APPENDIX B

CVC REPORT

ERIN SERVICING AND SETTLEMENT MASTER PLAN

Phase 1 – Environmental Component – Existing Conditions Report

MAY 2011

TOWN OF ERIN
PROGRESS IN UNITY

CVC
CREDIT VALLEY CONSERVATION

Erin Servicing and Settlement Master Plan

Phase 1 -
Environmental Component -
Existing Conditions Report

May 2011

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Town of Erin
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1.0 INTRODUCTION

The Town of Erin, in partnership with Credit Valley Conservation (CVC) and with the support of the Region of Peel (being a municipality located downstream of Erin), has initiated an Erin Servicing and Settlement Master Plan for the Erin Village and Hillsburgh. The Erin Servicing and Settlement Master Plan (SSMP) is a community-based process which is designed to address the planning, environmental and servicing implications of growth, in rural communities in a comprehensive and fully integrated manner for Erin Village and Hillsburgh.

The Erin SSMP is being executed as a result of four major events that have occurred. These events are as follows which are taken from the *Town of Erin Servicing and Settlement Master Plan Terms of Reference* (Triton Engineering Services Limited 2008):

1. The 1997 Provincial Policy Statement (PPS) required the protection/enhancement of quality and quantity of groundwater and surface water resources and the function of sensitive discharge/recharge areas, headwaters and aquifers. Further protective measures, detailed in the 2005 PPS require the protection, improvement or restoration of the quality and quantity of water and the establishment of the watershed as the ecologically meaningful scale for planning. The infrastructure policies in the PPS establish a clear policy framework with respect to servicing. Where full municipal services are not, or cannot be provided, communal services are the preferred means of servicing multiple lots/units. If the use of communal system is not feasible, lots may be serviced by individual on-site systems where conditions are suitable over the long-term.
2. In 2000, the Town of Erin released the *Erin Growth Strategy Report*, examining growth-related issues in the former Erin Village and surrounding area.
3. May 1999, the County of Wellington's Official Plan (OP) was approved and contains similar policy, directing growth to urban areas and in particular to those with municipal sanitary and water services.
4. December 2004, the County of Wellington approved the Town of Erin's OP. This OP sets out a community-based process known as a Servicing and Settlement Master Plan (SSMP), which is designed to address servicing, planning and environmental issues relating to the Town of Erin in a comprehensive manner. The Village of Hillsburgh is also to be included as part of a SSMP. This study is considered a Master Plan under the Municipal Engineer's Class Environmental Assessment (EA) Process since the servicing includes water, wastewater, transportation, and storm water management.

Erin is in the fortunate position of being able to create a renewed vision prior to significant growth pressures being felt. This will ensure that when new development is proposed, it will be guided by the results of this community-based study. The study is being undertaken in four phases, as discussed within the CVC Erin SSMP Data Gap Analysis Report (CVC et al. 2008).

This *Existing Conditions Report* discusses the current environmental conditions for the Erin SSMP study area. An analysis of each disciplines' data collected over 2007 and 2008 is included to determine existing conditions within the study area, as well as integrate the disciplines' findings to give an overall understanding of the key environmental features and functions of the study area.

The information from this report will be integrated into the Town of Erin's *Erin SSMP Phase 1 Background Issues Report* to describe the existing environmental conditions and indentify limitations and sensitivities.

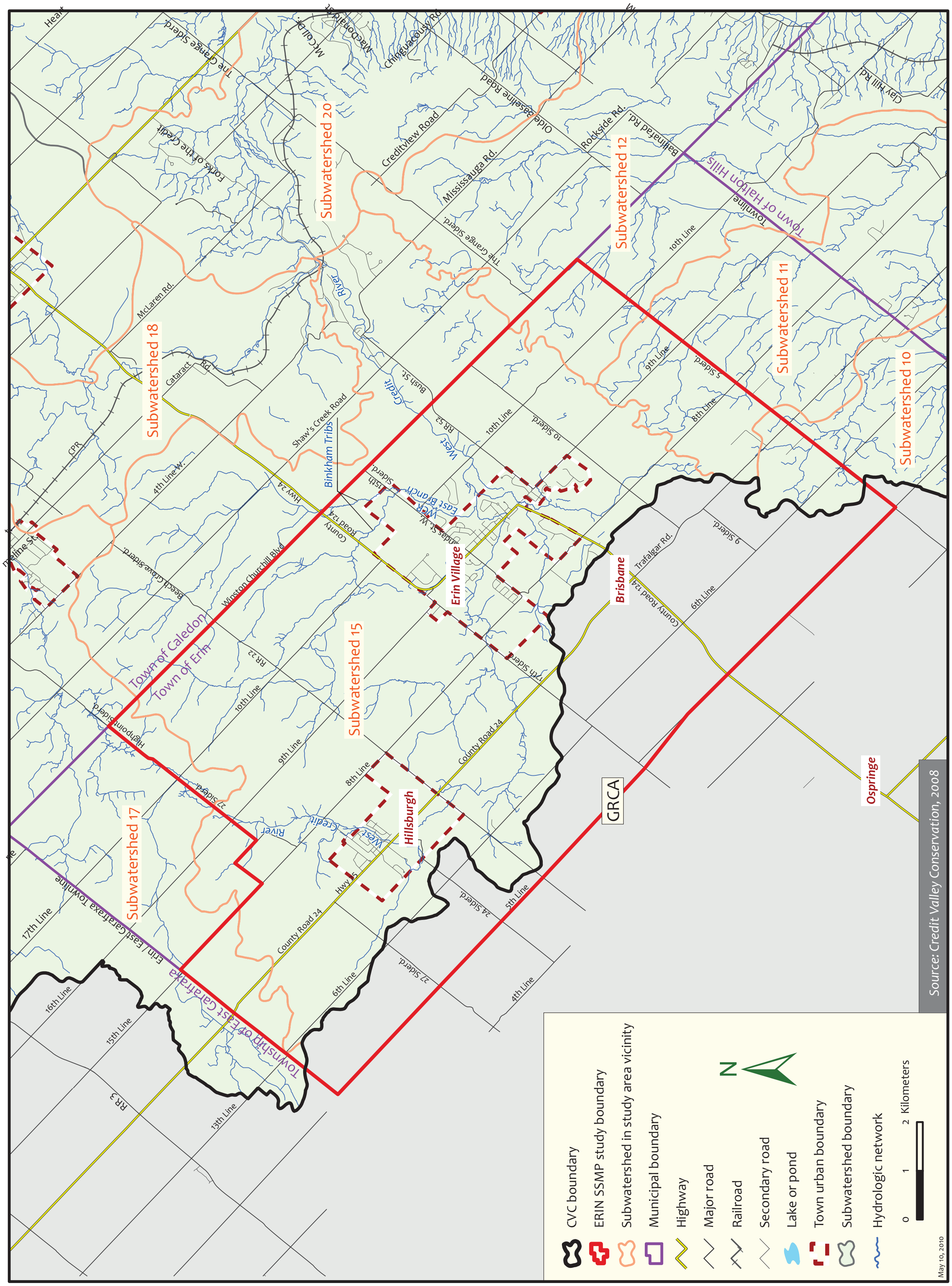
1.1 STUDY AREA

The area situated within the Erin SSMP study area lies predominantly within the Credit River watershed, but also crosses into the Grand River watershed. Although the area is thus presided over by two different conservation authorities, such boundaries are inconsequential to characterizing and studying the watercourses within the study area. The study area is illustrated within **Figure 1.1.1**.

The Erin SSMP study area is primarily within CVC's West Credit River subwatershed, also known as Subwatershed 15, but it also extends into the headwaters of Subwatersheds 10 (Black Creek), 11 (Silver Creek) and 12 (Cheltenham to Glen Williams – Credit River main branch and tributaries). In addition, small sections of Subwatersheds 17 (Shaw's Creek) and 18 (Melville to Forks of Credit – Credit River main branch) are included along the north and eastern boundary of the study area. The western section of the study area is within the headwaters of the Grand River (i.e., under the jurisdiction of the Grand River Conservation Authority). The watercourses within the Erin SSMP study area are illustrated in **Figure 1.1.2** along with arrows indicating direction of flow.

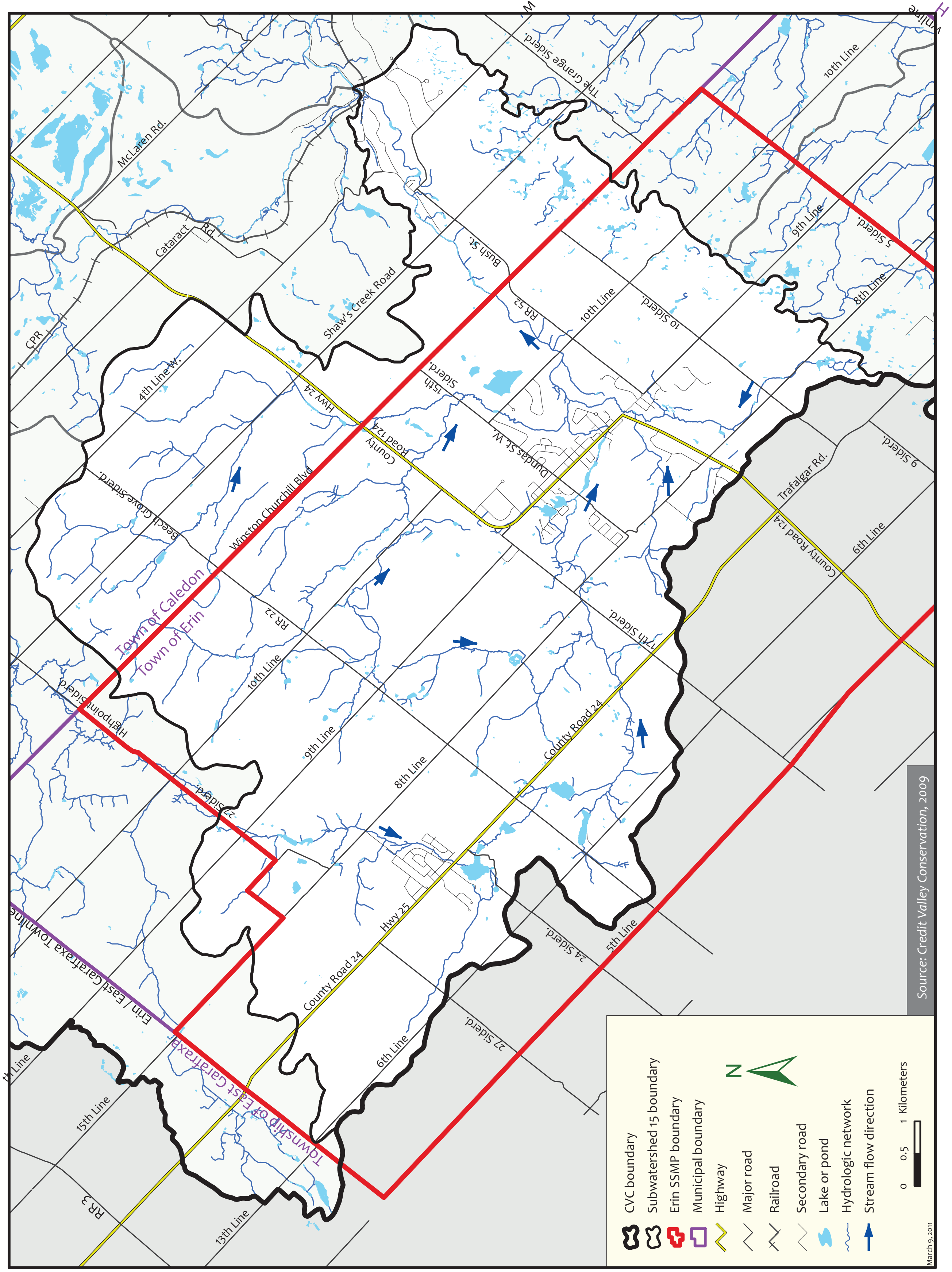
Two relatively small urban centres, Erin Village and Hillsburgh, are centered around the West Credit River. Urban and rural development account for 4.1% and 3.8% of the Erin SSMP study area. (Land uses are illustrated in **Figure 1.1.3** and details are provided in **Table 2.3.1**.) Intensive agriculture covers the largest percentage of the study area at 35.3% and non-intensive agriculture covers 11.1% of the Erin SSMP study area. Wetlands and forests cover 13.4% and 16.1%, respectively. Thus, the majority of watercourses within the study area are surrounded by agricultural land use and/or situated within a wooded or wetland corridor.

Figure 1.1.1 Erin SSMP Study Area and Stream Nomenclature



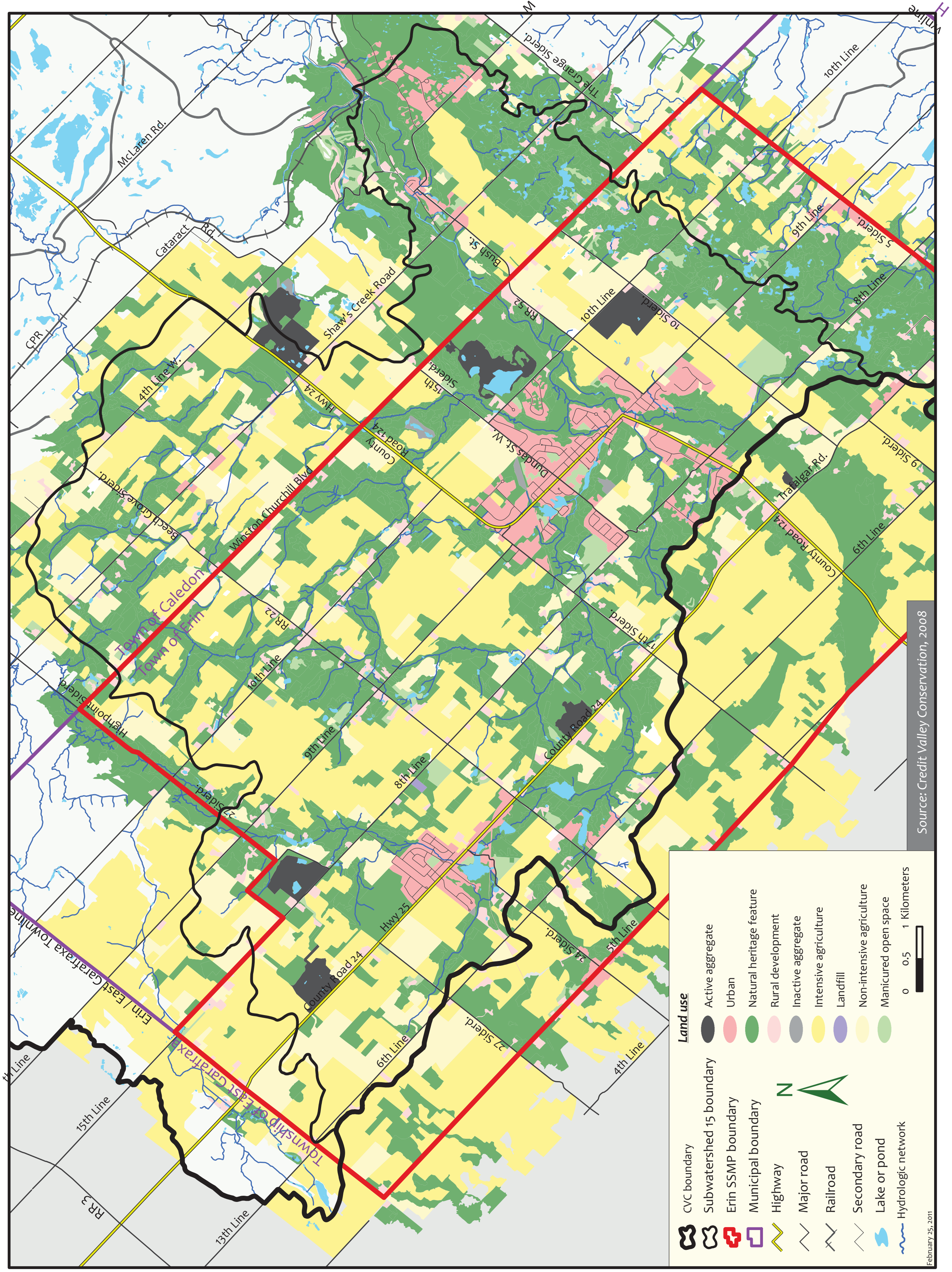
Source: Credit Valley Conservation, 2008

Figure 1.1.2 Stream Flow Directions



Source: Credit Valley Conservation, 2009

Figure 1.1.3 Existing Land Uses



Source: Credit Valley Conservation, 2008

2.0 ENVIRONMENTAL COMPONENT

The environmental component of this *Existing Conditions Report* is divided into the following environmental disciplines: hydrogeology, hydrology, hydraulics, natural heritage, fluvial geomorphology, benthic macroinvertebrates, fisheries, and water quality. The hydrogeology component evaluates the groundwater resources and characterizes interactions with surface water. The hydrology and hydraulic component characterizes meteorological and streamflow conditions in terms of floodplain and peak flows. The natural heritage component characterizes and evaluates the sensitivity of the terrestrial system. The fluvial geomorphological component evaluates the physical processes of the watercourses within the study area to determine sensitivity to changes in flow or sediment regimes. The water quality component will assess the existing water quality conditions in the West Credit River. The benthics and fisheries components will characterize the benthic macroinvertebrate and fish communities and serve as the integrator of all the environmental components to determine the health of the ecosystem.

