
Percent specialist and/or generalists species
Percent diseased fish
Total number of fish

Species relative abundance data that is commonly used in IBI makes it a “rapid bioassessment” tool. Biomass (weight) rather than numbers of fish (that range in size) is generally accepted as better measuring biological productivity and has been utilized in at least one referenced paper (Gammon 1976). In utilizing more quantitative biomass measurements for each species, a more accurate and statistically valid method of bioassessment is expected.

It is suggested that IBIs be regionally developed and tested for relatively homogeneous regions. However, in the Credit watershed, with three distinctly different physiographic regions including cold, cool and warmwater fish assemblages, would be better assessed with a more flexible approach (i.e. one index watershed wide).

Concerns with the traditional IBI is that its does not account for patterns of increasing species diversity with stream size, and actually employs number of species as a dominant metric. Healthy and pristine coldwater streams typically have only a few species. Species diversity will simply be assessed as number of species and need not be important in the proposed biomass index. What is considered important is the number or biomass of the most ecologically important species. It is anticpated that these “indicator” species will also increase with the total number of species downstream. Biomass is also expected to be dominated by “indicator” trout species in coldwater streams. The proposed method will also underestimate the biomass of tolerant/generalized species that typically increase overall species diversity and fish biomass in cold headwater streams.

It is, therefore, generally assumed higher fish productivity is a positive attribute (as reflected in DFO policy) and will decrease with habitat degradation. Since biomass productivity may be expected to increase in a downstream direction and with warmer water habitats it will have to be further tested and accounted for, during interpretation of results. This pattern, however, may be offset by the proportional loss of shoreline and riparian influences along widening river reaches downstream. Such cover has also been demonstrated to correlate with fish productivity. These habitats can be replaced with more productive wetland habitats and log debris deposits provided low gradient areas increase downstream. This does not seem to occur enough in the lower Credit that maintains a relatively moderate gradient and defined valley.

Habitat degradation of the lower river may also explain why preliminary analysis indicates no increase in biomass with stream size, yet the natural increase in species diversity is very apparent. The additional species are likely “minnows” that may have less effect on total biomass.

It can be noted that the application of this index is for monitoring changes over time such that spatial patterns in diversity and productivity with stream size may not be all that great of a concern. Where possible, however, it is useful to be able to hypothesize, statistically test and transfer predictions and cause and effect relationships from spatial to temporal patterns.

All in all it must be emphasized that the objective was to develop a simple, defensible index to combine the most basic ecological attributes of biomass productivity and the diversity of “indicator” species to assess the overall health of a site in space or time. The application of typical IBI metrics in scoring a fish community remains central to the index proposed for the Credit watershed. Selected metrics are described in terms of negative (-) and positive (+) values that are then tallied, following in Table 1.

Species Diversity

Number of species is reported as a separate index that should be interpreted with the expectation of greater diversities in stable warmwater habitats. However, native species are of particular value (+) for comparisons with “pristine” conditions. Rare or uncommon native species are of greatest concern (++) because losses may include genetic resources unique to watershed. “Preferred or managed” species that occupy a particular niche and are now self-sustaining such as brown trout might be considered as a positive (+), but populations (Pacific salmon) known still to be artificially hatched and stocked should be of no value. Even species known only to occasionally visit the lower Credit from their deep habitats in Lake Ontario may be discounted. Species native to Southern Ontario but not known to be endemic to parts of the Credit watershed originally may be considered as a negative (-) value including northern pike, sunfish and bass that escape from impoundments or manmade ponds. This would include stocked trout, particularly where brown and rainbow are found above the natural barrier of the Niagara Escarpment. Exotic pest species such as sea lamprey and carp can negatively (-) impact ecosystems.

Trophic Level

What a fish eats best determines where it is in the “food chain” and how sensitive it could be to other biological changes. Top predators are especially valuable (++) as they require larger territories or food supplies and are most sensitive to other processes such as the “bioaccumulation” of toxins. Some smaller fish may not consume other fish but still aggressively feed on insects. These insectivores (+) are closely related to the health of their food supplies, bugs, which are also sampled as biological indicators. Omnivorous fish (-) that can feed on a variety of plant and animal matter and even decomposing, detritus are often able to flourish as food sources become limited for other species. Herbivores have also been associated with excess nutrient inputs. Fish anatomy including mouth position and teeth, length ratio of digestive tracts, feeding behaviour and analysis of stomach contents are used to classify species into feeding guilds. The unique filter feeding strategies of larval lampreys or other specialized species may be assigned more of a neutral value.

Simple Lithophilic Spawners

These species are known to be dependent on gravels to conceal and incubate eggs relatively free of sediment. Excess sediments literally cause oxygen suffocation and is associated with other water quality and habitat impacts. Most species depend solely on a clean stream environment (+) and never care for the nest or young as do sunfish and bass (-) that can fan sediment away. Species such as trout actually prepare more specific nests and bury the eggs. Siltation can still be a problem for these species that are given a neutral value because of this extra precaution.

Tolerance Ratings

Generally species are chosen as key indicator species when they disappear from "polluted" waters. Brook trout are considered as the best indicator species of the Credit (++) but other trout, sculpins and darters are more widespread (+). Smallmouth and stonecats are also good indicator species in warmer reaches along with some of the many minnow species (+). A number of species that are apparently limited in their distribution but appear to be tolerant of some pollution, such as pike, sunfish, rock bass are not rated. Even longnose dace survive in urban streams provided there are high velocity riffles. Other species such as carp and bulhead catfish (--) are known to even flourish where no other fish can. Naturally stressed environments of intermittent streams as well as highly altered streams are often dominated by blacknose dace, creek chub, brook stickleback and bluntnose minnows that are also considered tolerant (-).These species are usually tolerant of low flows and oxygen, turbidity and high temperature fluctuations. Tolerance ratings are meant to be more reflective of water quality rather than of physical habitats discussed next.