The last section of the Environmental Component discusses the septic system impact assessment. This section provides an overview of septic systems, how they operate, and potential septic system impacts on water quality. A review of water quality through the Hillsburgh and Erin Villages is discussed through the completion of a mass balance and mass loading assessment in order to determine whether or not the water quality in these areas is being impacted by septic systems.

2.1 HYDROGEOLOGY

2.1.1 Existing Information

Considerable hydrogeological information is available from previous investigations and studies conducted for the Town of Erin and/or Credit Valley Conservation (CVC). The following lists the primary sources of information, and type of information in each report, which were used to assess the existing conditions for the hydrogeology component of this report:

- West Credit Subwatershed Study – *Phase 1 Characterization* report, prepared by CVC, January 1998. This includes information on general geology, hydrogeology recharge/discharge conditions, and baseflow.
- West Credit Subwatershed Study – *Draft Phase 2 Impact Assessment* report, prepared by CVC, January 2001. Additional baseflow data was collected and a groundwater flow model developed as part of several studies in the West Credit River subwatershed.
- West Credit Subwatershed Study – *Draft Phase 1 Addendum* report, CVC, 2001^{a}.
- *Groundwater Management and Protection Strategies, Groundwater Management Study, Town of Erin*, prepared by Blackport Hydrogeology Inc., 2005. Much of the work was done in 2001 and 2002 and included development of a groundwater

flow model, assessment of capture zones, wellhead protection areas, and aquifer vulnerability. Note that throughout this *Existing Conditions Report*, the *Groundwater Management and Protection Strategies, Groundwater Management Study, Town of Erin* is referred to as the Town of Erin Groundwater Management Study.

- Source Water Protection, *Interim Watershed Characterization Report for the Credit River Watershed*, prepared by CVC, 2007. This study included an update of information on a watershed wide basis, containing information, mainly in digital form on geology, water quality, and updated well field capture zones.
- *County of Wellington Groundwater Protection Study*, prepared by MHBC, Golder Associates and SRG, September 2006. The previous groundwater flow model was updated as part of the County's study, using the most recent hydrogeologic information and pumping data to refine the well field capture zones and aquifer vulnerability to contamination.
- Historical reports for municipal well test drilling and water supply assessment for the former Erin Village and for Hillsburgh in the former Township of Erin.

Additional information was also available through various consultants' reports, related to development applications, aggregate sites, and groundwater contamination studies as well as information on the existing municipal wells from the Town of Erin through the Drinking Water Surveillance Program and annual monitoring data.

Source Protection studies are also currently being completed as part of a technical assessment, under the Clean Water Act (2006) to produce locally developed, science based Assessment Reports and Source Protection Plans. This work includes an update of well field capture zones, vulnerability mapping, threats assessment, and water quality risk assessment. A draft report has been completed but is not yet publicly available.

The following sections present a summary of existing information and current understanding of geological and hydrogeological conditions throughout the general study area. It is noted that much of the information has been presented in the *Erin SSMP Data Gap Analysis Report*, and portions taken directly from some of the above noted reports.

It is also noted that Section 2.8 presents a detailed discussion of the potential impact of septic systems, as related to the West Credit River water quality, through groundwater discharge or direct runoff. Also, more details regarding local baseflow conditions and groundwater surface water interaction are presented in Section 2.8.

2.1.2 Geologic Conditions

2.1.2.1 General Physical Setting

The Erin SSMP study area encompasses much of the West Credit River subwatershed and is located between the main branch of the Credit River to the east and the headwaters of the Eramosa River to the west. **Figure 2.1.1** shows the topographic relief of the West Credit River subwatershed, as well as the main surface water features within the general study area. The western and northwestern most boundary of the subwatershed forms the regional high relief area, ranging in elevation from greater than 500 m amsl north of Hillsburgh to about 450 m amsl in the Hillsburgh area, approaching the West Credit River valley. This area is the physiographic region known as the Hillsburgh Sandhills and is part of the Orangeville Moraine, an important recharge area in the West Credit River subwatershed.

The eastern most area, to the northeast of the Village of Erin, is a locally low relief area with a significant valley cut outside of the area of study. The lowest relief area is found in the eastern portion of the West Credit River subwatershed, at an elevation of about 365 m amsl.

There is also an area of topographically high relief in the southern portion of the study area where ground surface elevations are greater than 440 m amsl in some areas. This ridge of high relief is in an area comprised of the Paris Moraine. This area also provides substantial recharge to the groundwater system. The area forms a topographic divide with the Niagara Escarpment to the south.

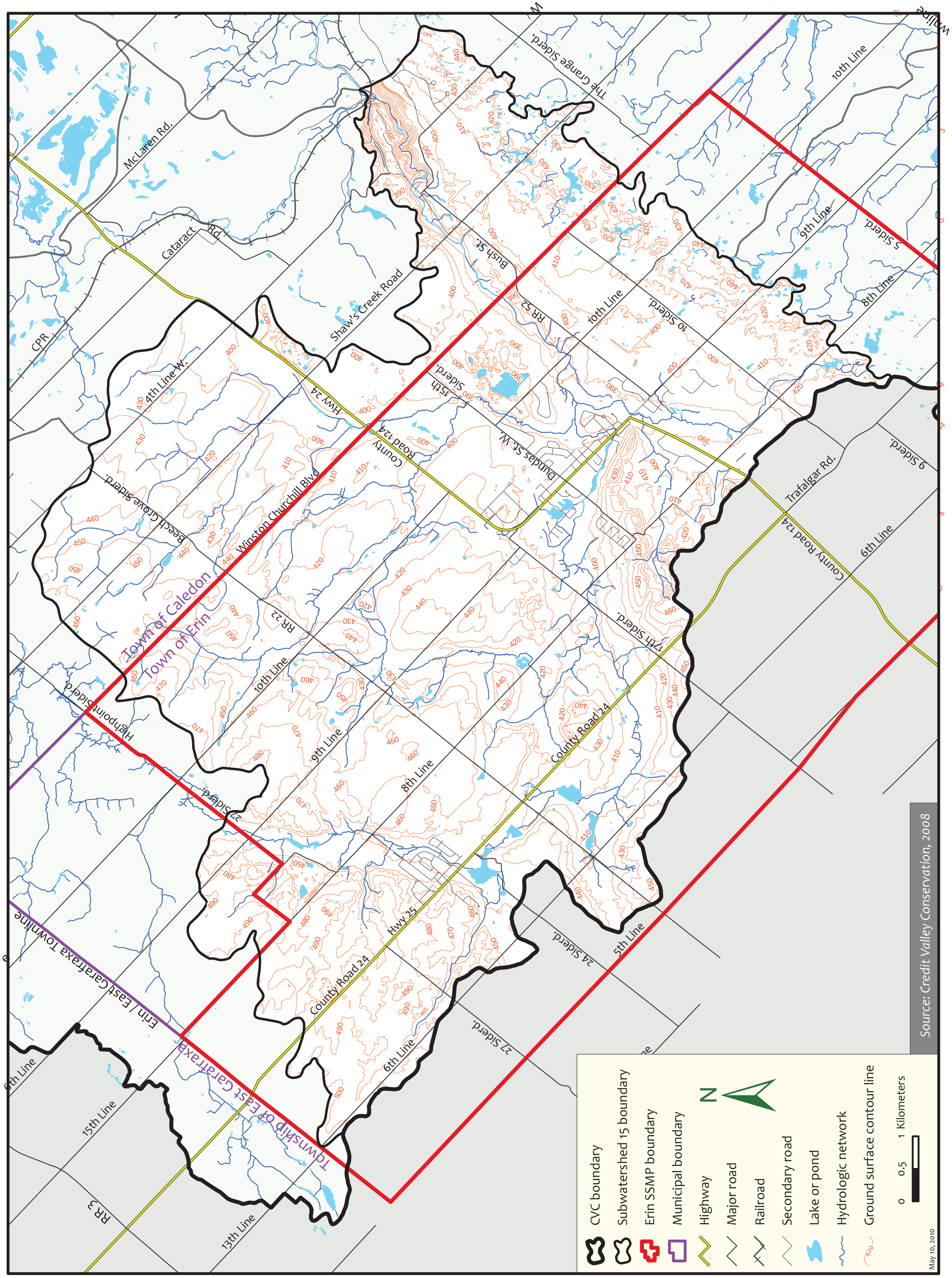
2.1.2.2 Surficial Geology

The surficial geology is a mapping of surface geological features which resulted from the last period of glaciation depositing geologic material in different forms (e.g., till sheets, glacial outwash). The surficial geology has been mapped in detail by Karrow (1968) and Cowan (1976) and presented in **Figure 2.1.2**. The surficial geology, combined with topographic relief is important in determining areas of major groundwater recharge and discharge throughout the subwatershed and local study area. The surficial geology will typically provide a good indication of the most permeable ground surface and therefore the area of greatest potential for groundwater recharge. It will not provide sufficient information to determine how deep this water will move and where it will discharge. Water well records will aid in interpreting the subsurface and regional geologic characteristics of the subwatershed, as presented in the next section.

The following comments highlight the relevant characteristics of the surficial geology of the West Credit River subwatershed, as adapted from the *West Credit Subwatershed Study, Phase 1 Characterization* report (CVC 1998[a]):

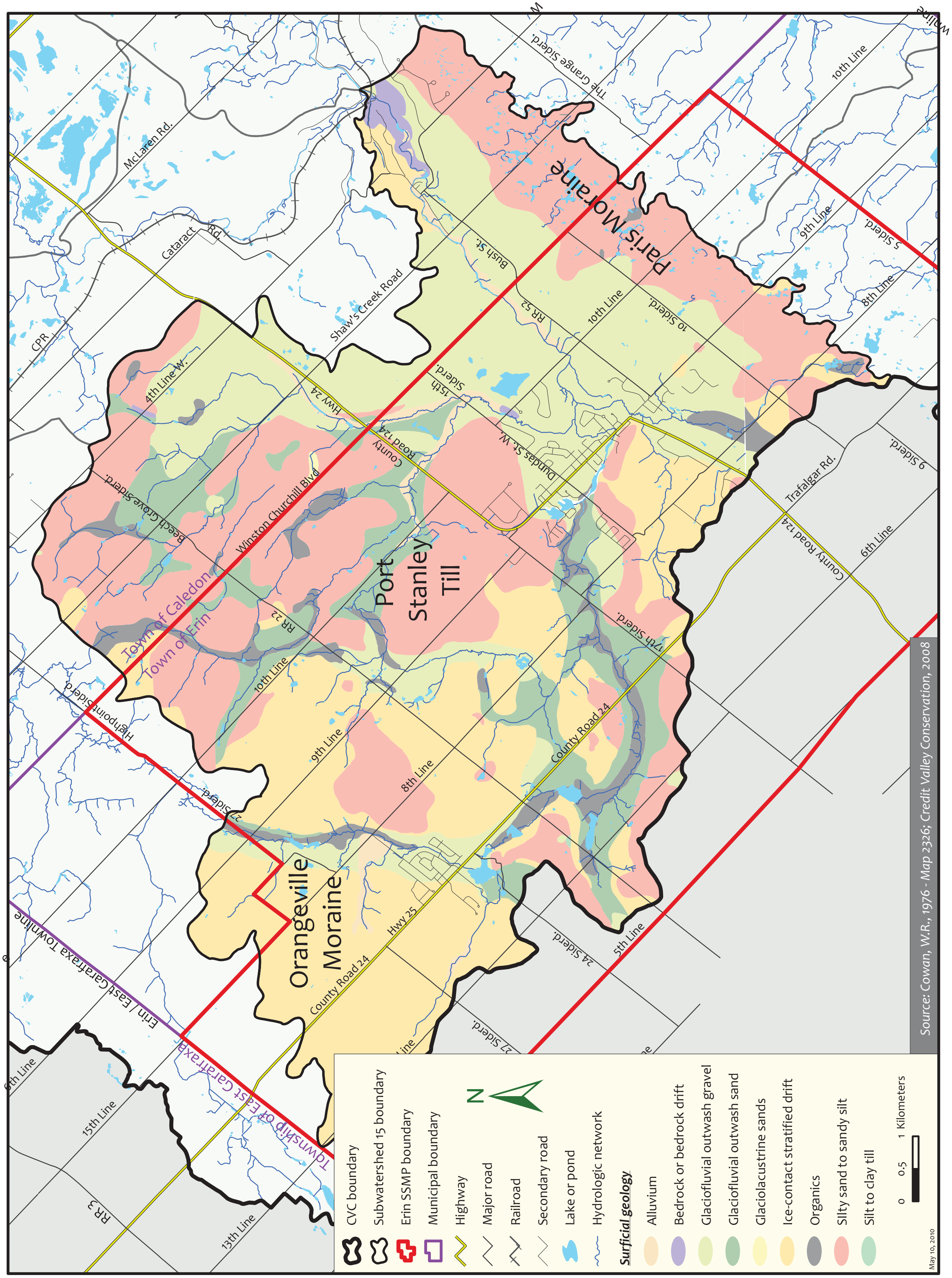
- The surficial geology is characterized by five main geologic units representing three types of geologic conditions. Two units are tills of similar characteristics, two units are glacial outwash sands, and one unit is ice-contact sand and gravel.

Figure 2.1.1 Topographic Relief



Source: Credit Valley Conservation, 2008

Figure 2.1.2 Surficial Geology



Source: Cowan, W.R., 1976 - Map 2326; Credit Valley Conservation, 2008

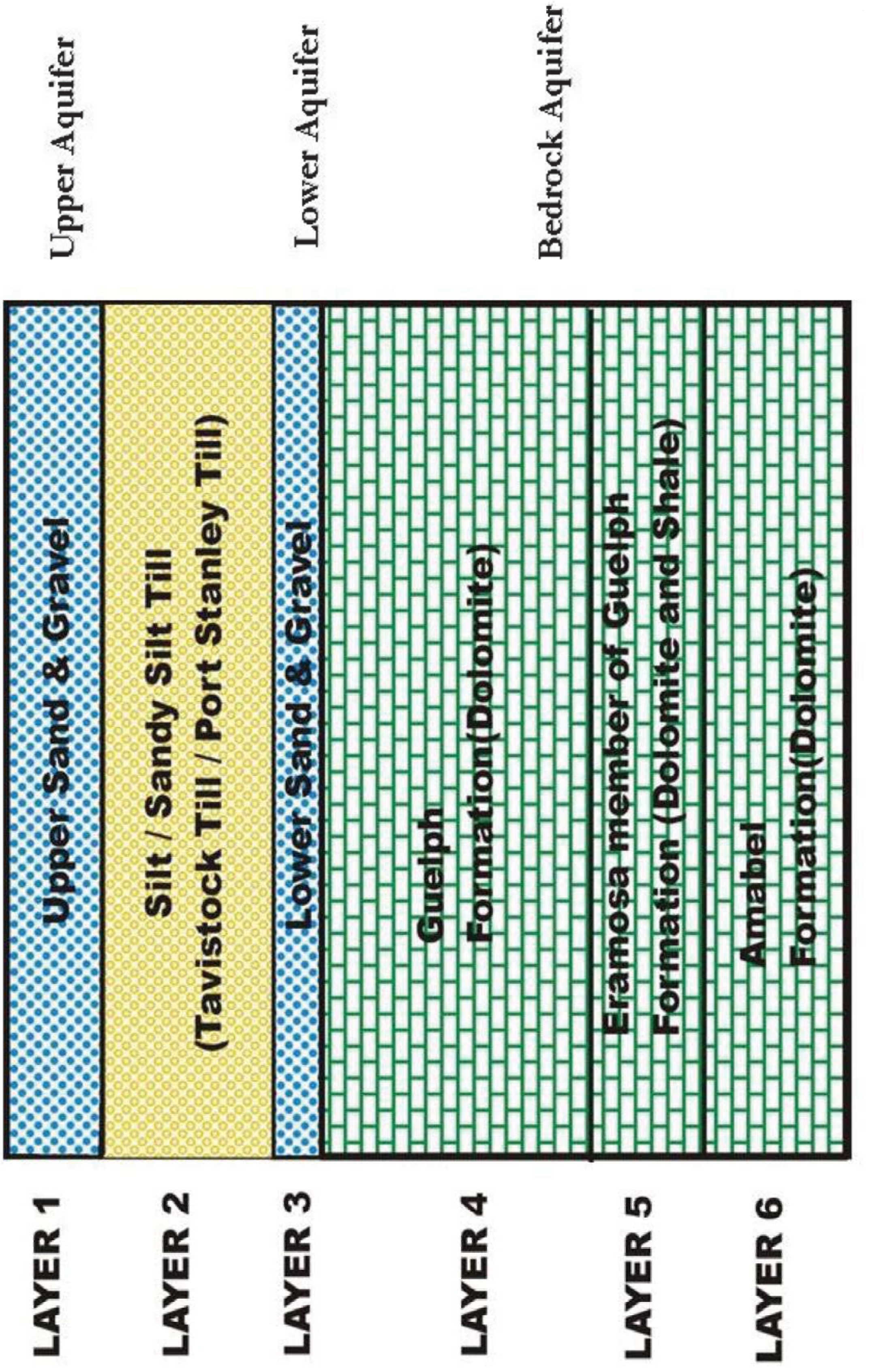
- The two major till units present, are the Port Stanley Till and the Wentworth Till, both described as sandy silt tills. The Port Stanley Till is present throughout much of the central portion of the subwatershed. The Wentworth Till is present in the southeastern portion of the subwatershed as part of the Paris Moraine. These units typically have a moderately low infiltration rate, especially in the Port Stanley Till. The Wentworth Till however, because of the hummocky nature of the ground surface of the Paris Moraine, has a greater recharge as more water is "trapped" in depressions and will continually infiltrate to the water table.
- The major upland area in the western portion of the subwatershed (Hillsburgh Sandhills) is comprised of ice-contact sand and gravel with some till present. Ice-contact sand and gravel is deposited at the edge of a melting glacier. Much of this area is part of the Orangeville Moraine, which is also quite hummocky. This unit provides a significant potential for groundwater recharge, given the highly permeable nature of the geologic material, the high relief, and the hummocky terrain minimizing runoff. The West Credit River cuts through this area creating a low relief valley, providing considerable opportunity for groundwater to discharge to this portion of the river.
- Extensive glaciofluvial outwash sands are present between the two major till units. The lower portion of the West Credit River flows through these outwash sands. Numerous gravel pits are located within this unit.

2.1.2.3 Subsurface Geology

The subsurface geology of the West Credit River subwatershed is comprised of a variable thickness of glacier deposited material, as a result of numerous ice advances and retreats 10,000 to 70,000 years ago. Underlying this material is bedrock consisting primarily of dolostone. As part of the West Credit Subwatershed Study (CVC 1998[a]) and the Town of Erin Groundwater Management Study (Blackport Hydrogeology Inc. 2005) the subsurface geology within the study area was interpreted using water well records on file with the Ministry of Environment (MOE).

Figure 2.1.3 shows the interpreted conceptual geologic model for the study area as developed from the Quaternary geology interpretation by Cowan, (1976) and the interpretation of the water well records (Blackport Hydrogeology Inc. 2005). These units formed the basis for the construction of a three-dimensional groundwater flow model developed for the *West Credit Subwatershed Study, Phase 2 Impact Assessment* report (CVC 2001[b]) and the Town of Erin Groundwater Management Study (Blackport Hydrogeology Inc. 2005). These geologic units may vary in thickness throughout the area and in fact may not be continuous throughout the entire study area. The following provides a brief description of each layer and the geologic units or properties associated with the layer as adapted from the Town of Erin Groundwater Management Study (Blackport Hydrogeology Inc. 2005):

Figure 2.1.3 Conceptual Geologic Model



Source: Cowan, 1976; Blackport Hydrogeology Inc., 2005

May 19, 2010

Layer 1 - Layer 1 is comprised of the permeable surficial geologic units, primarily associated with kame moraine, till moraine, or ice contact sand and gravel deposits of the Orangeville Moraine and the Paris Moraine as discussed in the previous section, Section 2.1.2.2. These units are capable of providing a high volume of recharge to the groundwater system. The units are not continuous throughout the study area, but are present in most of the high relief areas creating a significant potential for recharge to the groundwater system in these areas. This is interpreted to be an upper aquifer unit.

Layer 2 - Layer 2 consists of several till units mapped throughout the study area. The two major till units present are the Port Stanley Till and the Wentworth Till, both sandy silt tills. In some areas, the uppermost till is exposed at ground surface, while in other areas these tills underlie the upper sand and gravel of Layer 1. The Port Stanley Till is present at ground surface throughout much of the area north of Erin Village. The Wentworth Till is present in the south and south-eastern portion of the study area and is part of the Paris Moraine. These units are interpreted to have a moderate to low permeability and typically act as aquitards, although they may be “leaky” locally in some areas, where the units are very thin.

Layer 3 - Below the till units described in Layer 2 and immediately above bedrock are discontinuous sand and gravel glaciofluvial deposits. These areas may be exposed at ground surface in the valleys, especially in areas where bedrock is near ground surface. These units are typically hydraulically connected to the upper bedrock. The upper bedrock and this sand and gravel layer will typically act as one aquifer unit.

Layer 4 - The uppermost bedrock unit in the Town of Erin consists predominantly of the Guelph Formation, an extensive dolostone (also known as dolomite) unit that is a major water bearing formation throughout the Town. Layer 4 is the Guelph Formation consisting of a cream and brown, porous fine to medium crystalline dolomite. The upper portion of the Guelph Formation is typically fractured and can produce a considerable quantity of water, locally. The majority of private water wells are located in this unit.

Layer 5 - The Eramosa Member of the Guelph Formation forms the bottom of the Guelph Formation. This unit is more massive bedded and consists of dolomite interbedded with shale. This unit typically does not produce much water, compared to the bedrock units above and below it, and in some areas may in fact act as a confining layer for the deeper bedrock, depending on the extent of vertical fracturing.

Layer 6 - The Amabel Formation underlies the Eramosa Member of the Guelph Formation. It is a gray to blue-gray medium crystalline dolomite. This unit is also capable of producing substantial quantities of water. Much of the water produced from the municipal wells for Erin Village and Hillsburgh is produced from this unit. Typically well records report major fracture zones at depth.

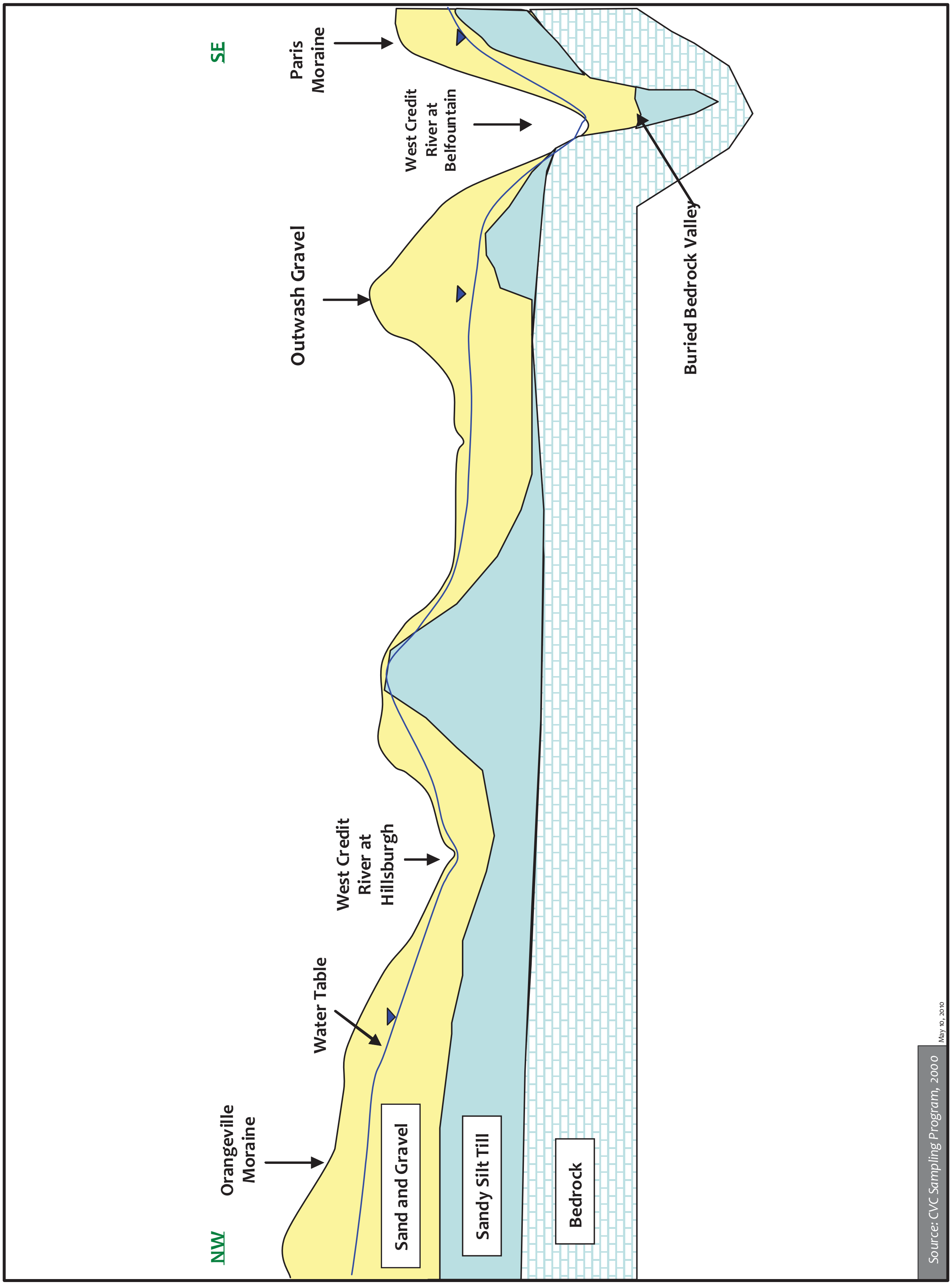
A database, developed from the MOE water well database, was used to construct geologic cross-sections throughout the Town of Erin as part of the Groundwater Management Study (Blackport Hydrogeology Inc. 2005). A total of 23 geologic cross-sections were constructed using over 800 MOE water well records as part of the development of a groundwater flow model for the groundwater study. These cross-sections were not reproduced in this report; however **Figure 2.1.4** shows a simplistic schematic geologic cross-section in a general west-east direction through the subwatershed.

Using information from the water well records, an overburden thickness map can be developed. **Figure 2.1.5** shows the interpreted overburden thickness throughout the West Credit River subwatershed as adapted from AquaResource (2006). The interpreted bedrock topography is shown in **Figure 2.1.6** as adapted from AquaResource (2006). This information is from the *Interim Watershed Characterization Report for the Credit River Watershed* (CVC 2007).

The following summarizes the general interpretation of the geologic conditions in the study as adapted from the Town of Erin Groundwater Management Study (Blackport Hydrogeology Inc. 2005):

- The surficial sand and gravels found in the Orangeville Moraine (i.e., the northwest portion of the study area, north of Hillsburgh) are relatively thick but typically do not extend to bedrock. A lower permeability till unit appears to be present above bedrock in this area providing natural protection to the bedrock aquifer.
- Overburden thickness is up to 45 metres thick in the area of the Orangeville Moraine, except in the valley areas, where the overburden has been eroded and is much thinner. The sandy silt tills present in the central portion of the study area (between Erin Village and Hillsburgh) appear to extend to depth. There does not appear to be any extensive sand and gravel (aquifer) units at depth in this area. The overburden is still relatively thick (greater than 30 metres) throughout this area.
- The area of outwash gravels present in the area of the northern tributaries (e.g., near County Rd. 124 and Winston Churchill Blvd.) appear to extend to the bedrock at many locations. The overburden thins considerably in this area and is on the order of 5-15 metres thick at many locations. It was noted in the Town of Erin Groundwater Management Study that this is an area where baseflow is lost in a number of tributaries (i.e., the tributaries are losing streams), as the tributaries flow off the till onto the outwash sand and gravel.
- Bedrock topography (**Figure 2.1.6**) indicates a bedrock high north of Hillsburgh with regional topographic slope towards the main branch of the West Credit River at Erin Village. There is a deep bedrock valley present in the downstream portion of the subwatershed that extends almost to Erin Village. This deep bedrock valley controls deeper groundwater flow to the east of Erin Village, and is discussed in more detail the next section.

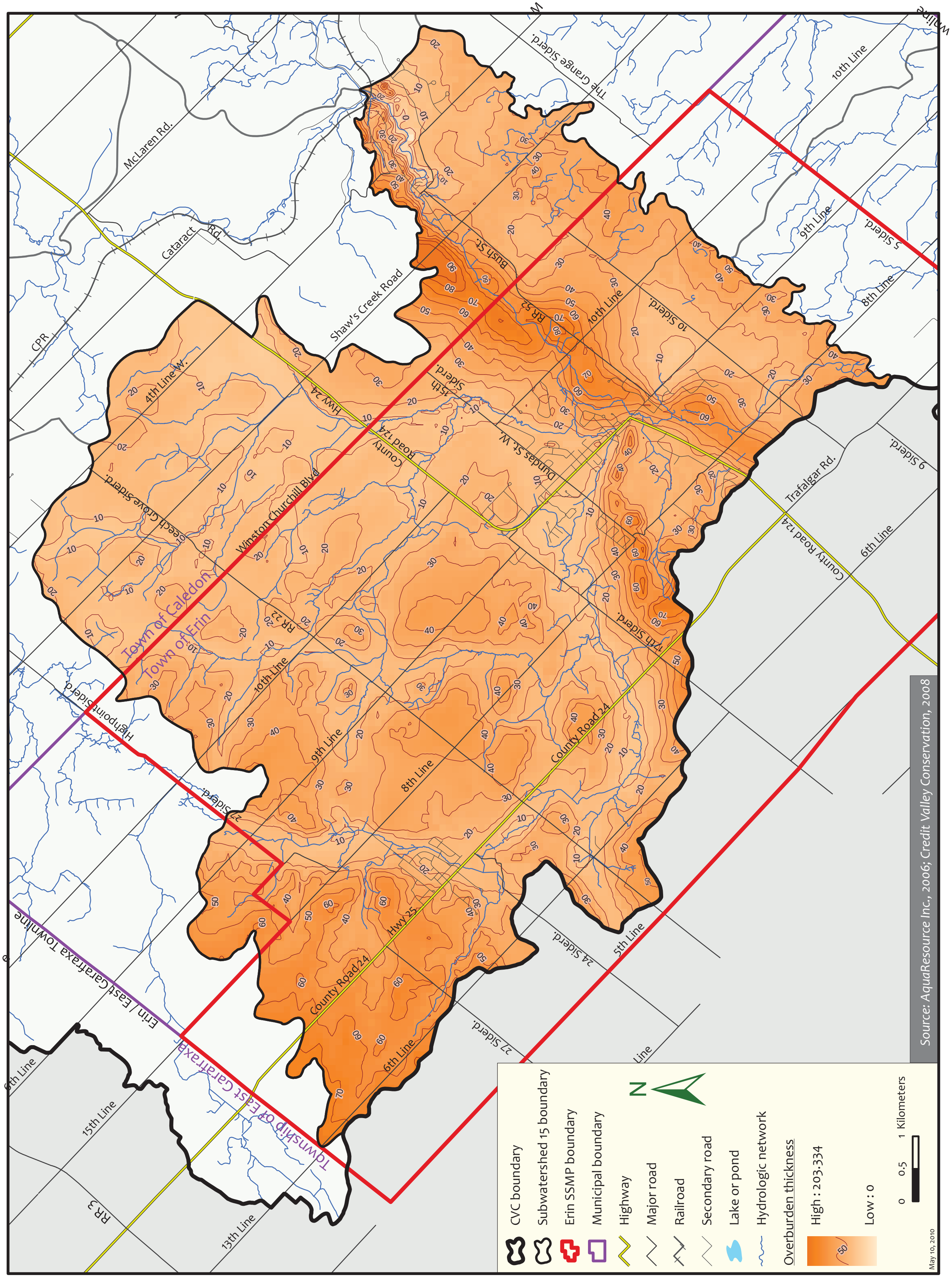
Figure 2.1.4 Schematic Geologic Cross-section