Habitat Specialists / Generalists

Many authors have described species according to their physiological abilities to specifically adapt to restricted niches or to survive in a variety of different conditions. Generalists or "opportunists" are nonselective in their habits (-) and range over more than a single trophic level. Creek chub and blacknose dace are often most cited in the literature as an adaptive generalist to degraded habitats or as a colonizing species into new or temporary habitats. In contrast some species are very unique in their anatomy and behaviour that they have evolved for the exploitation of specific habitats (+) such as cold groundwater areas for brook trout or high velocity rock riffles of the longnose dace. These species also tend to produce fewer offspring and sexually mature later (e.g. 3yrs for redside dace) than generalists species that may even spawn more than once a year (e.g. fathead minnow) Any changes to such specific requirements are usually reflected in the simplest form of presence/absence data. A few species were not classified as a generalist nor specialist.

Table 1. IBI Metric Scores for Fishes of the Credit Watershed.

Species	Index of Biotic Integrity Total Metrics Score	Rare/Uncommon Native ++ Native/Endemic or fully Naturalized + Stocked 0 Exotic/Pest/ Lentic escapees -	Omnivore/ Detrivore – Filter/Herbe-vore 0 Insectivore+ Carnivore ++	Simple Litho-Philic Spawner+ Other silt tolerant breeders-	Intolerant Species + Tolerant Species -	Specilaist + (benthic, mid-water, coldwater, bogs and late maturing) Generalist Species –
American brook lamprey	+3	+			+	+
Sea lamprey	+1	-			+	+
Coho salmon	+3	-	++		+	+
Chinook salmon	+3	-	++		+	+
Rainbow trout	+4		++		+	+
Atlantic salmon	+4		++		+	+
Brown trout	+5	+	++		+	+
Brook trout	+6	+	++		++	+
Northern pike	+2		++	-		+
Central mudminnow	+1	+	+	-	-	+
White sucker	+1	+	-	+	-	+
Northern hog sucker	+5	+	+	+	+	+
Goldfish	-6	-	-	-	--	-
Northern redbelly dace	+3	+			+	+
Finescale dace	+3	+			+	+
Redside dace	+7	++	+	+	++	+
Carp	-6	-	-	-	--	-
Brassy minnow	+1	+		-		+
River chub	+6	++	+	+	+	+
Golden shiner	-1	+		-	-	
Emerald shiner	0	+		-		
Common shiner	+1	+	+			-
Spottail shiner	+4	+	+		+	+
Rosyface shiner	+5	+	+	+	+	+
Spotfin shiner	0	+	-	-		+
Bluntnose minnow	-4	+	-	-	--	-
Fathead minnow	-4	+	-	-	--	-
Blacknose dace	+1	+	+	+	-	-
Longnose dace	+4	+	+	+		+
Creek chub	0	+	+		-	-
Pearl dace	+2	+	+	-		+
Brown bullhead	-3	+		-	--	-

Stonecat	+3	+	+	-	+	+
Brook stickleback	+1	+	+	-	-	+
Rock bass	+3	+	++	-		+
Pumpkinseed sunfish	0	+	+	-		-
Smallmouth bass	+4	+	++	-	+	+
Largemouth bass	+1	-	++	-		+
Black crappie	+1	-	++	-		+
Yellow perch	+1	-	++	-		+
Rainbow darter	+5	+	+	+	+	+
Iowa darter	+3	+	+	-	+	+
Fantail darter	+4	+	+	+		+
Johnny darter	+3	+	+	-		+
Mottled sculpin	+4	+	+	-	+	++
Slimy sculpin	+4	+	+	-	+	++
Hornyhead chub	+2	++	-	+		
Troutperch	+5	+	+	+	+	+
Alewife	-1	-	+	+		

IBI Species Biomass Factors

Total scores ranging from –6 to +7 (in one case) are then reduced to three categories and assigned an "IBI Species Biomass Factor as follows:

-6 to +1= 1 X factor (i.e. species providing simple biomass conversion function)
+2 to +3= 2 X factor (i.e. species with several or dominant ecological roles)
+4 to +7= 3 X factor (i.e. most valuable "indicator species" re: biological integrity)

These categories were chosen such that all "negatively" scoring species are equally treated as providing the most basic ecological function of converting energy and nutrients to biomass (as measured). Including scores <1 in this category and assigning scores >+3, a 3X biomass factor resulted in a reasonably even distribution of species in the Credit to each of the three categories summarized in Table 2. The distribution of larger vs. smaller and common vs. uncommon species also appears equitable. It can also be noted that definitive coldwater species (trout and sculpin) score high which may reflect the larger number of functions they may perform to counteract the natural tendancy of coldwater habitats to be less diverse and productive.
The reduction of scores to three factor classes is not as sensitive to some disagreement among biologists when assigning a whole range of negative and positive ecological values to each species.

Table 2. Summary of Fish Species by IBI Biomass Factors

IBI Factor: 3X	2X	1X
"Larger fish"		
Rainbow trout	American brook lamprey	*Sea lamprey*
Brown trout	*Coho salmon*	White sucker
Atlantic salmon	*Chinook salmon*	Pumpkinseed sunfish
Brook trout	*Northern pike*	Largemouth bass
Northern hog sucker	Creek chub	*Black crappie*
Smallmouth bass	Stonecat	*Yellow perch*
	Rock bass	Brown bullhead
		Carp
		Alewife
"Minnows"		
Redside dace	Northern redbelly dace	Common shiner
River chub	*Finescale dace*	Bluntnose minnow
Spottail shiner	Central mudminnow	*Spotfin shiner*
Rosyface shiner	*Pearl dace*	Fathead minnow
Longnose dace	*Hornyhead Chub*	Blacknose dace
Rainbow darter		*Emerald shiner*
Iowa darter		*Golden shiner*
Fantail darter		*Brassy minnow*
Johnny darter		Brook stickleback
Mottled sculpin		Goldfish
Troutperch		
Slimy sculpin		

*common and *uncommon* species for the Credit noted

1 X factor (i.e. species providing simple biomass conversion function)
2 X factor (i.e. species with several or dominant ecological roles)
3 X factor (i.e. most valuable "indicator species" re: biological integrity)

Calculation of a Station Health Index

At each sampling station on the Credit the biomass/square meter of each species is now multiplied by its corresponding IBI Species Biomass Factor. All species are then totaled to provide a Fish Health Index of Biotic Integrity for comparisons over time at each station and across the watershed. This single index combines the measures of fish biomass with weighted values related to the diversity of species found and their ecological values. One can still refer to and compare the total number of species and total fish biomass/square meter sampled at each station. Other patterns requiring further hypotheses testing and analysis can be visualized with bar graphs depicting each species biomass with each sampling season.