Source: CVC Sampling Program, 2000

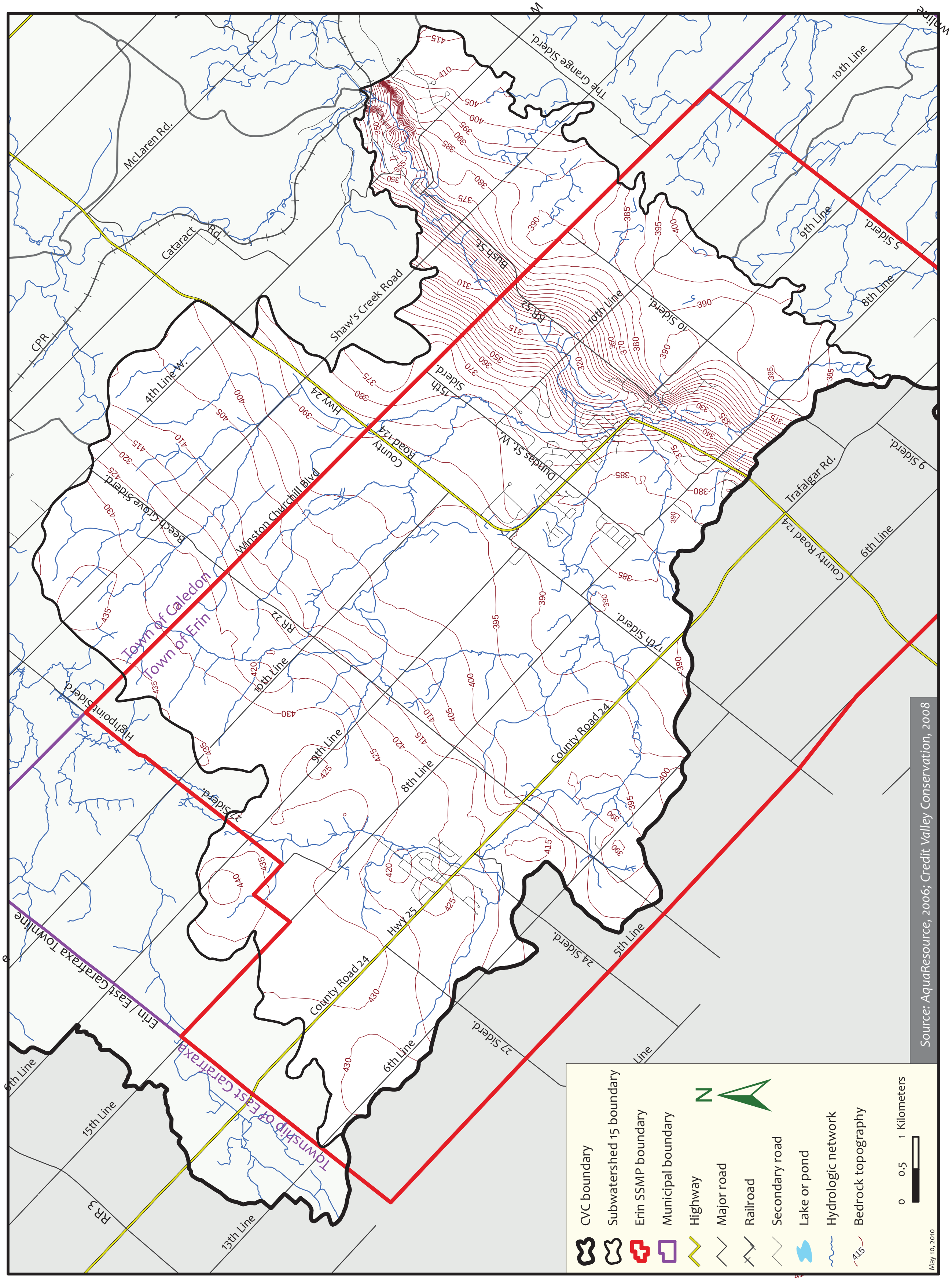
May 10, 2010

Figure 2.1.5 Overburden Thickness



Source: AquaResource Inc., 2006; Credit Valley Conservation, 2008

Figure 2.1.6 Bedrock Topography



Source: AquaResource, 2006; Credit Valley Conservation, 2008

2.1.3 Groundwater Flow

2.1.3.1 Water Table Conditions and Shallow Aquifer Flow

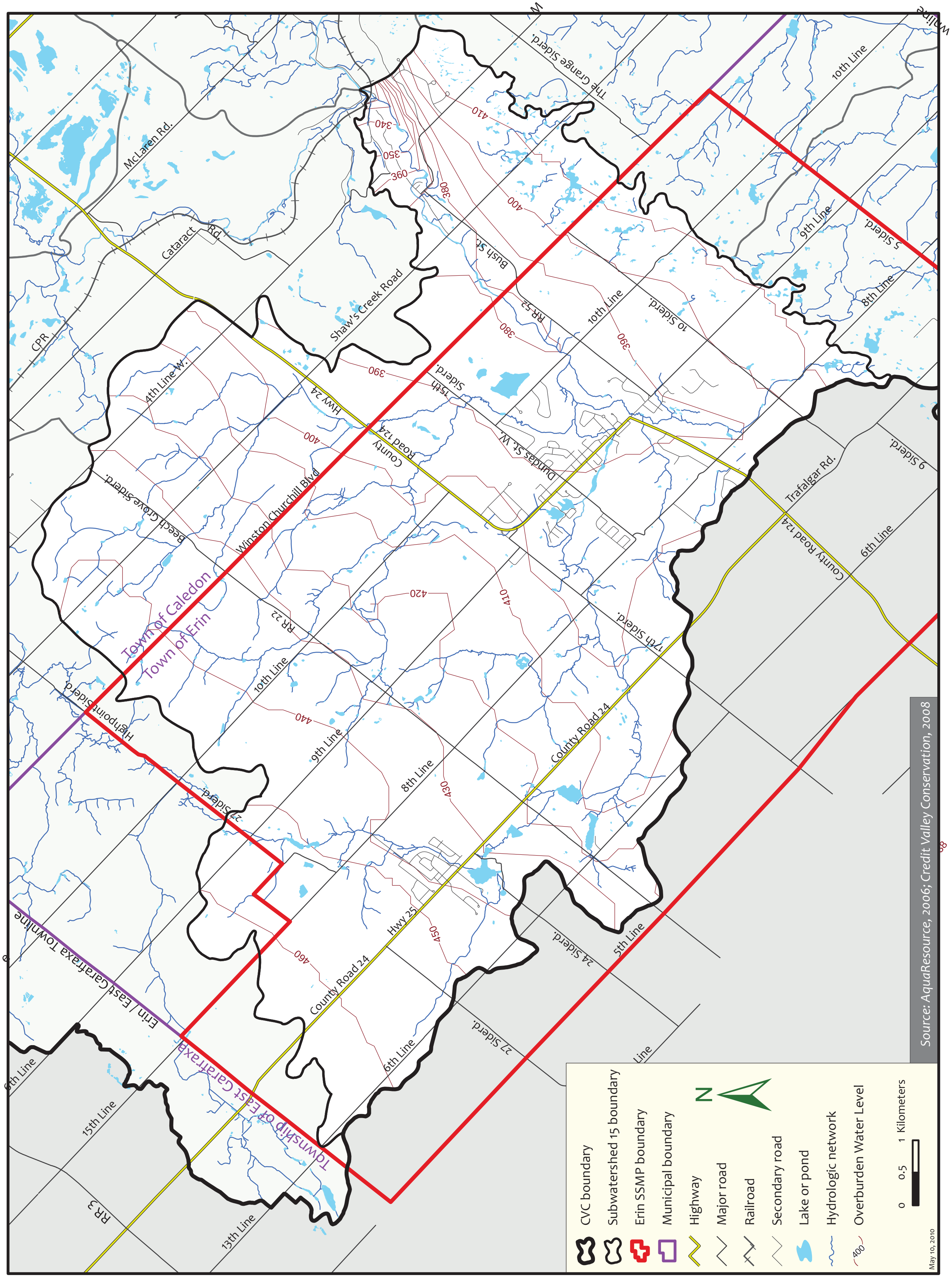
Regional water table mapping has been generated in several previous studies [e.g., Town of Erin Groundwater Management Study (Blackport Hydrogeology Inc. 2005); and the Source Water Protection Report, *Interim Watershed Characterization Report for the Credit River Watershed* (CVC 2007)] using water levels from shallow water wells and elevations of major surface water features.

Figure 2.1.7 shows the interpreted water table contours throughout the general study area as taken from the Town of Erin Groundwater Management Study. As seen in **Figure 2.1.7** groundwater flow is generally north to south through the study area following the general topographic relief (**Figure 2.1.1**). Water level elevations range from about 475 m above mean sea level (amsl), in the northern portion of the study area, north of Hillsburgh, to 360 m amsl towards the southern boundary of the Town, south of the study area. Locally, groundwater flow is controlled or influenced by the local topographic lows (i.e., valleys) in some areas, typically where major surface water features exist. These areas will typically create local groundwater discharge areas where the topographic lows intersect the water table.

The following is noted, with respect to water table conditions throughout the general study area, as summarized from the Town of Erin Groundwater Management Study (Blackport Hydrogeology Inc. 2005):

- The regional water table contours generally follow the topographic relief. The highest water table contours generally coincide with the regional high relief areas. Regional groundwater flow in the study area originates north of Hillsburgh, in the areas of highest relief within the Orangeville Moraine.
- There is a relatively steep decline in the water table moving away from the topographic high, with water levels declining from 465 m amsl to 400 m amsl entering the valley areas near Erin Village, Brisbane, and Ospringe, where the water table flattens considerably in the low relief areas.
- The areas of low water table generally correspond to areas of low topographic relief (**Figure 2.1.7**) and topographic lows in the bedrock surface (**Figure 2.1.6**). It is interpreted that the lower water table levels are controlled by the bedrock lows throughout the general study area.
- There are several local water table highs in the south part of the study area, south of Erin Village. These areas generally correlate to local high bedrock topography (**Figure 2.1.6**) and the Paris Moraine, where there is increased recharge.

Figure 2.1.7 Interpreted Water Table Contours



Source: AquaResource, 2006; Credit Valley Conservation, 2008

May 10, 2010

2.1.3.2 Bedrock Water Levels and Groundwater Flow in the Bedrock

Bedrock water levels from water wells installed in the bedrock were also compiled as part of the previously noted studies and were used to interpret the groundwater flow in the bedrock aquifer system. **Figure 2.1.8** shows the interpreted groundwater levels in the bedrock aquifer as adapted from the AquaResource (2006) from the *Interim Watershed Characterization Report for the Credit River Watershed* (CVC 2007). The following general interpretations are noted:

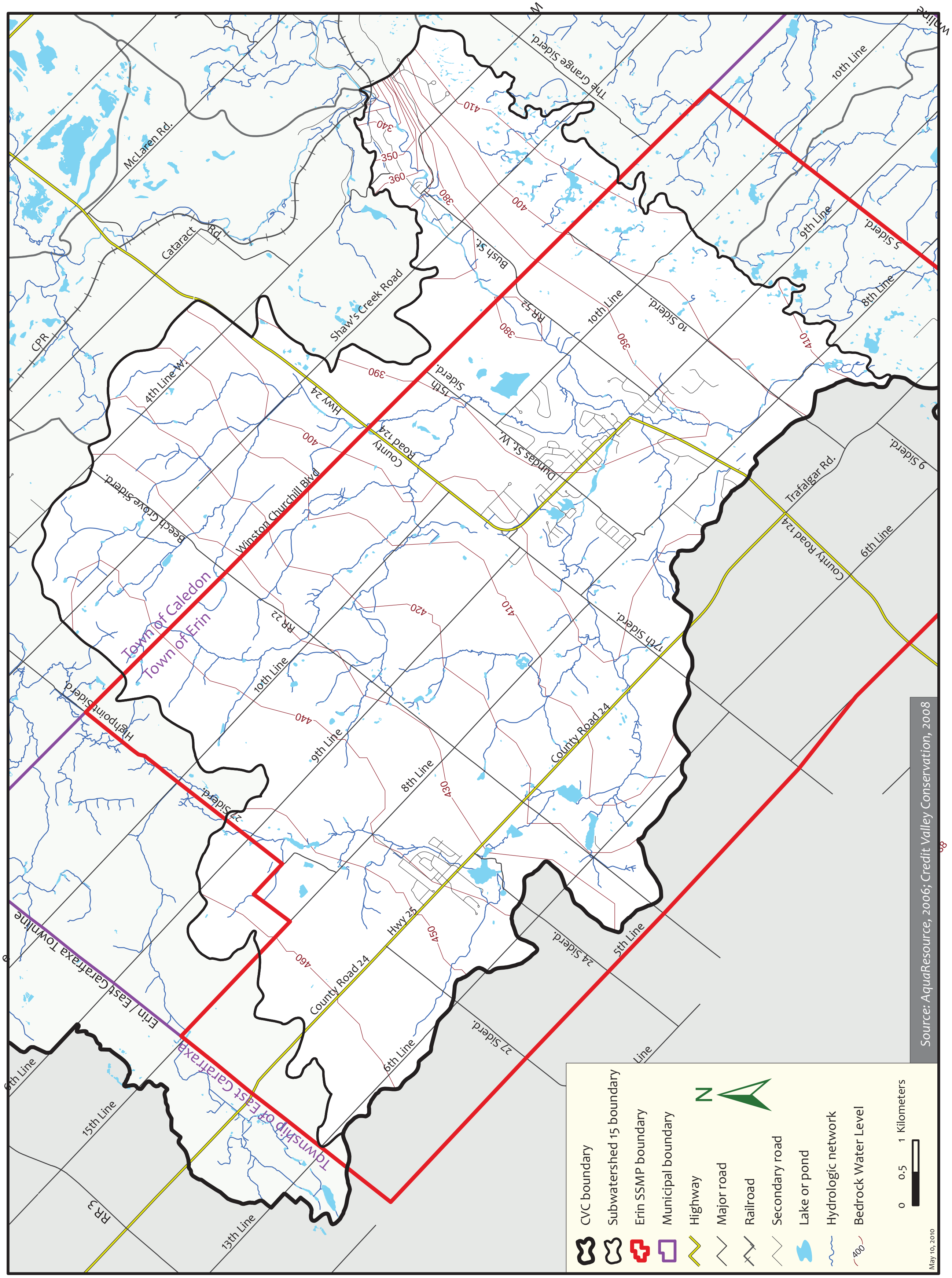
- Interpreted water level contours in the bedrock generally mimic the water table contours, but are typically lower by 10-20 metres.
- Water levels in the bedrock range 470 m amsl in the northwest of Hillsburgh to less than 350 m amsl in the bedrock valley to the east of Erin Village.
- Regional groundwater flow in the bedrock is generally northwest to southeast. Locally, there is groundwater flow easterly out of the Town of Erin, where groundwater flow is controlled by the elevation of the deep bedrock valley east of Erin.
- There is an interpreted local groundwater divide west of the Town of Erin, where groundwater flows south-westerly, generally following the lower bedrock relief into the Grand River watershed.

2.1.3.3 Groundwater Recharge and Regional Groundwater Flow

Figure 2.1.9 shows the interpreted recharge rates throughout the general study area. The major recharge areas are primarily the areas of higher elevations (**Figure 2.1.1**) with more permeable sand and gravel at ground surface (**Figure 2.1.2**). The rate of recharge is relatively high throughout the West Credit River subwatershed, resulting in a significant contribution of groundwater to baseflow in the West Credit River. There is also a significant contribution to the baseflow of tributaries of the Eramosa River and Blue Springs Creek within the Grand River watershed, to the west of the general study area. Recharge rates of greater than 300 mm can be expected in many areas, however the average recharge throughout the Town of Erin is estimated to be 160-200 mm (CVC 2001[b]).