Descriptive Classifications

After an assessment of the range of values for the Fish Health Index of Biotic Integrity was generated across the watershed a further descriptive classification was assigned:

- >15 Excellent "Health"
- 10-15 Good
- 5-10 Fair
- 3-5 Degraded
- 0-2 Severely degraded

Recommended IBI Statistical Tests

IBI vs. number of species and total biomass.
IBI vs. invertebrate indices
IBI vs. selected water quality parameters (DO, phosphorous, toxins, chlorides, bacteria)
IBI coldwater vs. warmwater sites (or fish management zones as per Fisheries Management Plan)
IBI vs. watershed area, width, depth and/or volume
IBI vs. baseflow and flood peaks / unit watershed area
IBI vs erosion or similar geomorphic stability index
IBI vs. substrate size and embeddedness or % fines
IBI vs. % watershed urban and/or other ELC land use designations
IBI vs. instream and/or riparian cover
IBI vs. "impacted" and "natural" stations considering impacts other than urban area (e.g. # sewage, stormwater or other point sources, water withdrawls, mining, intensive agricultural, dams, length of headwater loss or channelization)
Individual metrics and/or species could also be tested for different physiographic regions and stream size and how much of a correlation with the IBI it alone can account for.

Preliminary Analysis of Results

Figure 1. Ranking of Stations by IBI score and with biomass density and number of species.

Table 3. Approximation of Stations as warm vs. coldwater, large vs. small size and habitat conditions as natural vs. impacted.

- Species diversity is highest in all main river stations (regardless of habitat conditions) but the IBI is not related to stream size. Likewise there does not seem to be a correlation between biomass density and stream size.
- Species diversity does not appear to be greater in warm vs. coldwater streams.

- Stations first perceived to have the most natural habitat conditions are not necessarily reflected by their IBI. Stations perceived to have "impacted" habitat conditions appear to have a lower IBI.
- Intermittent streams tend to have a lower IBI.
- There is a slight tendency for cold water stations to have a higher IBI and warmwater stations to be less healthy.
- There is a correlation between total biomass density and the derived IBI weighted species biomass densities, as expected but with sufficient variation to suggest the value of using weighted "indicator" species (rather than # of species).
- No correlation is apparent between species diversity and the IBI.
- Species diversity may have a weak correlation with increasing biomass (using more "natural" stations).

"Impacted" sites correlate better with the IBI than species diversity.

Spatial correlations found to be significant will be further investigated for cause and effect relationships over time at various stations. The IBI based Index proposed for the Credit will consider these tests to better interpret results or to revise the index along with peer reviews and increased knowledge of individual species.

REFERENCES

Gammon, J.R. 1976. The Fish Populations of the Middle 340km of the Wabash River. Purdue Univ. Water Res. Research Cen. Tech. Rep. 86.

Simon, Thomas P. editor, 1999. Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities, CRC Press, Boca Raton, Florida.

Smogar Roy A. and Paul L. Angermeier. 1999. Effects of Drainage Basin and Anthropogenic Disturbance on Relations Between Stream Size and IBI Metrics in Virginia in Simon 1999.

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessing Biological Integrity in Running Waters: A Method and Its Rationale. Illinois Natural History Surtvey Special Publication 5, Champaign.

Table 3. Approximation of Stations as warm vs. coldwater, large vs. small size and habitat conditions as natural vs. impacted.

Station Name	**large**	**small**	**cold**	**warm**	**natural**	**impacted**
Mill Creek u/s Dawson Rd		X		X		*
Mullet Creek u/s Erin Centre Blvd				X		X
Caledon Creek trib d/s 15th SR		X		X		
Credit River u/s Old Derry Rd	X			X		
Escarpment trib d/s Winston Churchill Blvd		X			X	*

Rogers Creek d/s Winston Churchill		X				*
Black Creek u/s 8th L			X		X	
Credit River @ Terra Cotta Inn	X				X	
Caledon Creek trib d/s McCorm Rd		X		X		X*
MillCreek @ Amanda St		X				X*
Credit River @ Port Credit marshes	X			X		X
Silver Creek d/s Wildwood					X	
West Credit River @ Belfountain			X		X	
Levi Creek u/s Derry Rd				X		X
Huttonville Creek d/s Queen St		X				
West Credit River @ 8th L						
Credit River d/s Forks	X		X		X	
West Credit u/s 10th L			X			
Shaws Creek u/s Hwy 136						
Shaws Creek d/s Mississauga Rd					X	
Black Creek d/s 3rd L			X			
Credit River @ Glen Williams	X				X	
East Credit River trib u/s Grange SR		X	X		X	
Caledon Creek u/s Credit River confluence		X	X			
Fletchers Creek u/s 2cd L				X		X
Credit River @ Ferndale	X				X	
Credit River @ Mill St Cheltenham	X				X	
Silver Creek u/s Hwy 7 Norval						
Huttonville creek u/s Queen St		X		X		*
Lower Monora Creek u/s 1st L			X			
Credit River u/s south Hwy 10 crossing	X		X			
Shaws Creek trib d/s Town Line			X		X	

* denotes intermittency that may represent a natural constraint similar to other impacts

Fisheries Biomass Data

East Credit River E of Hwy 10 @ Caledon Rail Trail

Station: **501200005**

STATION INFORMATION:

Electrofishing Date		July 22, 1999	
Sampling Notes:	**UTM Northing**	4851601	**UTM Easting** 586163
Start Time:	11:30 AM	**Water**	22
End Time:	1:30 PM	**Air temperature**	28
Total Electrofishing	7200		

time (seconds)

Weather **Flow Conditions:**

FISH SPECIES INFORMATION:

Species	Number of Individuals	Total Biomass (g)	Biomass Density (g/m2)	Sensitivity *	Station Health Index
Blacknose Dace (Rhinichthys atratulus)	50	159	0.582	1	0.582
Bluntnose Minnow (Pimephales notatus)	13	39	0.143	1	0.143
Brown Trout (Salmo trutta)	3	467.5	1.712	3	5.135
Central Mudminnow (Umbra limi)	1	0.5	0.002	1	0.002
Common Shiner (Notropis cornutus)	54	297	1.087	1	1.087
Creek Chub (Semotilus atromaculatus)	115	1099.5	4.025	1	4.025
Fantail Darter (Etheostoma flabellare)	23	46	0.168	3	0.505
Fathead Minnow (Pimephales promelas)	1	3	0.011	1	0.011
Johnny Darter (Etheostoma nigrum)	25	38.5	0.141	2	0.282
Mottled Sculpin (Cottus bairdi)	2	5	0.018	3	0.055
Northern Hog Sucker (Hyphentelium	5	165	0.604	3	1.812
Northern Redbelly Dace (Phoxinus eos)	1	1	0.004	2	0.007
Pumpkinseed Sunfish (Lepomis	17	140.5	0.514	1	0.514
Rainbow Darter (Etheostoma caeruleum)	15	32	0.117	3	0.351
Rock Bass (Ambloplites rupestris)	1	41	0.150	2	0.300
White Sucker (Catostomus commersoni)	4	148.5	0.544	1	0.544
Total: **16 species**	**330**	**2683**	**9.822**		**15.356**

**** Credit Valley Conservation. 1999. Natural Heritage Project: Habitat Utilization for***

Sensitivity is rated according to the tolerance listing for fish, as shown in the Natural Heritage Project, where sensitive species (S) are given a score or 3 (most sensitive) and tolerant species (T) are given a score of 1 (least sensitive)

STATION DIMENSIONS:

Station Length 45 **Average Station Width:** 6.07 **Area of Station:** 273.150

NOTES:

Electrofishing Station Summary

East Credit River E of Hwy 10 @ Caledon Rail Trail

Station: **501200005**

STATION INFORMATION:

Electrofishing Date		July 19, 2000	
Sampling Notes: **UTM Northing**	4851601	**UTM Easting**	586163
Start Time:	1:45 PM	**Water**	17
End Time:	2:50 PM	**Air temperature**	20
Total Electrofishing time (seconds)	3900		

Weather
clear, sunny

Flow Conditions:

FISH SPECIES INFORMATION:

Species	Number of Individuals	Total Biomass (g)	Biomass Density (g/m2)	Sensitivity *	Station Health Index
American Brook Lamprey (Lampetra	1	13	0.041	2	0.083
Blacknose Dace (Rhinichthys atratulus)	14	64	0.203	1	0.203
Bluntnose Minnow (Pimephales notatus)	9	23	0.073	1	0.073
Brook Stickleback (Culaea inconstans)	3	5	0.016	1	0.016
Brown Trout (Salmo trutta)	6	242	0.768	3	2.304
Central Mudminnow (Umbra limi)	1	1	0.003	1	0.003
Common Shiner (Notropis cornutus)	22	88	0.279	1	0.279
Creek Chub (Semotilus atromaculatus)	46	850	2.698	1	2.698
Fantail Darter (Etheostoma flabellare)	8	15	0.048	3	0.143
Johnny Darter (Etheostoma nigrum)	18	27	0.086	2	0.171
Northern Hog Sucker (Hyphentelium	4	198	0.628	3	1.885
Rainbow Darter (Etheostoma caeruleum)	11	23	0.073	3	0.219
Rock Bass (Ambloplites rupestris)	1	40	0.127	2	0.254
White Sucker (Catostomus commersoni)	5	275	0.873	1	0.873
Total: 14 species	**149**	**1864**	**5.917**		**9.205**

**** Credit Valley Conservation. 1999. Natural Heritage Project: Habitat Utilization for***

Sensitivity is rated according to the tolerance listing for fish, as shown in the Natural Heritage Project, where sensitive species (S) are given a score or 3 (most sensitive) and tolerant species (T) are given a score of 1 (least sensitive)

STATION DIMENSIONS:

Station Length 45 **Average Station Width:** 7.00 **Area of Station:** 315.045

NOTES:

Little East Credit R trib u/s The Grange Siderd

Station: 501130002

STATION INFORMATION:

Electrofishing Date August 16, 2000

Sampling Notes: **UTM Northing** 4856182 **UTM Easting** 588122

Start Time: 10:30 AM **Water**

End Time: 11:15 AM **Air temperature**

Total Electrofishing time (seconds) 2700

Weather **Flow Conditions:**

partly cloudy

FISH SPECIES INFORMATION:

Species		Number of Individuals	Total Biomass (g)	Biomass Density (g/m2)	Sensitivity *	Station Health Index
American Brook Lamprey (Lampetra		1	9	0.063	2	0.127
Brook Trout (Salvelinus fontinalis)		34	543	3.819	3	11.456
Mottled Sculpin (Cottus bairdi)		12	44	0.309	3	0.928
Total:	**3 species**	**47**	**596**	**4.192**		**12.511**

**** Credit Valley Conservation. 1999. Natural Heritage Project: Habitat Utilization for***

Sensitivity is rated according to the tolerance listing for fish, as shown in the Natural Heritage Project, where sensitive species (S) are given a score or 3 (most sensitive) and tolerant species (T) are given a score of 1 (least sensitive)

STATION DIMENSIONS:

Station Length 61 **Average Station Width:** 2.33 **Area of Station:** 142.191

NOTES:

Electrofishing Station Summary

Little East Credit R trib u/s The Grange Siderd

Station: 501130002

STATION INFORMATION:

Electrofishing Date		July 27, 2001	
Sampling Notes: **UTM Northing**	4856182	**UTM Easting**	588122
Start Time:	10:45 AM	**Water**	13
End Time:	11:30 AM	**Air temperature**	21
Total Electrofishing time (seconds)	2700		
Weather		**Flow Conditions:**	

FISH SPECIES INFORMATION:

Species	Number of Individuals	Total Biomass (g)	Biomass Density (g/m2)	Sensitivity *	Station Health Index
American Brook Lamprey (Lampetra	1	4.5	0.035	2	0.070
Brook Trout (Salvelinus fontinalis)	29	493	3.830	3	11.491
Total: 2 species	**30**	**497.5**	**3.865**		**11.561**

**** Credit Valley Conservation. 1999. Natural Heritage Project: Habitat Utilization for***
Sensitivity is rated according to the tolerance listing for fish, as shown in the Natural Heritage Project, where sensitive species (S) are given a score or 3 (most sensitive) and tolerant species (T) are given a score of 1 (least sensitive)

STATION DIMENSIONS:

Station Length 61 **Average Station Width:** 2.11 **Area of Station:** 128.710

NOTES:

Electrofishing Station Summary

East Credit River E of Hwy 10 @ Caledon Rail Trail

Station: 501200005

STATION INFORMATION:

Electrofishing Date July 20, 2001

Sampling Notes: **UTM Northing** 4851601 **UTM Easting** 586163

Start Time:	10:05 AM	**Water**	21
End Time:	11:35 AM	**Air temperature**	28
Total Electrofishing time (seconds)	5400		
Weather		**Flow Conditions:**	

FISH SPECIES INFORMATION:

Species	Number of Individuals	Total Biomass (g)	Biomass Density (g/m2)	Sensitivity *	Station Health Index
Blacknose Dace (Rhinichthys atratulus)	12	51	0.181	1	0.181
Bluntnose Minnow (Pimephales notatus)	7	27	0.096	1	0.096
Brassy Minnow (Hybognathus	3	5.5	0.020	1	0.020
Brook Stickleback (Culaea inconstans)	1	1	0.004	1	0.004
Brown Trout (Salmo trutta)	1	99.5	0.353	3	1.059
Central Mudminnow (Umbra limi)	3	11	0.039	1	0.039
Common Shiner (Notropis cornutus)	7	34.5	0.122	1	0.122
Creek Chub (Semotilus atromaculatus)	34	366.5	1.300	1	1.300
Fantail Darter (Etheostoma flabellare)	6	14	0.050	3	0.149
Johnny Darter (Etheostoma nigrum)	35	29	0.103	2	0.206
Northern Hog Sucker (Hyphentelium	7	327.5	1.162	3	3.485
Pumpkinseed Sunfish (Lepomis	3	41	0.145	1	0.145
Rainbow Darter (Etheostoma caeruleum)	14	33	0.117	3	0.351
White Sucker (Catostomus commersoni)	11	345.5	1.226	1	1.226
Total: 14 species	**144**	**1386**	**4.916**		**8.382**

**** Credit Valley Conservation. 1999. Natural Heritage Project: Habitat Utilization for***

Sensitivity is rated according to the tolerance listing for fish, as shown in the Natural Heritage Project, where sensitive species (S) are given a score or 3 (most sensitive) and tolerant species (T) are given a score of 1 (least sensitive)

STATION DIMENSIONS:

Station Length 45 **Average Station Width:** 6.27 **Area of Station:** 281.925

NOTES:

APPENDIX B

APPENDIX B: Water Quality

East Credit River at Highway 10 1998 (June to September) Results

Parameter	Units	Method Detection Limit (ug/ml)	Expected Concentration (ug/ml)	Found Concentration (ug/ml)	Recovery %	Site 1: Little Credit R. 51374	Site 1: Little Credit R. 51374
						13-Aug-98	13-Aug-98
BOD	ug/ml	0.1	48.4	42.4	96	<2	1.9
(Nitrate+Nitrite)-N	ug/ml	0.033	5.21	4.95	95	0.179	0.179
Ammonia-N	ug/ml	0.02	6.13	5.87	96	0.04	0.04
Total Phosphorus	ug/ml	0.01	3.05	3.20	105	0.09	0.09
Soluble P as orthophosphate	ug/ml	0.03	15.56	15.15	97	<.03	0.02
TKN	ug/ml	2	5.44	5.21	88	0.5	0.5
pH	units	-	9.02	8.96	99	7.78	7.78
Parameter	**Units**	**Method Detection Limit (ug/ml)**	**Expected Concentration (ug/ml)**	**Found Concentration (ug/ml)**	**Recovery %**	**Site 1: Little Credit R. 48107**	**Site 1: Little Credit R. 48107**
Date						**24-Jun-99**	**24-Jun-99**
BOD*	ug/ml	10*	51.3	56	109	1.8	1.8
(Nitrate+Nitrite)-N	ug/ml	0.01	3.65	3.41	93	0.186	0.186
Ammonia-N	ug/ml	0.02	13.9	13.1	94	0.06	0.06
Total Phosphorus	ug/ml	0.01	3.05	3	98	0.075	0.075
Soluble P as orthophosphate	ug/ml	0.03	15.56	15.13	97	<.03	0.02
TKN	ug/ml	0.1	5.44	4.96	91	0.6	0.6
pH	units	-	9.05	8.83	98	7.72	7.72
Parameter	**Units**	**Method Detection Limit (ug/ml)**	**Expected Concentration (ug/ml)**	**Found Concentration (ug/ml)**	**Recovery %**	**Site 1: Little Credit R. 47744**	**Site 1: Little Credit R. 47744**
						17-Jun-99	**17-Jun-99**
BOD*	ug/ml	10	51.3	47.35	92	<10	2
(Nitrate+Nitrite)-N	ug/ml	0.01	8.66	8.95	103	0.103	0.103
Ammonia-N	ug/ml	0.02	13.9	12.94	93	<.02	0.01
Total Phosphorus	ug/ml	0.01	3.05	3.04	100	0.09	0.09
Soluble P as orthophosphate	ug/ml	0.03	15.56	15.38	99	<.03	0.02
TKN	ug/ml	0.1	5.66	5.82	103	0.6	0.6
pH	units	-	9.05	8.89	98	7.7	7.7

Parameter	Units	Method Detection Limit (ug/ml)	Expected Concentration (ug/ml)	Found Concentration (ug/ml)	Recovery %	Site 1: Little Credit R. 50162	Site 1: Little Credit R. 50162
						22-Jul-99	22-Jul-99
BOD	ug/ml	2	72.2	57.3	79	2.1	2.1
(Nitrate+Nitrite)-N	ug/ml	0.002	5.21	4.81	92	0.327	0.3271
Ammonia-N	ug/ml	0.02	13.9	13.4	96	<0.02	0.01
Total Phosphorus	ug/ml	0.01	3.07	3.02	98	0.11	0.11
Soluble P as orthophosphate	ug/ml	0.03	15.56	14.66	94	<.03	0.02
TKN	ug/ml	0.1	5.44	5.45	100	0.7	0.7
pH	units	-	9.02	8.97	99	7.77	7.77
Parameter	**Units**	**Method Detection Limit (ug/ml)**	**Expected Concentration (ug/ml)**	**Found Concentration (ug/ml)**	**Recovery %**	**Site 1: Little Credit R. 51857**	**Site 1: Little Credit R. 51857**
						21-Aug-99	21-Aug-99
BOD	ug/ml	2	48.4	56	116	<2	1.9
(Nitrate+Nitrite)-N	ug/ml	0.003	3.65	3.54	97	0.148	0.148
Ammonia-N	ug/ml	0.02	13.9	15.3	110	0.06	0.06
Total Phosphorus	ug/ml	0.01	3.05	3.14	103	0.04	0.04
Soluble P as orthophosphate	ug/ml	0.03	15.56	15.82	102	<.03	0.02
TKN	ug/ml	0.1	5.44	5.67	104	0.49	0.49
pH	units	-	9.02	8.99	100	8.11	8.11
Parameter	**Units**	**Method Detection Limit (ug/ml)**	**Expected Concentration (ug/ml)**	**Found Concentration (ug/ml)**	**Recovery %**	**Site 1: Little Credit R. 51857**	**Site 1: Little Credit R. 51857**
						25-Sep	25-Sep
BOD	ug/ml	2	48.4	42.8	88	<2	1.9
(Nitrate+Nitrite)-N	ug/ml	0.003	5.21	4.78	92	0.147	0.147
Ammonia-N	ug/ml	0.02	3.12	3.12	100	<0.02	0.01
Total Phosphorus	ug/ml	0.01	3.05	3.04	100	0.06	0.06
Soluble P as orthophosphate	ug/ml	0.03	15.56	13.55	87	<0.03	0.02
TKN	ug/ml	0.1	5.30	5.70	108	0.7	0.7
pH	units	-	9.02	8.82	98	7.71	7.71

Diurnal Survey, August 13, 1998 (River Low Flow Period)

East Credit at Hwy 10							
Time	**Temp**	**Dosat**	**DO**	**% Saturation**	**pH**	**Observations**	
	oC	**mg/l**	**mg/l**				
6:55	16.5	9.78	7.1	73%	7.84	dawn, water clear	

9:10	16.5	9.78	7.3	75%	7.91	sunny, water clear	
12:00	18.2	9.44	7.6	80%	7.95	sunny, water clear	
14:35	21	8.91	8.4	94%	8.02	sunny, water clear	
17:00	21.7	8.78	8.2	93%	8.07	sunny, water clear	
19:40	21	8.91	7.6	85%	8.06	sunny, water clear	

Diurnal Survey, June 24, 1998 (Peak Aquatic Growth Period)

East Credit at Hwy 10							
Time	**Temp**	**Dosat**	**DO**	**% Saturation**	**pH**	**Observations**	
	oC	**mg/l**	**mg/l**				
6:00	19	9.29	6.7	72%	7.81	dawn; water slightly turbid	
8:20	19	9.29	7	75%	7.84	sunny; water slightly turbid	
11:25	19	9.29	8	86%	7.87	sunny; water slightly turbid	
14:35	23.5	8.45	7.9	93%	7.94	sunny; water clear	
17:00	24.8	8.23	8	97%	8.00	partly cloudy; water clear	
19:45	24	8.36	7.6	91%	7.98	cloudy; water clear	

East Credit River at Highway 10 January 2002 Results

24-Jan-02	Cl- SM 4110B mg/L	NO3-N SM 4110B mg/L	NO2-N Cobas mg/L	PO4-3 SM 4110B mg/L	pH SM 4500B pH Units
E. CREDIT R@ HWY10	38.3	0.6	0.04	< 1	7.94
Blank	< 0.5	< 0.2	< 0.01	< 1	
QC Standard (found)	34.4	16.6	0.37	9	7.03
QC Standard (expected)	35.0	17.0	0.40	9	7.00
Repeat E. CREDIT R@ HWY10	38.7	0.6	0.04	< 1	7.97

24-Jan-02	TDS SM 2540C mg/L	BOD (5) SM 5210B mg/L	DIC A. Col. mg/L	DOC SM 5310C mg/L	Total P SM 4500C mg/L
E. CREDIT R@ HWY10	348	1.2	35.0	3.2	0.019
Blank	< 2	< 0.5	< 0.2	< 0.2	< 0.002
QC Standard (found)	246	6.0	29.5	4.9	0.027
QC Standard (expected)	250	6.0	30.0	5.0	0.028
Repeat E. CREDIT R@ HWY10	344	1.1	33.3	3.0	0.018

24-Jan-02	C-Hard. Calc. mg CaCO3/L	Ag ICP/MS mg/L	Al ICP/MS mg/L	As ICP/MS mg/L	B ICP/MS mg/L
E. CREDIT R@ HWY10	279.0	< 0.0001	0.051	< 0.002	0.013
Blank	0.3	< 0.0001	< 0.005	< 0.002	< 0.005
QC Standard (found)	172.0	0.0030	0.909	0.097	0.045
QC Standard (expected)	172.0	0.0030	1.000	0.100	0.050