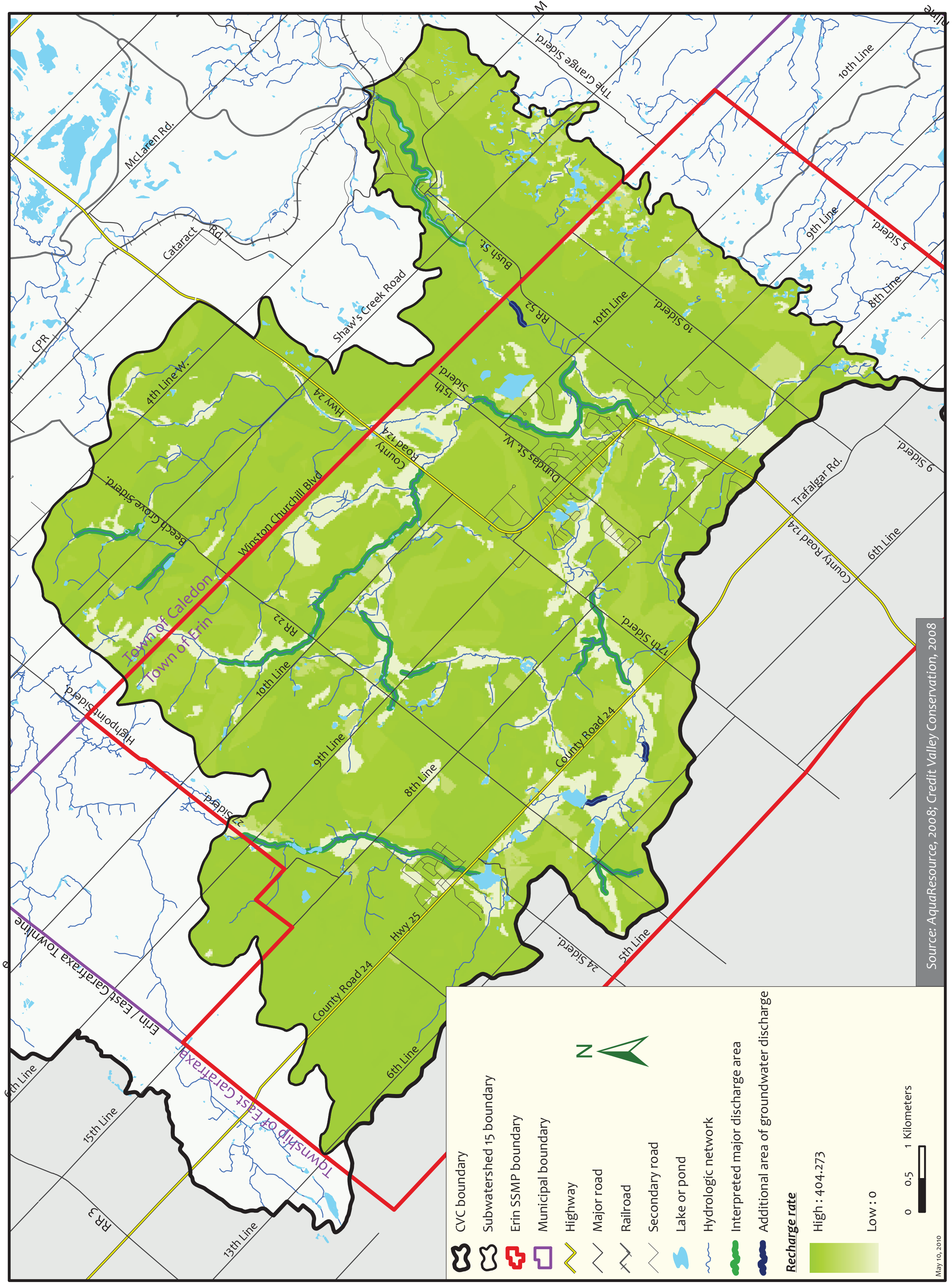
There is generally a regional downward component to groundwater flow throughout the West Credit River subwatershed indicating recharge conditions are prevalent throughout the subwatershed. Water that recharges or infiltrates to the water table in the areas of higher elevation will follow the path of least resistance through the groundwater flow system. If there is an extensive low permeability till unit underlying the sand and gravel then the much of the groundwater will not move to depth and likely discharge as baseflow to a local surface water feature. If there is a good hydraulic connection to the deeper groundwater system, then much of the water is likely to move to the lower aquifer system.

Figure 2.1.8 Interpreted Bedrock Water Levels



Source: AquaResource, 2006; Credit Valley Conservation, 2008

Figure 2.1.9 Interpreted Recharge and Discharge Areas



Source: AquaResource, 2008; Credit Valley Conservation, 2008

The groundwater flow becomes more focused into the bedrock valley (east of Erin Village) with depth indicating much of the bedrock groundwater is discharging regionally into the bottom end of the subwatershed or moves easterly, outside the subwatershed to the main branch of the Credit River.

The main recharge areas are located in the sands and gravels of Orangeville Moraine, north of Hillsburgh, and the Paris Moraine area southeast of Erin Village (**Figure 2.1.2**). The underlying bedrock is the main water supply aquifer for the subwatershed as well as much of this part of Ontario.

2.1.3.4 Baseflow and Groundwater Discharge

The *West Credit Subwatershed Study, Phase 1 Characterization* report (CVC 1998[a]) identified regional and local discharge conditions throughout the subwatershed. The results of the groundwater studies are found in Appendix A of the *Draft Phase 1 Addendum* report (CVC 2001[a]) and will not be presented in detail here. A major part of the hydrogeological component of the West Credit Subwatershed Study was the identification of existing regional and local discharge conditions throughout the West Credit River and its tributaries within the subwatershed (**Figure 2.1.9**).

Discharge of groundwater to streams maintains baseflow. The two main functions of baseflow with respect to aquatic habitat are to maintain volumetric baseflow and to contribute to direct discharge (i.e., upwelling) through the stream bed. The volume of baseflow is critical to maintain a minimum depth of water in the various stream channels and to moderate temperatures, cooling in the summer and warming in the winter. This is important to maintain fisheries habitat and the general health of the stream.

The baseflow could be potentially important to the Erin SSMP, depending on potential waste water treatment options, with respect to the assimilative capacity of the West Credit River. Baseflow contribution is variable across the West Credit River subwatershed. Baseflow is also quite variable throughout the year. Seasonal variations are generally a function of water table conditions, with typically higher spring and late fall conditions producing higher baseflow then during the summer. It will be important to understand the baseflow conditions, as well as water quality conditions, in assessing the assimilative capacity of the West Credit River. Previous assimilative capacity studies have been conducted using data from the CURB studies (Triton Engineering Services Limited 1995).

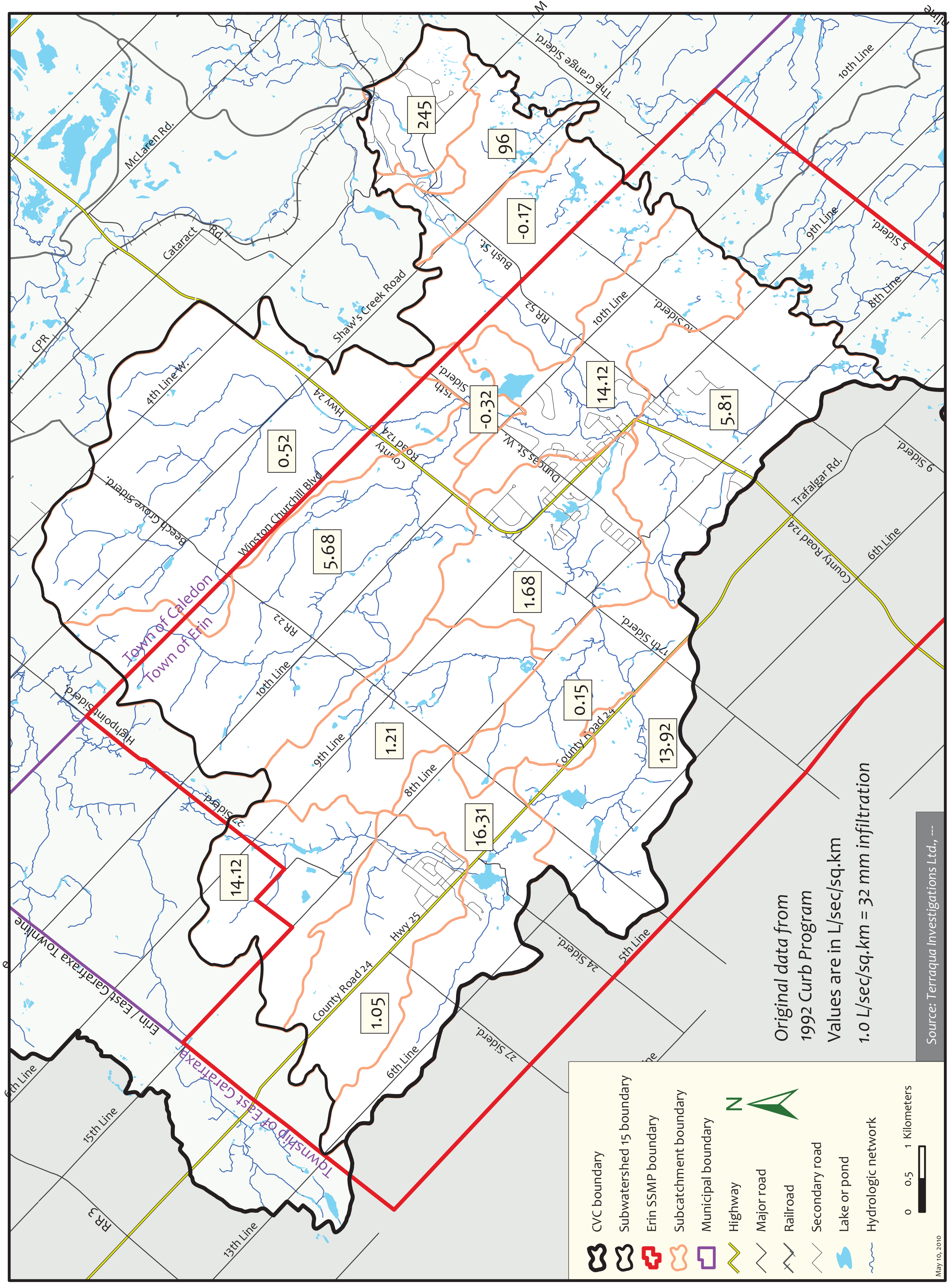
Historical surface flow data is available for the West Credit River subwatershed. Spot baseflow was collected during the subwatershed study (CVC 1998[a], and 2001[a]), mostly at the same locations as those collected for the CURB studies, to supplement historical flow data from the flow gauge upstream of Erin Village.

The general findings of baseflow investigations in previous studies of the West Credit River can be summarized as follows:

- The West Credit River maintains a high volume of baseflow relative to most of the Credit River watershed. Baseflow, at least above Erin Village, where the continuous flow gauge is present on 8th Line, is the equivalent of 349 mm of precipitation annually. This is approximately 40% of the total precipitation and is almost double the average baseflow elsewhere in the Credit River.
- The contribution to baseflow is highly variable throughout the subwatershed as a result of variable recharge rates (surficial geologic conditions), location in the groundwater flow system (i.e., local, intermediate, or regional flow), and topographic relief. **Figure 2.1.9** shows the previously interpreted areas of major baseflow in the West Credit River.
- The majority of discharge to the West Credit River originates from local recharge within the subwatershed. The main contributing areas to baseflow on the West Credit River are: the Orangeville Moraine north of Hillsburgh; the Paris Moraine in south of Erin Village; and, portion of the outwash sands and gravels in the central portion of the study area.
- The area downstream of Erin Village and the area upstream of Belfountain both show significant increases in baseflow. The most significant increase in baseflow is in the most downgradient portion of the West Credit, near Belfountain. It was interpreted that this area is a regional discharge area. This is the result of a significant decrease in topographic relief in the area and the presence of a deep buried bedrock valley "channeling" regional groundwater flow (towards the buried valley). Much of the baseflow "gained" in this area likely originates from the area of the northern tributaries, in the northeast portion of the study area.

Selected data from the collection of baseflow data from the West Credit River Subwatershed Study (CVC 1998[a], 2001[ab]) is presented in **Figures 2.1.10 to 2.1.13** to illustrate variations in baseflow contribution and discharge areas in the West Credit River subwatershed. **Figure 2.1.10** shows the contribution to baseflow for various subcatchments in the subwatershed during low flow conditions from data collected in August 1992. The values represent the contribution to baseflow within each subcatchment in L/sec/km^2 of each subcatchment. It is noted that 1.0 L/sec/km^2 is equal to 32 mm of infiltration discharging within the subcatchment. The contribution is based on subtracting the flow measured at the upstream station of the subcatchment from the downstream station of the subcatchment and dividing by the area of the subcatchment. **Figure 2.1.11** shows the results for the same baseflow data, but presented as cumulative baseflow within the subwatershed. The values represent the total flow upstream of each subcatchment divided by the total area upstream of the subcatchment, including the subcatchment area. **Figures 2.1.12** and **2.1.13** show the same assessment but for a high baseflow period in November 1995. The following is noted with respect to baseflow contribution within the West Credit River subwatershed:

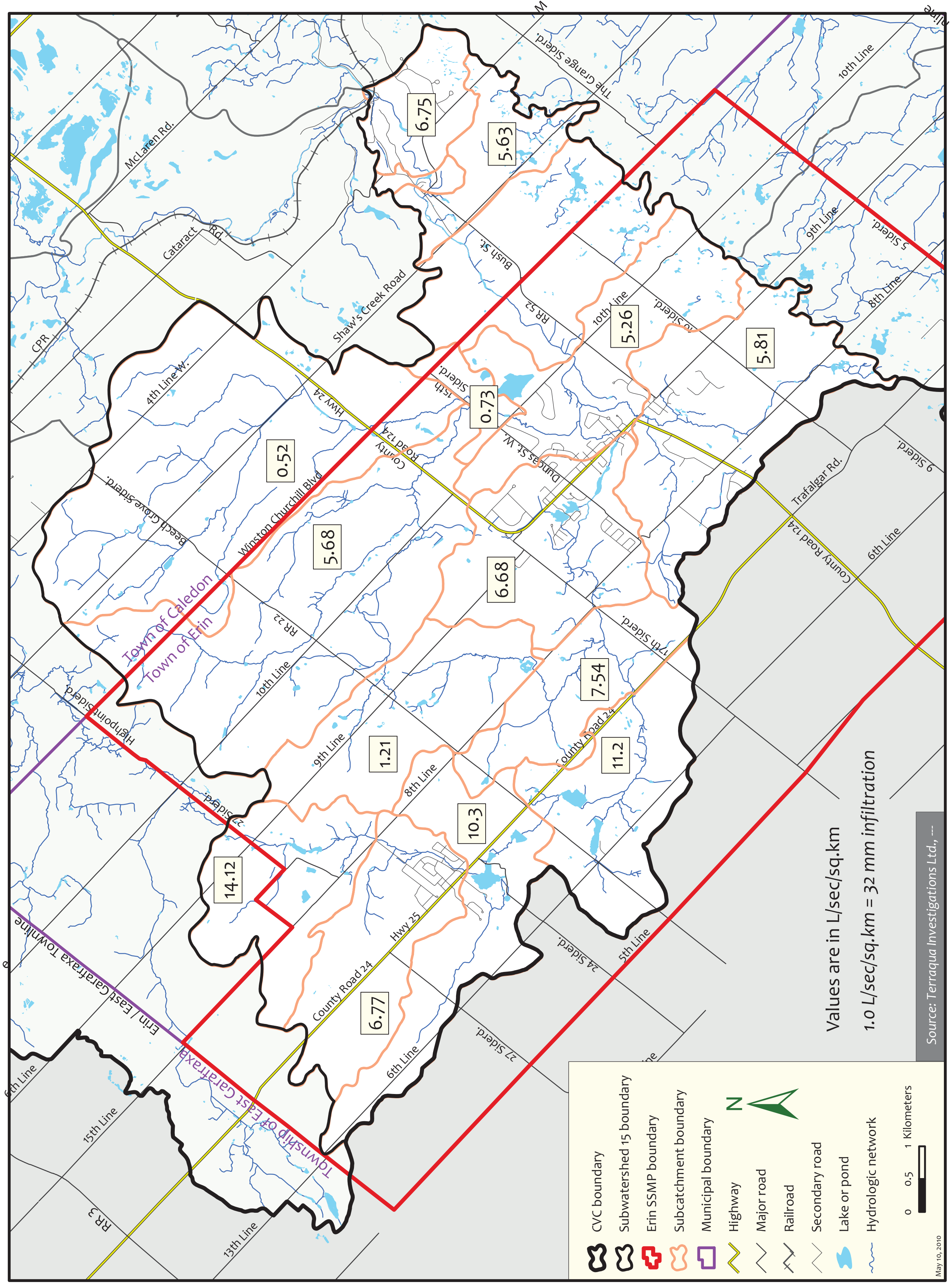
Figure 2.1.10 Subcatchment Contribution to Baseflow, August 1992



Original data from 1992 Curb Program
Values are in L/sec/sq.km
1.0 L/sec/sq.km = 32 mm infiltration