Repeat E. CREDIT R@ HWY10	283.0	<0.0001	0.038	<0.002	0.013

24-Jan-02	Ca ICP/MS mg/L	Cd ICP/MS mg/L	Co ICP/MS mg/L	Cr ICP/MS mg/L	Cu ICP/MS mg/L
E. CREDIT R@ HWY10	86.0	<0.0001	<0.0001	<0.005	0.0011
Blank	<0.5	<0.0001	<0.0001	<0.005	<0.0005
QC Standard (found)	5.2	0.0483	0.0486	0.048	0.0471
QC Standard (expected)	5.0	0.0500	0.0500	0.050	0.0500
Repeat E. CREDIT R@ HWY10	85.1	<0.0001	<0.0001	<0.005	0.0007

24-Jan-02	Mn ICP/MS mg/L	Mo ICP/MS mg/L	Na ICP/MS mg/L	Ni ICP/MS mg/L	P ICP/MS mg/L
E. CREDIT R@ HWY10	0.076	<0.001	16.2	<0.001	<0.05
Blank	<0.005	<0.001	<0.1	<0.001	<0.05
QC Standard (found)	0.048	0.050	4.8	0.047	0.92
QC Standard (expected)	0.050	0.050	5.0	0.050	1.00
Repeat E. CREDIT R@ HWY10	0.074	<0.001	16.3	<0.001	<0.05

24-Jan-02	Si ICP/MS mg/L	Sn ICP/MS mg/L	Sr ICP/MS mg/L	Ti ICP/MS mg/L	Tl ICP/MS mg/L
E. CREDIT R@ HWY10	5.13	<0.001	0.206	<0.005	<0.00005
Blank	<0.05	<0.001	<0.001	<0.005	<0.00005
QC Standard (found)	0.81	0.104	0.048	0.050	0.10500
QC Standard (expected)	1.00	0.100	0.050	0.050	0.10000
Repeat E. CREDIT R@ HWY10	5.14	<0.001	0.200	<0.005	<0.00005

24-Jan-02	Sp. Cond. SM 2510B umhos/cm	Alk 4.5 SM 2320B mg CaCO3/L	TSS SM 2540B mg/L
E. CREDIT R@ HWY10	586	238	<1
Blank	1	<1	<1
QC Standard (found)	714	255	49
QC Standard (expected)	718	250	50
Repeat E. CREDIT R@ HWY10	585	242	<1

24-Jan-02	NH3-N SM 4500H mg/L	TKN SM 4500B mg/L	COD SM 5220D mg/L
E. CREDIT R@ HWY10	<0.03	0.30	10

Blank	< 0.03	< 0.03	< 5
QC Standard (found)	1.38	0.31	40
QC Standard (expected)	1.50	0.28	40
Repeat E. CREDIT R@ HWY10	< 0.03	0.28	10

	Ba	Be	Bi
	ICP/MS	ICP/MS	ICP/MS
	mg/L	mg/L	mg/L
24-Jan-02			
E. CREDIT R@ HWY10	0.056	< 0.001	< 0.001
Blank	< 0.005	< 0.001	< 0.001
QC Standard (found)	0.096	0.005	0.103
QC Standard (expected)	0.100	0.005	0.100
Repeat E. CREDIT R@ HWY10	0.055	< 0.001	< 0.001

	Fe	K	Mg
	ICP/MS	ICP/MS	ICP/MS
	mg/L	mg/L	mg/L
24-Jan-02			
E. CREDIT R@ HWY10	0.23	1.5	17.80
Blank	< 0.03	< 0.1	< 0.05
QC Standard (found)	1.06	1.0	0.99
QC Standard (expected)	1.00	1.0	1.00
Repeat E. CREDIT R@ HWY10	0.24	1.5	17.80

	Pb	Sb	Se
	ICP/MS	ICP/MS	ICP/MS
	mg/L	mg/L	mg/L
24-Jan-02			
E. CREDIT R@ HWY10	< 0.0005	< 0.0005	< 0.002
Blank	< 0.0005	< 0.0005	< 0.002
QC Standard (found)	0.0517	0.0941	0.095
QC Standard (expected)	0.0500	0.1000	0.100
Repeat E. CREDIT R@ HWY10	< 0.0005	< 0.0005	< 0.002

	U	V	Zn
	ICP/MS	ICP/MS	ICP/MS
	mg/L	mg/L	mg/L
24-Jan-02			
E. CREDIT R@ HWY10	0.0004	< 0.0005	0.028
Blank	< 0.0001	< 0.0005	< 0.005
QC Standard (found)	0.0045	0.0474	0.048
QC Standard (expected)	0.0050	0.0500	0.050
Repeat E. CREDIT R@ HWY10	0.0004	< 0.0005	0.015

APPENDIX C

APPENDIX C: Glossary

Abiotic – Not relating to living things.

Aquatic – growing or living in, or frequenting water.

Aquiclude – A saturated geologic unit that is incapable of transmitting significant quantities of water under ordinary conditions.

Aquifer – A saturated permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients.

Attenuation (Flow) – Flow that is lessened or weakened, or the severity reduced.

Bank Stability – The ability of a stream bank to resist change.

Base Flow –The water that flows into a stream through the subsurface.

Bedrock – The solid rock underlying unconsolidated surface material

Bedrock Geology – The study of the solid rock underlying unconsolidated surface material. Also refers to the description of bedrock types.

Benthic Invertebrates – Organisms without an internal skeletal structure that live on or in a body of water, e.g., water insects.

Biological Diversity - the variability among organisms and the ecological complexes of which they are a part .

Biomass – The amount of living matter, usually measured per unit area or volume of habitat.

Biotic – Relating to or caused by living beings.

Climate – The average weather conditions of a place or region throughout the seasons.

Conductivity – The quality or power of conducting or transmitting.

Contiguous – Having contact with, or touching along a boundary or point.

Discharge Area - An area where water leaves the saturated zone across the water table surface.

Drainage Density – Length of watercourse per unit drainage area.

Ecological – Relating to the totality or pattern relations between organisms and their environment.

Ecosystem - Systems of plants, animals and micro-organisms together with the non living components of their environment, related ecological process and humans.

Elevation – The height of a portion of the earth's surface in relation to its surroundings.

Entrain – To draw in and transport through water.

Episodic - Made up of separate loosely connected episodes.