Source: Terraqua Investigations Ltd., ---

Figure 2.1.11 Cumulative Baseflow, August 1992

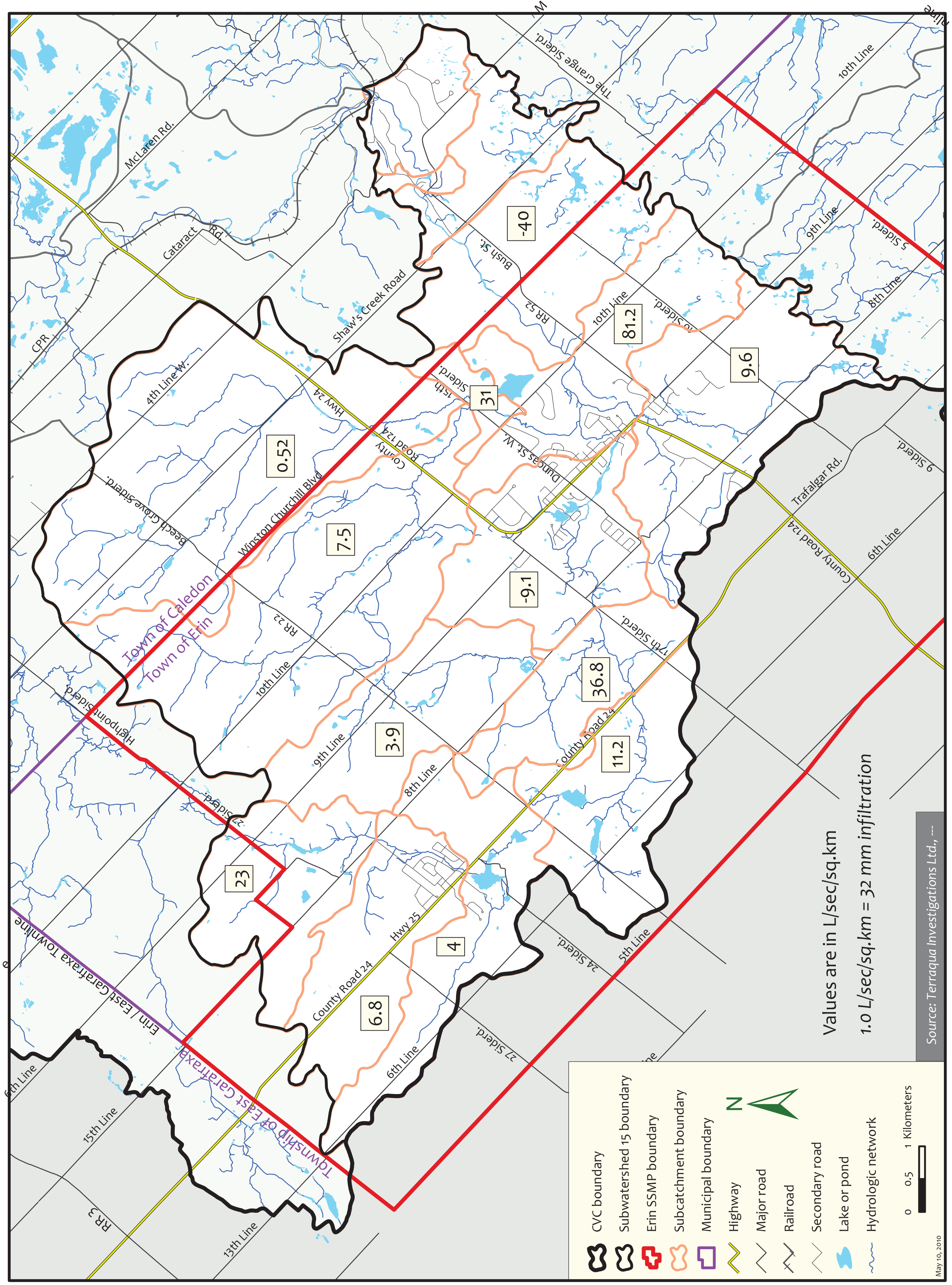


Values are in L/sec/sq.km

1.0 L/sec/sq.km = 32 mm infiltration

Source: Terraqua Investigations Ltd., --

Figure 2.1.12 Subcatchment Contribution to Baseflow, November 1995

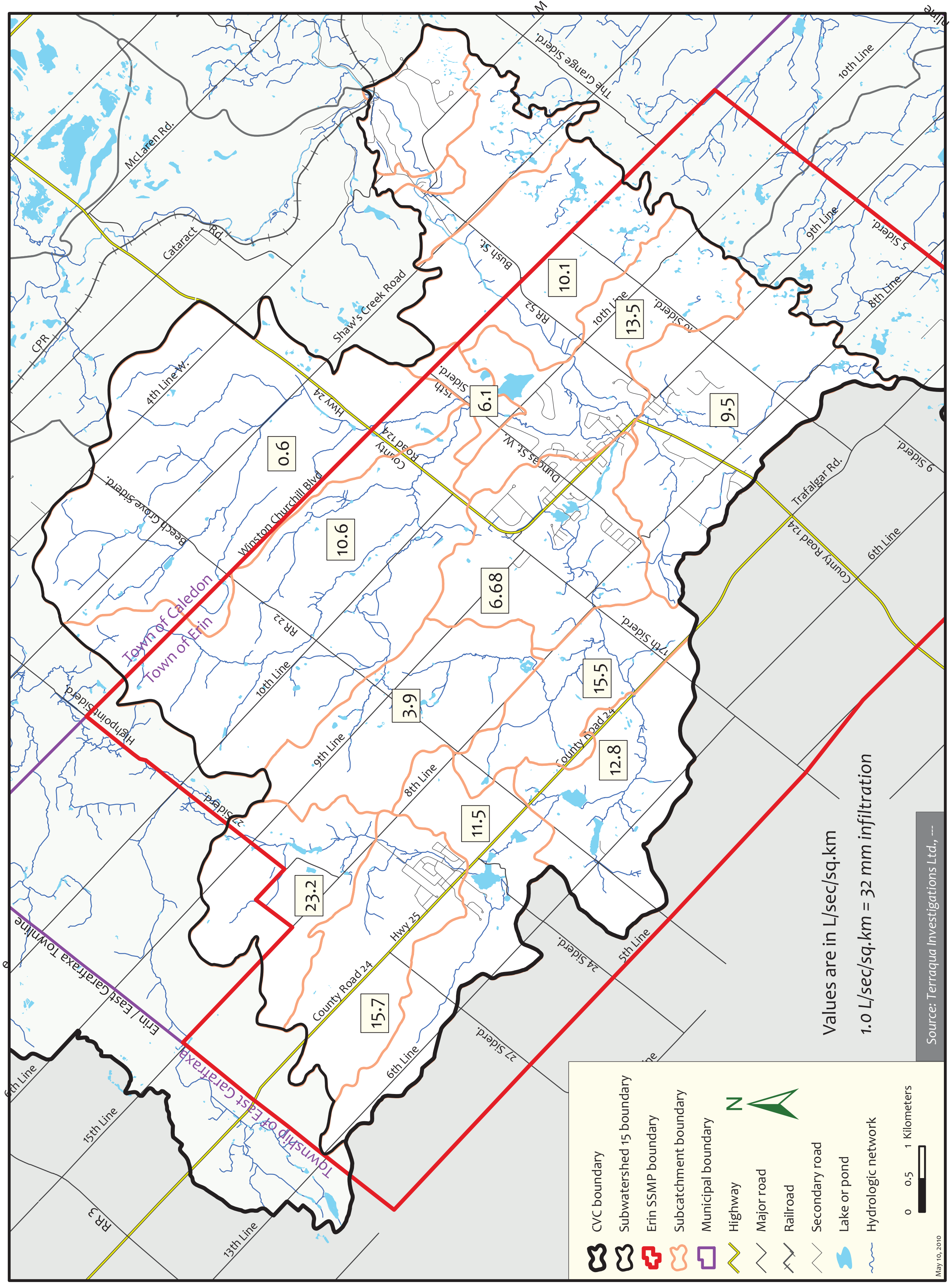


Values are in L/sec/sq.km

1.0 L/sec/sq.km = 32 mm infiltration

Source: Terraqua Investigations Ltd., ---

Figure 2.1.13 Cumulative Baseflow, November 1995



Values are in L/sec/sq.km

1.0 L/sec/sq.km = 32 mm infiltration

Source: Terraqua Investigations Ltd., --

May 10, 2010

- **Figure 2.1.10** shows the wide variation in baseflow contribution moving downstream along the main branch of the West Credit River. Based on the August 1992 "snapshot" of baseflow it is interpreted that there is little contribution to baseflow within the Hillsburgh reach, in the western portion of Erin Village and upstream of Erin Village, and upstream of Shaw's Creek Road. In contrast, there was a substantial gain in baseflow downstream of the core area of Hillsburgh, and downstream of Erin Village. The largest relative gains however were in the extreme downstream reaches, near Belfountain where it appears there is considerable discharge from the regional groundwater flow system. It is noted that the northern tributaries, to the northeast of Erin Village, show a loss of baseflow (-0.32 L/sec/km^2), where the tributaries flow into the outwash sand and gravel (**Figure 2.1.2**).
- **Figure 2.1.11** shows the variation in cumulative baseflow throughout the subwatershed, during low flow conditions. There is a general decrease in cumulative baseflow contribution moving downstream along the main branch of the West Credit River, until the approaching the most downstream reaches of the West Credit River. The Hillsburgh reach is the exception, where there is a greater decrease in cumulative flow, but much of this flow is regained south of the core area of Hillsburgh.
- **Figure 2.1.12** shows the variation in subcatchment baseflow during a "snapshot" of high baseflow in November 1995. Compared to the August 1992 baseflow snapshot there is some gain in flow through Hillsburgh and a substantial gain upstream of Erin Village, however the largest gain was downstream of Erin Village (no flows were collected near Belfountain). It is also noted that the northern tributaries, east of Erin Village (the Binkham tributaries) now show a substantial gain in baseflow compared to a loss, as indicated in first bullet. Also of note is an apparent loss in baseflow in the western portion of Erin Village.
- **Figure 2.1.13** shows the variation in cumulative baseflow for the November 1995 snapshot. Cumulative baseflow appears to be more consistent along the main branch of the West Credit River, compared to during the low flow snapshot. Cumulative baseflow, immediately downstream of Erin Village was more than double the baseflow compared to the baseflow conditions for low flow snapshot.

Additional baseflow and water quality data was collected as part of the septic system impact assessment (Section 2.8). The local baseflow conditions for Erin Village and Hillsburgh are discussed in more detail in Section 2.8.7, related to understanding water quality and mass loading along various reaches and tributaries of the West Credit River. The more recent data collection does indicate the following, relative to the previous interpretation of groundwater discharge as shown in **Figure 2.1.9**:

- Baseflow data obtained from additional stations along the reach of the West Credit River through the core area of Hillsburgh clearly show this reach is a losing stream, as baseflow decreases through this area. This decrease is based on geological conditions, with flow being “lost” into an outwash sand and gravel underlying this portion of the West Credit River.

- The gaining and losing portions of the West Credit River through the Erin Village area is variable and recharge/discharge conditions are more complex than previously interpreted. The implications are discussed in more detail in Section 2.8.7.

2.1.4 Groundwater Usage

There are many groundwater uses within the study area including: municipal drinking water, private water wells, commercial water taking, aquaculture, agriculture, industrial, and commercial uses. The following is a general overview of groundwater usage throughout the Town of Erin.

2.1.4.1 Private Residential Water Supplies

All residential drinking water supplies in the Town of Erin are from water wells. There are approximately 2300 private domestic water wells in the Town of Erin. The majority of the wells obtain water from the bedrock aquifer system. It is estimated that less than a third of these wells are located in the general study area. Private residential wells typically pump sufficient water to meet the daily needs of individual residences, usually on the order of 1000-2000 L/day. This water is not all lost from the groundwater system since it is re-circulated to the shallow groundwater, via septic systems. This water may ultimately be re-circulated back to the bedrock aquifer or it may increase the local recharge to the shallow aquifer system and potentially enhance baseflow.

2.1.4.2 Private Groundwater Water Taking

There are a number of private water takers within the Town of Erin, most of which are located within the study area. Most of these water takings require a Permit To Take Water (PTTW), since the water taking is usually greater than 50,000 litres per day (L/d). Permits to Take Water on file with the Ministry of the Environment show that, except for the municipal wells, there are only a few groundwater takings where the groundwater is "lost" from the system, primarily related to commercial water bottling companies.

Figure 2.1.14 shows the different categories of the Permits to Take Water (PTTW) from the MOE database located within the SSMP Study Area as of February 2010[1].

The private water takings within the study area are used for a variety of purposes including drinking water, agriculture (aquaculture), industrial such as aggregates washing, and commercial uses such as water bottling and golf course irrigation. **Table 2.1.1** lists the permitted daily maximum water takings within the Study Area as of February 2010. The permitted daily maximum number does not indicate the volume of water that is actually taken on a daily basis but represents the maximum taking that can

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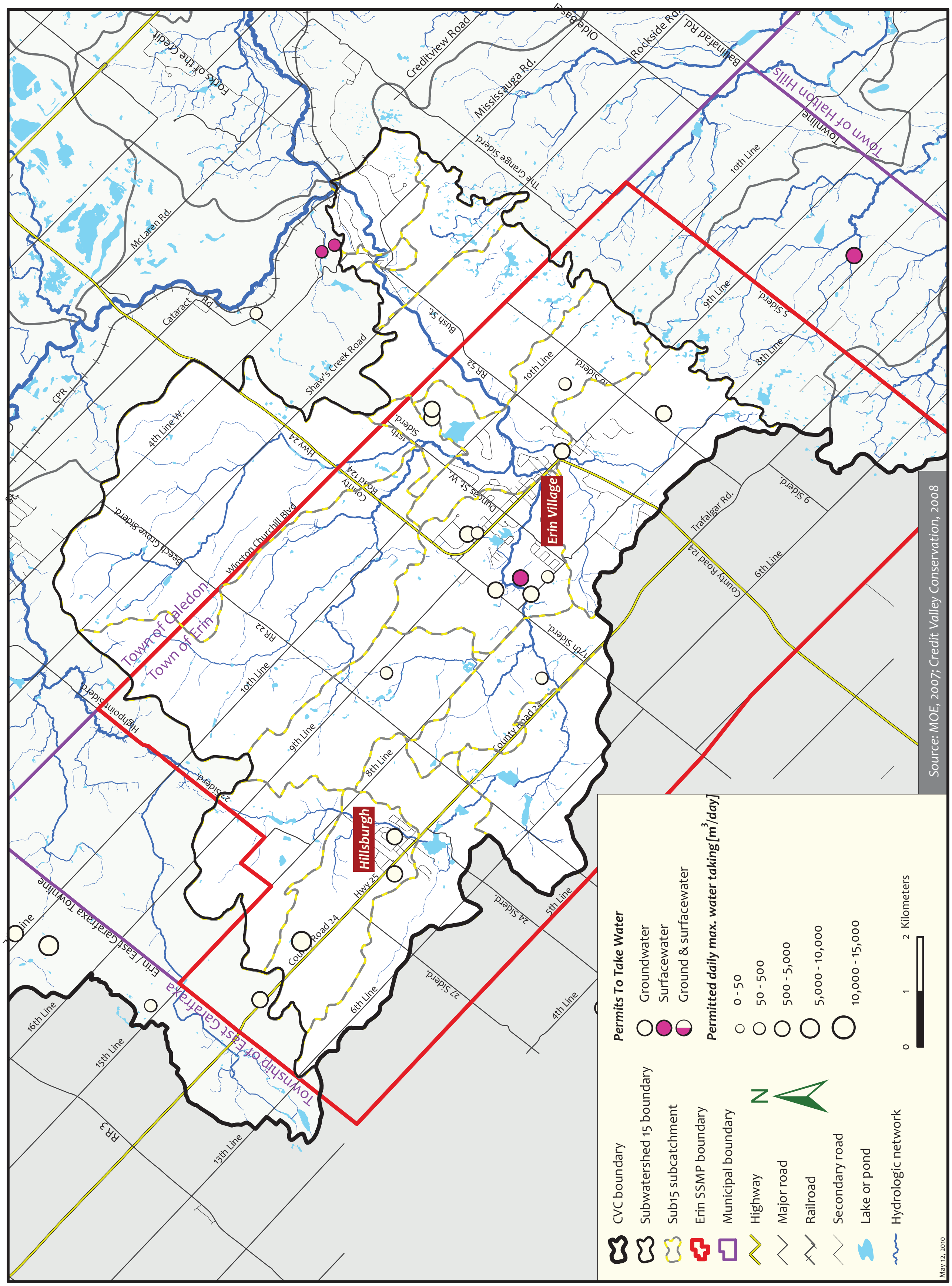
[1] Note the PTTW included in this report are those that CVC is aware of and may not be inclusive.

Figure 2.1.14 Permitted Water Takings



Source: MOE, 2007; Credit Valley Conservation, 2008

]

occur on each day. The following is noted with respect to the water taking permits in **Table 2.1.1,** (Note: this table contains information that CVC obtained just prior to report completion)**:**

- The largest water takers listed are aggregate companies. Most of this water is used for washing operations, so only limited percentage of the water is lost, typically through water retained by aggregate when it is shipped off-site. A number of these water takings indicate a groundwater source but it is typically a below water table wash pond and the water is merely re-circulated in a series of ponds.
- The sum of all of the municipal water supply permits represents the second largest water taking in the study area, and is discussed in more detail below. Most of this water is re-circulated to the shallow groundwater zone via septic systems. This water represents about 1% of the groundwater in the Town of Erin.
- Water taking for the aquaculture operation listed in the table is shown on the PTTW as a groundwater taking. The "groundwater" is water collected from several springs on-site. This water is utilized in the aquaculture operation and is discharged back to the surface water. It is basically a "flow through" operation with minor volumes of water lost in the operation.
- The groundwater remediation listed in **Table 2.1.1** is a "pump and treat" system with the water pumped from, and re-circulated back into the bedrock system, so no water is lost from the groundwater system.
- Water extraction by commercial bottled water companies is shipped out of the subwatershed and is the only water lost to the groundwater system and the subwatershed.

Table 2.1.1 Permits to Take Water from Groundwater within the Study Area

Category/Purpose	Permitted DailyMax [L]	Total Litres
Institutional, Schools	100,000	100,000
Water Supply, Municipal	2,160,000	7,070,624
Water Supply, Municipal	1,964,000	
Water Supply, Municipal	982,000	
Water Supply, Municipal	655,000	
Water Supply, Municipal	655,000	
Water Supply, Municipal	654,624	
Industrial, Aggregate Washing	2,288,000	46,781,934
Industrial, Aggregate Washing	982,000	
Industrial, Aggregate	16,365,600	
Industrial, Aggregate	7,816,000	
Industrial, Aggregate	5,940,000	
Industrial, Aggregate	4,003,560	

Category/Purpose	Permitted DailyMax [L]	Total Litres
Industrial, Aggregate	2,727,600	
Industrial, Aggregate	392,774	
Industrial, Aggregate	73,000	
Industrial, Pits and Quarries	2,455,200	
Industrial, Pits and Quarries	2,455,200	
Commercial, Bottled Water	363,680	588,680
Commercial, Bottled Water	225,000	
Commercial, Aquaculture	2,620,000	3,274,000
Commercial, Aquaculture	654,000	
Commercial, Golf course	982,000	1,275,000
Commercial, Golf course	238,000	
Commercial, Golf course	55,000	
Remediation, Groundwater	983,000	1,305,000
Remediation, Groundwater	322,000	
Agriculture, Irrigation	1,210,000	1,210,000

2.1.4.3 Current Municipal Water Taking

There are currently two separate municipal water supply systems in the Town of Erin, one system in Hillsburgh and one in Erin Village. There are currently four wells in operation, two in Erin Village and two in Hillsburgh (**Figure 2.1.15**). There is one non-operating water supply system known as the Bel-Erin wells located adjacent to the Bel-Erin subdivision in the south part of Erin Village. The information within this section comes from the 2009 Annual Monitoring Reports (Blackport Hydrogeology Inc. 2009[a], 2009[b]) prepared for the Town of Erin for submission to the Ministry of the Environment.

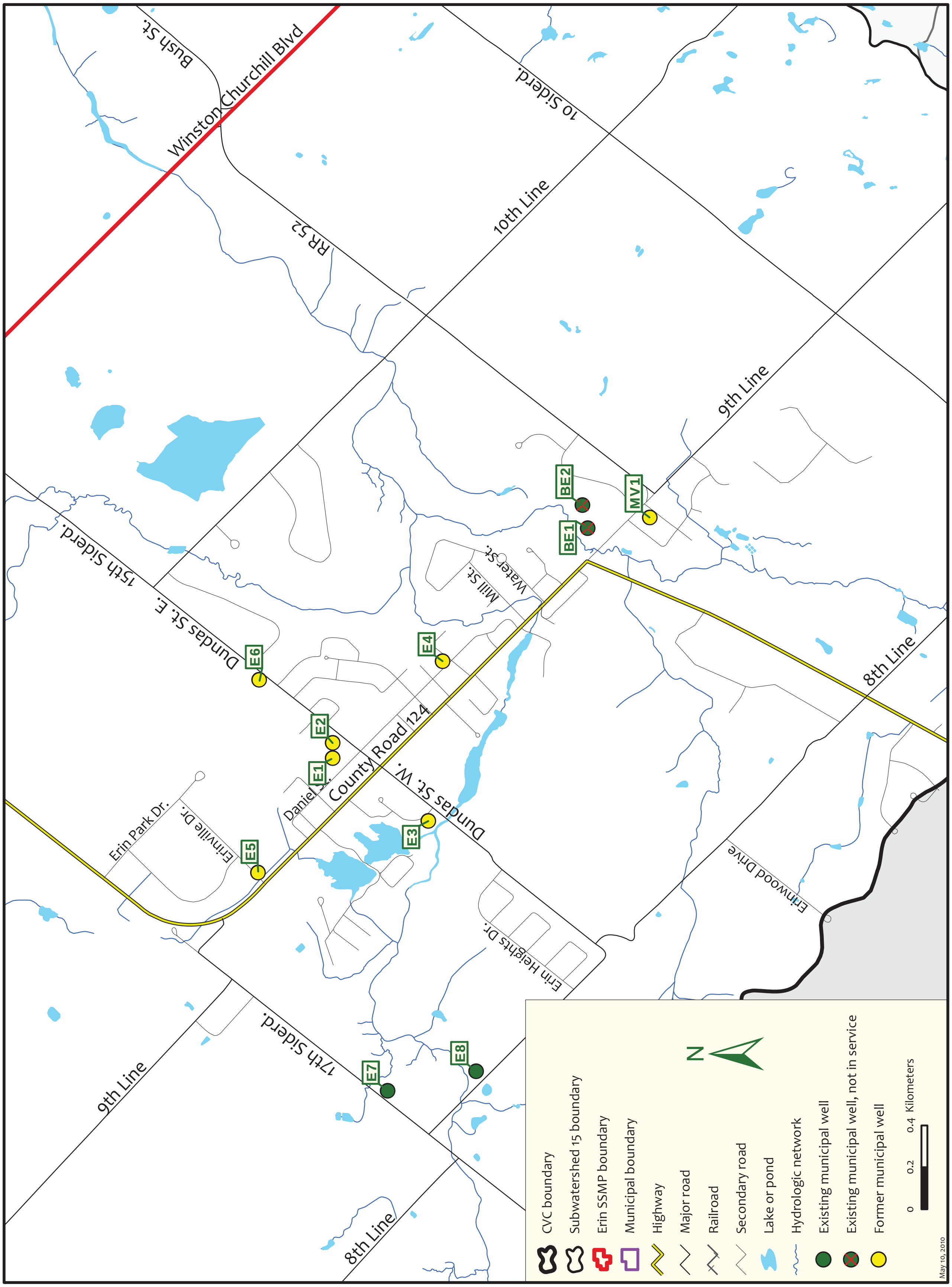
Erin Well No. E7 and Well No. E8 are in use in the Erin Village, and are operated under PTTW Permit No. 93-P-2104 and Permit 93-P-2114, respectively. Well No. H2 (Hillsburgh Heights) and Well No. H3 (Victoria Park Well) are located in Hillsburgh and operate under PTTW Permit No. 92-P-2021 and Permit 73-P-0370, respectively.

Erin Well No. E7

Well No. E7, located at 46 Shamrock Road (**Figure 2.1.15**), was drilled in 1986 for the former Village of Erin and has been in production since the early 1990's. The total depth of the well is 42 metres below ground surface (mbgs) and obtains water from the bedrock aquifer. The well was originally a flowing well, flowing at a rate of about 7.6 L/sec. The well was originally pump tested at a rate of 22.7 L/sec [300 imperial gallons per minute (igpm)]. Water levels stabilized at about 10 mbgs, during the original pumping test. It was concluded at the time that the well could provide a sustained yield of 22.7 L/sec without causing undue interference. Well No. E7 is currently permitted for a rate not to exceed 1,800 L/min (395 igpm).

Upgrades to the well were conducted in 2004, including building a new storage reservoir. During these activities, concerns were noted with respect to the shallow portion of the well casing and possible GUDI (<u>G</u>roundwater <u>U</u>nder the <u>D</u>irect <u>I</u>nfluence) issues. GUDI refers to groundwater sources (wells, springs, infiltration galleries, etc.) where there is a hydraulic connection that allows rapid recharge between the groundwater source and surface water and that there is potential for microbial pathogens to travel from nearby surface water to the groundwater source. To ensure there were no GUDI issues, the well casing was extended to 19.1 mbgs. The assessment of the impact of water loss to the well from the upper bedrock, as a result of extending the casing, was discussed in the *2004 Annual Monitoring Report* submitted to the MOE by the Town of Erin (Blackport

Figure 2.1.15 Municipal Well Locations, Town of Erin



Hydrogeology Inc. 2005). It was concluded that there as only a 7% loss in well yield as a result of extending the casing into the upper bedrock. Most water of the water production from the well was from the lower portion of the bedrock. No hydraulic connection to surface sources of water has been found.

Erin Well No. E8

Well No. E8 (**Figure 2.1.15**) was drilled in 1991 for the former Village of Erin and has been in production since 1993. The total depth of the well is 46 mbgs, also obtaining water from the bedrock aquifer. The well was originally cased to 8.5 mbgs. The well was pressure grouted to a depth of 16.8 mbgs to minimize any potential connection to the local surface water. The well was also originally a flowing well, estimated to be capable of flowing at 19.2 L/sec (244 igpm). The original static water level was about 6.5 m above ground surface. At the time of construction, a pumping test was conducted at a rate of 29.9 L/sec (395 igpm) and it was concluded that the well could provide a sustained yield of this rate. The well is still under artesian conditions when not being pumped. Well No. E8 is permitted for a rate not to exceed 1,640 L/min (360 igpm) and an amount not to exceed 1,964,000 L/day (equivalent of 20 hours a day at the permitted rate).

Extensive testing was conducted in 1993 to assess the potential for impact on and hydraulic connection to local surface water features (the well is located near the main branch of the West Credit River) from pumping of Well E7 and Well E8 under normal operating conditions. Testing included the installation of numerous shallow monitoring wells and stream bed piezometers along the West Credit River, and continuous monitoring of these wells during normal pumping cycles. Results of testing showed there was no direct connection or impact of groundwater discharge to the West Credit River or adjacent wetlands. Currently, water levels typically recover daily, from the daily cycle of pumping, at 8-10 hours in operation and then shutdown.

Hillsburgh Well No. H2

Well H2 is located in the Hillsburgh Heights subdivision in the north part of Hillsburgh (**Figure 2.1.15**). The well is 88 m deep, obtaining water from the regional bedrock aquifer. The well has been in operation since 1992. Well H2 is permitted to pump at a rate not to exceed 682 L/min or 982,000 L/day. In 2002, elevated concentrations of lead (but below Ontario Drinking Water Standards) were found in the raw water. The well was offline in 2003 and did not come back online until June 2004 when a new treatment system to remove lead was approved and the well was operational. The well has been operated routinely since 2005. The average pumping rate in 2009 was about 77,000 L/day, well below the permitted rate.

Hillsburgh Well No. H3

Well H3, located in Victoria Park, near the Glendevon Reservoir in Hillsburgh (**Figure 2.1.15**). It is 57.9 m deep, also obtaining water from the regional bedrock aquifer. It is permitted to pump at 454 L/min and a total volume of 653,760 L/day. It is noted that H3 replaced well H1, known as the Glendevon well, which was located at the Glendevon reservoir and adjacent to the West Credit River. Well H1 was abandoned due to problems with iron-reducing bacteria (refer to Section 2.1.4.4). Prior to abandonment a long-term pumping test was conducted in 1995 (Terraqua Investigations Ltd. 1995) to assess the potential hydraulic connection to the adjacent upper portion of the West Credit River. Shallow monitoring wells and stream bed piezometers were installed and water levels were monitored in the wells and surface water to assess the potential for hydraulic connection between the pumping well and shallow groundwater/surface water. Results of the pumping test indicated no direct connection between H1 and the adjacent 400 m reach of the West Credit River at the pumping rate it was being used (3.33 L/sec) to provide the municipal water supply. Well H2 was used as a replacement well, several hundred metres further away from the West Credit River and currently pumps at a lower rate. It was concluded that Well H3 is not hydraulically connected to the surface water system and the well is not GUDI.

Bel-Erin Municipal Wells, BE1 and BE2

The Town of Erin owns two municipal water supply wells, referred to as Bel-Erin Wells, BE1 and BE2 (**Figure 2.1.15**). The subdivision is located at the southeast edge Erin Village, between a small tributary of the West Credit River and Wellington Road 52. The Bel-Erin wells are installed into an unconfined overburden aquifer, consisting of a sand and gravel outwash deposit. The shallowest well is cased to 11 metres depth and the well screen is only 8 metres below the water table. The wells were originally used to supply the Bel-Erin Estates residential subdivision. The drift thickness mapping indicates that the overburden is about 8 metres thick near the tributary of the West Credit River located about 100 m to the north of the wells. Several water wells are reported for the subdivision area located south of the Bel-Erin wells. One test-hole drilled near Wellington Road 52 encountered bedrock at 13.4 metres. Two private wells, reported between the Bel-Erin municipal wells and Wellington Road 52, indicate that a local bedrock depression is present, with overburden thickness of up to 50 metres. A buried bedrock valley is mapped throughout this area but the exact locations and dimensions are variable (**Figure 2.1.6**).

The wells were installed in July 1991 and December 1990, prior to the construction of the subdivision. Wells BE1 and BE2 are permitted for individual pumping rates of 655,200 L/d with total pumping from either well or both wells not to exceed this rate. When the two wells were in use for the subdivision they were pumped on an alternate basis, with an average water taking of about 108,000 L/day.

As part of an initial screening for a GUDI assessment in 2001 (Blackport Hydrogeology Inc. 2002), shallow monitoring wells and stream bed piezometers were installed along a tributary of the West Credit River, located less than 100 m north of the wells. The assessment concluded the wells were not GUDI under the existing pumping rates, which were lower than the permitted rates, however it was concluded that chemically assisted filtration would likely be required in order to use the wells for a municipal supply. It was decided in 2001 that Town of Erin supply the subdivision with water from the Erin municipal wells. The Bel-Erin wells have not been in operation since then, although they are still officially listed as municipal wells.

Table 2.1.2 presents a summary of well depths and maximum permitted pumping rates and average pumping rates for 2009.

Table 2.1.2 Summary of Erin Municipal Water Supply Wells

Well	Location	Total Depth (m)	Maximum Permitted Rate	Average pumping rate in 2009
E7	bedrock	43	2,160,000 L/day	500,000 L/day
E8	bedrock	46	1,964,000 L/day	449,000 L/day
H3	bedrock	57.9	653,760 L/day	118,000 L/day
H2	bedrock	88	982,000 L/day	77,000 L/day
BE1, BE2	overburden	11.3-16.2	655,200 L/day	Not operational

The higher permitted pumping is necessary for these wells, as they are the only wells currently supplying water to either Hillsburgh or Erin Village. Sufficient capacity is required in each well in case one of the wells has to be offline in order to provide for maximum day demand as well as supplement fire flow from storage.

2.1.4.4 Historical Municipal Water Supply Wells

A number of municipal water supply wells have been developed and abandoned, mostly in the former Village of Erin. Prior to amalgamation of the former Township of Erin and Village of Erin, in 1998, the Village of Erin obtained municipal water supplies from within the municipal boundary of the Village. Hillsburgh obtained water supplies from within the boundary of Hillsburgh. Several private communal wells existed in subdivisions adjacent to the Village of Erin but within the former Township of Erin. The following is a summary of the history of municipal water supply development in Erin Village, Hillsburgh, and the area adjacent to Erin Village.

Erin Urban Area

The first wells for municipal use in the Village of Erin were Well E1 and Well E2. These wells were drilled along Dundas Street East in September 1954 and May 1955, respectively, and were only 4.5 m apart (**Figure 2.1.15**). Well E1 was drilled to 19 m and Well E2 to 20 m depth. Both wells were completed in bedrock. Bedrock was encountered at about 8.8 m depth with overburden material mostly sand and gravel. Initial testing was at 26.5 L/sec (350 igpm) with the static water level at 3 mbgs and a drawdown to 6.7 mbgs when pumped at the test rate. Retesting of the wells in 1974 showed a considerable decline in sustainable yield. A review of the Village of Erin Water Supply System by Gamsby and Mannerow (1984) indicated a further decline in well yield, as the wells were operating at a combined rate of 9.8 L/sec (130 igpm) with a water level at about 9 mbgs. Water quality was also an issue with high levels of iron and iron reducing bacteria as well as some water samples results showing the presence of coliform bacteria. These wells were taken out of service when Well E5 (discussed below) was brought into operation in July, 1984.

To supplement Well E1 and Well E2, Well E3 was drilled in 1976, further west on Dundas Street near the West Credit River (**Figure 2.1.15**). Aquifer testing at this location identified three aquifer units, a shallow sand deposit, extending from surface to a depth of 6 m, a basal sand and gravel zone from 2-3 m thick, directly overlying the bedrock and a fracture zone at a depth of 33.5-35 mbgs. A series of four test wells were drilled to various depths but the only well that produced much water was ultimately Well E3, which was drilled 15.8 m into bedrock but subsequently screened in the basal sand, from 7.6-9.1 mbgs. The well was tested at 4.5 L/sec. It appears that a bored well was also installed in the shallow sand and gravel and both were connected into the distribution system at the pump house. Records indicated that a PTTW was issued in 1976 for 2,182,080 L/day (25.2 L/sec). The *Municipal Waterworks System, Village of Erin, February, 1984* report by Gamsby and Mannerow (1984) indicates that the bored well was not used and Well E3 was used at the time only for emergencies under a temporary PTTW to meet peak demands. This report concluded the amount of water available did not justify the installation of permanent pumping and treatment facilities at Well E3.