Erosion – The wearing away of the land by the action of water, wind or glacial ice.

Flood Pulse – The peak flow during a flooding event.

Floodplain – A plain bordering a river, which has been formed from deposits of sediment carried down the river. When a river rises and overflows its banks, the water spreads over the floodplain.

Flow Regime – The pattern of how water levels change in a stream.

Flow Stability - Determined by measuring the ratio of surface discharge to groundwater discharge on an annual basis.

Fluvial - Relating to a stream or river.

Geology – The science of the composition, structure and history of the earth. It thus includes the study of the materials of which the earth is made, the forces which act upon these materials and the resulting structures.

Geomorphology - The scientific study of the origin of land, riverine and ocean features on the earth's surface.

Glaciation – The covering of an area or the action on that area, by an ice sheet or by glaciers.

Gradient – The rate of regular or graded ascent or descent.

Granular – Having a texture composed of small particles.

Groundwater – Water below the earth's surfaces that lies in the area of total saturation. Groundwater can exist in rock or granular material.

Groundwater Table – The meeting point between the groundwater and the unsaturated layer above it.

Habitat - The environment of an organism; the place where it is usually found.

Hydrogeology - The scientific study of groundwater.

Hydrology - The scientific study of surface water.

Imperfect Drainage – Occurs when water cannot easy flow over the land surface through a well formed drainage network

Infiltration – Water entering the pores of the earth's surface.

Intermittent Stream – A watercourse that does not flow permanently year round.

Invertebrates – Animals lacking a spinal column

Local Discharge – Discharge to a watercourse that originates nearby. The water moves through the upper layers of the groundwater system.

Lowflow - The flows that exist a stream channel in dry conditions.

Macroinvertebrates - Animals lacking a spinal column that are visible with the unaided eye.

Meandering - A curve in the course of a river which continually swings from side to side.

Meltwater Channel - The path of drainage, and leftover sedimentary deposits from ice or snow melt.

Moraine -The debris or rock fragments brought down with the movement of a glacier.

Morphology - see geomorphology

Non Renewable Resources - A resource that is not capable of being replaced by natural ecological cycles or sound management practices within the timeframe of a human life.

Nutrient –Something that nourishes and promotes growth. It is possible to have too many nutrients in an ecosystem, which can result in an unhealthy imbalance or overgrowth of certain species.

Organic Matter – Of, relating to, or derived from, living organisms.

Permeability – The quality of having pores or openings that allow liquids to pass through.

Physiography - Study or description of landforms (see geomorphology)

Precipitation – The deposits of water in either liquid or solid form which reach the earth from the atmosphere. It includes rain, sleet, snow and hail.

Productivity – Rate of production, especially of food or solar energy by producer organisms.

Recharge Area - An area where water enters saturated zone at the water table surface.

Regional Discharge – Water that has traveled deep beneath the ground through the saturated zone and resurfaces at the water table.

Renewable Resources – A resources that is capable of being replaced through ecological processes or sound management practices.

Return Period – The frequency in which a flow event in a stream is likely to repeat itself.

Riffle:Pool System – A riverine system that alternates cycles of shallow broken water (riffle) and deeper still water (pool).

Riparian - Relating to or located on the bank of a watercourse.

Riparian Zone – Areas adjacent to a stream that are saturated by groundwater or intermittently inundated by surface water at a frequency and duration sufficient to support the prevalence of vegetation typically adapted for life in saturated soil.

Saturated Soil – Soil that is full of moisture.

Scale – A graduated series or scheme of rank or order.

Sediment – Material deposited by water, wind or glaciers.

Sedimentary Bedrock - Rock formed of mechanical, chemical or organic sediment such as rock formed from sediment transported from elsewhere, by chemical precipitation from solution or from inorganic remains of living organisms.

Slope – Ground that forms a natural or artificial incline.

Spawn – To produce or deposit eggs in the reproductive process (used of aquatic animals).

Stratigraphy – Geology that deals with the origin, composition, distribution and succession of layers of the earth.

Stream – A body of running water flowing on the surface of the earth.

Substrate – The base on which an organism lives.

Subwatershed - A region or area bounded peripherally by a water parting and draining ultimately to a tributary of a larger watercourse or body of water.

Subwatershed Planning – A method used to deal with environmental concerns over broad areas of land. The subwatershed plan integrates the functions of resource management and the land use planning process. A subwatershed plan does not set out ideal land uses, but it does make valuable contributions to the land use decision making process by developing a detailed understanding of the subwatershed ecosystem and making recommendations regarding the management of the ecosystem, in light of alternative land use patterns.

Surficial Geology – Deals with the study and description of the forms on the outer layer of the earth.

Terrestrial - Living on or growing on land.

Thermal Regime – The characteristic behaviour and pattern of temperature.

Till – A tough unstratified clay loaded with stones originating from finely ground rock particles that were deposited by glacial activity.

Topography – A detailed description or representation of the features, both natural and artificial, of an area. Also the physical and natural features of an area, and their structural relationships.

Valley – A long, narrow depression on the earth's surface, usually with a fairly regular downward slope. A river or stream usually flows through it.

Water Budget - The movement of water within the hydrologic cycle can be described through a water budget or water balance. It is a tool that when used properly, allows the user to determine the source, and quantity of water flowing through a system. From a groundwater perspective the key components of a water budget are: infiltration, contribution to baseflow, deeper groundwater flow outside the study area, and groundwater taking.

Water Cycle – The continuous movement of water from the oceans to the atmosphere (by evaporation), from the atmosphere to the land by condensation and precipitation, and from the land back to the sea (via stream flow).

Water Quality Indicator – An entity that provides information on the condition and quality of water through their life cycle patterns. Water quality can also be determined through non living sources, like chemical sampling.

Watershed - A region or area bounded peripherally by a water parting and draining ultimately to a particular watercourse or body of water.

Weathering -The disintegration of the earth's crust by exposure to the atmosphere, most importantly, rain.

Wetland – An area where the water table is seasonally above the substrate surface, and the saturation period long enough to promote hydric or organic soils. A wetland can provide an important role in the hydrologic cycle and host unique species of flora and fauna.