Well E4, located on Daniel Street was brought into service in 1976 (**Figure 2.1.15**). It is assumed the well was drilled earlier as it was indicated at the time the well was brought into service it was rehabilitated to yield 6.8 L/sec (90 igpm). Limited information was found on the well. It was noted in Gamsby and Mannerow (1984) that the well yield quickly decreased after rehabilitation. There were water quality issues, including high iron concentrations and high concentrations of nutrients, as well as coliform counts. It appears the well was only used for a short time before being abandoned due to water quality issues and well performance associated with water quality problems.

In 1980, Hydrology Consultants Limited drilled a test well (TW1/80), which later became Well E5 (**Figure 2.1.15**). The well was drilled to a depth of 38 m in bedrock, with the top of bedrock encountered at 6 m. The well was located in an industrial subdivision. Well testing indicated the well could be pumped at a sustained rate of 22.7 L/sec (330 igpm). Higher pumping rates caused interference with bedrock wells to the northwest. Water quality was determined to be excellent (e.g., low iron, nitrate, chloride, and sodium). Well E5 was officially brought into operation in July, 1984. In 1992, elevated concentrations of trichloroethylene (TCE) were found in the well and the well was shut down. An attempt was made to control the off-site migration of TCE to the well, under actual operating conditions, but this was ultimately determined not to be feasible and the well was officially abandoned in 2007.

At the same time the drilling program for Well E5 was being initiated, a preliminary hydrogeologic investigation was conducted to identify additional areas exhibiting the potential for large-yield supply wells (Hydrology Consultants Limited 1979). Four target areas were selected, and three were later tested. Two locations were tested in 1985 (Well E6) and 1986 (existing Well E7). The other location was the Bel-Erin wells, previously discussed. Well E6, was drilled in the eastern portion of Erin Village, along Dundas

Street East, to the east of Well E1 and Well E2 (**Figure 2.1.15**). Well E6 was drilled to a depth of 36 m. Bedrock was encountered at 8.3 mbgs. Overburden consisted of mainly sand and gravel, with minor silt. The initial pumping test indicated that the well could produce a continuous yield of about 5.7 L/sec (75 igpm) however there was considerable drawdown in the well. The well was never developed for use as a municipal well and rather than being abandoned, the well is currently part of the Provincial Groundwater Monitoring Network.

Well E8 was subsequently drilled and as discussed in the previous section, Well E7 and Well E8 are the two municipal wells currently in use in the Erin Village.

Hillsburgh Urban Area

The original municipal water supply well in Hillsburgh, Well H1, was completed in 1968 by International Water Supply Limited (IWS). The well was located on Water Street near the West Credit River, in the core area of Hillsburgh about 120 m south of Well H3. The well was drilled into bedrock to a total depth of 37.2, with bedrock encountered at 17.4 m below ground surface.

Well H1 was rated for 6.8 L/sec (90 igpm). The well was used until 1995 and was abandoned due to apparent iron bacteria problems. It was interpreted that the iron bacteria problems resulted in the well requiring regular rehabilitation. A decision was made in 1995 by the former Township of Erin to abandon the well and drill a replacement well, farther away from the West Credit River but still in close proximity to the reservoir at H1. Well H3 was the replacement well, located about 120 m to the north of Well H1.

Additional water supply well testing was undertaken in 1989. The “Firehall” well was drilled at the Hillsburgh Firehall (2 Station Street, about 600 m south west of H3) in 1989 to assess the potential for municipal water supply at the Firehall and for use as supply well for fire services. The well is a bedrock well, 62 m deep with 13 m of sand and gravel overburden. The well was tested at a rate of 9.5 L/sec (125 igpm) but was interpreted to have the potential to produce 22.7-30.3 L/sec (300-400 igpm) with limited drawdown at the well. Water quality testing at the time showed generally good water quality, however there was evidence of impacts from surface sources of contamination with a nitrate (as NO_3-N) concentration of 3.12 mg/l and a chloride concentration of 23.8 mg/L. The well has not been used for a municipal supply as it was ultimately decided that well H3 would be used instead, given the short distance to the reservoir. The Firehall well currently provides water for fire services.

2.1.5 Water Quality

2.1.5.1 Water Quality of Existing Municipal Wells

Water quality data is collected through operational monitoring of the water supply systems under the Drinking-Water Systems Regulation (O. Reg. 170/03), as part of the Drinking Water Surveillance Program (DWSP). The most recent results indicate that all organic parameters, which include volatile organic compounds, pesticides and herbicides, were non-detectable at all operational municipal wells in the Town of Erin.

Trihalomethane (THM) concentrations ranged from 2.6 to 6.7 ug/L, well below the current drinking water standard of 100 ug/L. No exceedances of trace metals were noted; however, as previously indicated, there is a treatment system on Well H2 in Hillsburgh, to remove lead. Elevated concentrations of lead were found in the raw water near or at the Ontario Drinking Water Standards (ODWS) of 10 ug/L, requiring treatment. The source of the lead appears to be natural.

Sodium concentrations range from 5-12 mg/L, typical of background concentrations in the bedrock. Nitrate concentrations ranged from non-detect (ND) to 1.2 mg/L at Well No. H2, located upgradient of Hillsburgh. An assessment of historical water quality was conducted as part of the Source Water Protection, *Interim Watershed Characterization Report for the Credit River Watershed* (CVC 2007). No water quality trends were noted, with respect to increasing concentrations of sodium, chloride, or nitrate over time at any of the municipal wells.

Water quality results indicate that there are no apparent impacts from non-point sources of contamination (i.e., road salting, septic effluent, or fertilizer application) in Well E7 and Well E8, given the very low sodium, chloride, and nitrate concentrations. It would appear that, given the location of the wells, there is little local recharge to the wells. Well H3 and Well E8 likely obtain most water from deeper in the bedrock, having higher sulphate concentrations of 204 and 145 mg/L respectively, compared to the other wells.

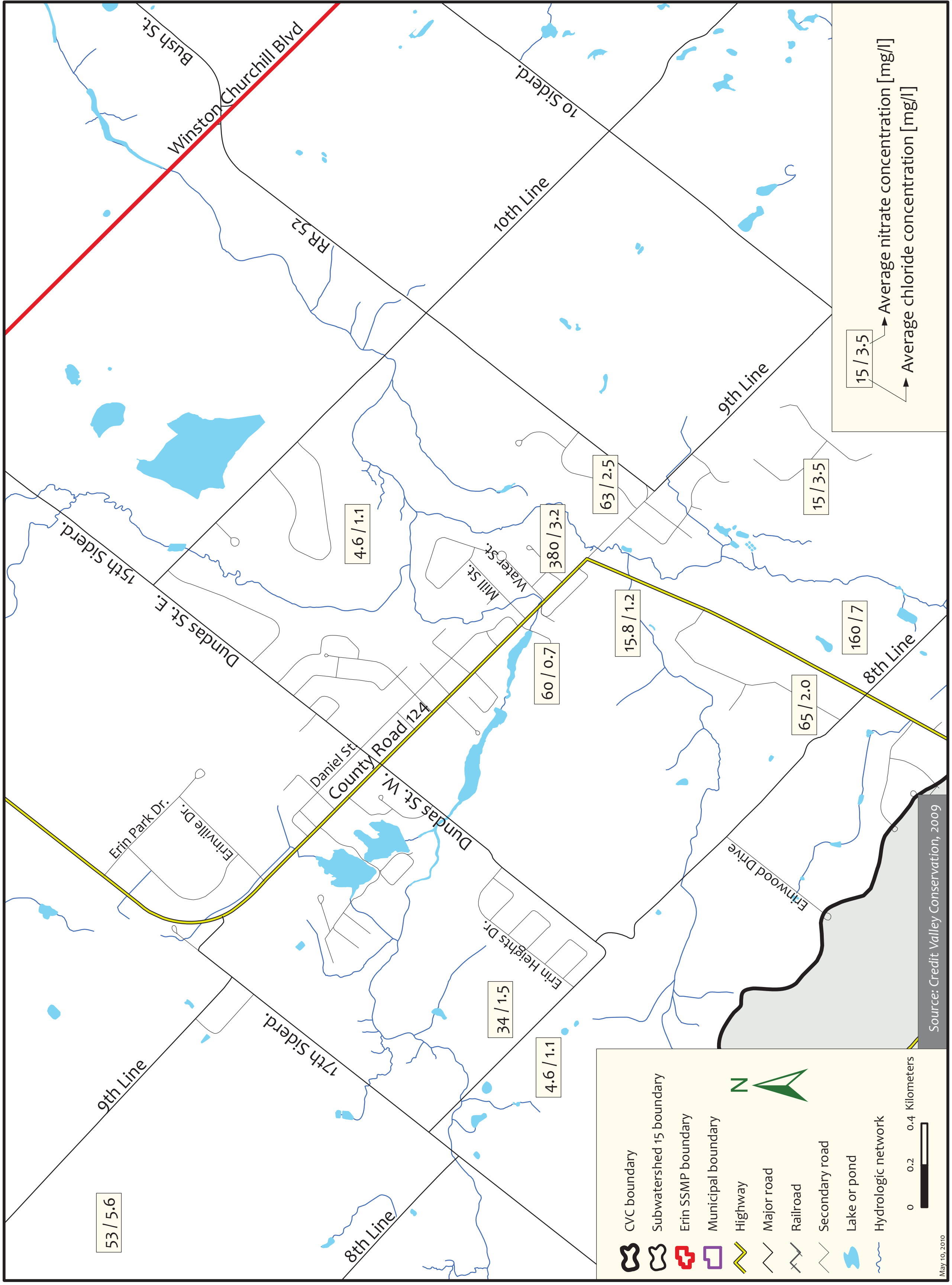
2.1.5.2 Background Groundwater Quality

Selected water quality data has often been collected as part of supporting documentation for development applications. The data are often collected as a one time assessment of existing site conditions. Water quality data is also collected, related to known contamination issues. Various consultants' reports have been reviewed to obtain existing water quality data throughout the Erin and Hillsburgh area. The general results presented in this section are based on a compilation of available data found in these reports. The reports vary in age from 20 years old to recent. Although there is limited data in most areas to establish water quality trends over time, the review provides some assessment of the variation in water quality throughout the Erin and Hillsburgh area. **Figures 2.1.16** to **2.1.19** provide some of the water quality information obtained from various consultants' reports on file with the Town of Erin. The most common water quality parameters obtained were chloride and nitrate. These parameters do provide a general indication of impact on groundwater from surface sources of contamination. **Figures 2.1.16** and **2.1.17** show chloride and nitrate concentrations in shallow (overburden) and deep (bedrock) groundwater, respectively, in the Erin Village area. **Figures 2.1.18** and **2.1.19** show chloride and nitrate concentrations in shallow and deep groundwater, respectively, in the Hillsburgh area. At sites where a number of monitoring wells are located, average concentrations were presented. Based on available water quality data from these reports the following is noted:

- Most areas in Erin Village showing either elevated chloride or nitrate in the shallow groundwater are located in the south and southeast portion of Erin Village and are typically within the zone mapped as having high aquifer vulnerability, as shown in **Figure 2.1.20** in Section 2.1.6.
- Locations with the highest chloride concentrations in the shallow groundwater are found adjacent to and just downgradient of major roads, indicating road salt impacts in these areas. At one location, near County Road 124 and 8th Line, there is elevated chloride extending into the bedrock aquifer (**Figure 2.1.16** and **Figure 2.1.17**). The same location also shows elevated nitrate.
- The deep groundwater zone in Erin shows little evidence of impact from nitrate, but shows several localized areas with elevated chloride concentrations.
- There is only one area in the vicinity of Erin Village that showed concentrations of nitrate above ODWS concentration of 10 mg/L, in the southern most portion of Erin Village (shown on Figure 2.1.16 as currently 15/3.5). The area was formerly an agricultural area where there was a turkey operation. Nitrate concentrations were greater than 30 mg/L at some monitoring locations in the late 1990s. The area is now a subdivision of Erin Village and over the last 10 years nitrate concentrations have declined to an average of about 3.5 mg/L.
- There is only one area showing elevated chloride and nitrate, upgradient of Erin Village, with a chloride concentration of 53 mg/L and nitrate of 5.6 mg/L, in an agricultural area near a main road.
- There is limited data on chloride concentrations in the shallow groundwater in Hillsburgh, however the only elevated chloride concentrations noted are along the Highway 25 corridor, south of the core area of Hillsburgh. Nitrate concentrations throughout this area as well as the area to the east (**Figure 2.1.18**) are elevated, compared to background concentrations, and likely originate from both septic systems and agricultural activities. As discussed in the next section, Section 2.1.6, this area is also mapped as an area of high aquifer vulnerability.
- The deep aquifer in the same area of Hillsburgh also shows evidence of impact from surface sources with elevated chloride and nitrate (**Figure 2.1.19**).

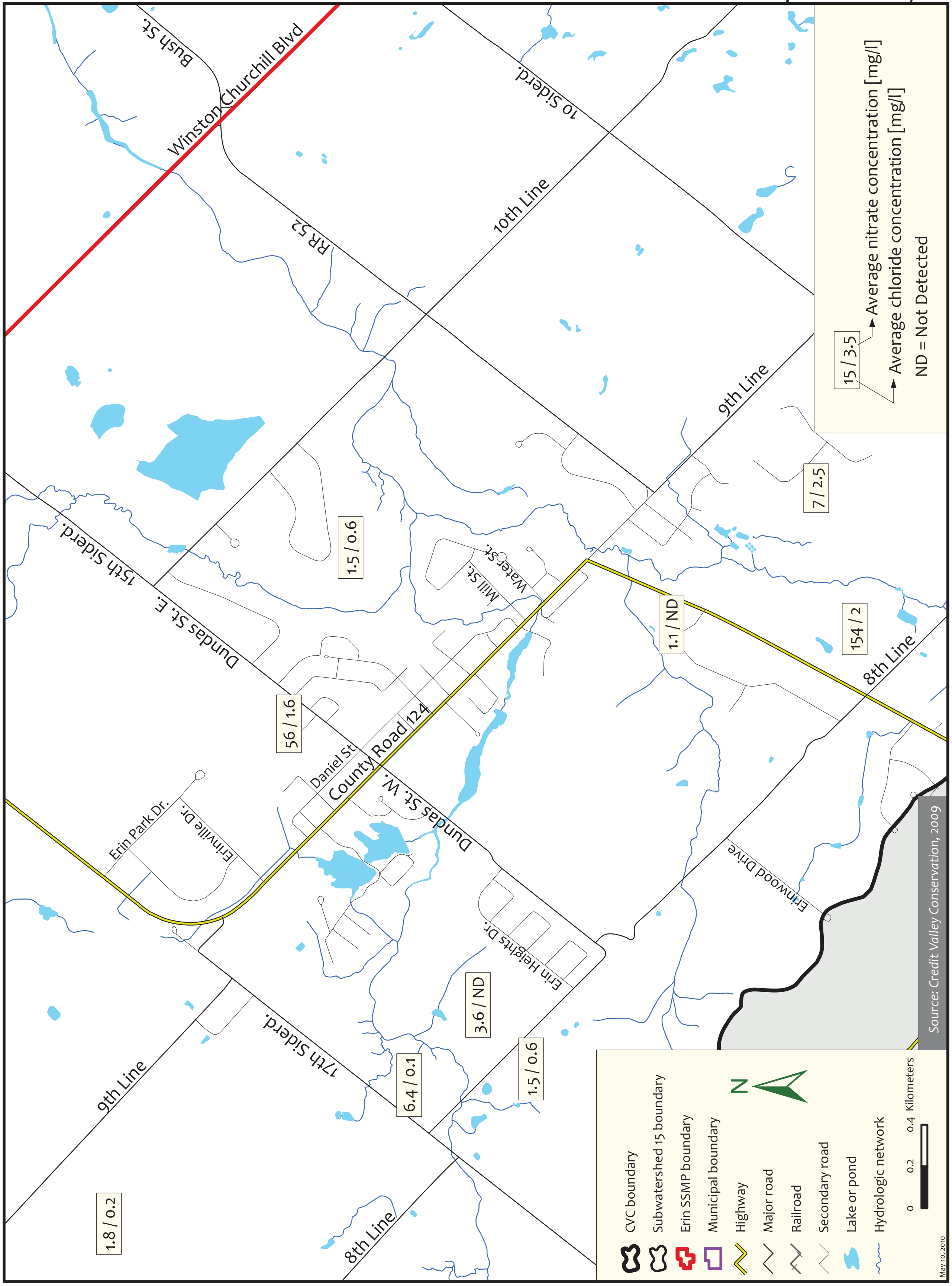
Although the background water quality data for the groundwater zone is not extensive, the existing water quality does indicate some areas of impact and potential concern with respect to urban development. Many of the areas are associated with areas of high aquifer vulnerability as discussed in the next section.

Figure 2.1.16 Historic Background Chloride and Nitrate Concentrations- Shallow Groundwater, Erin



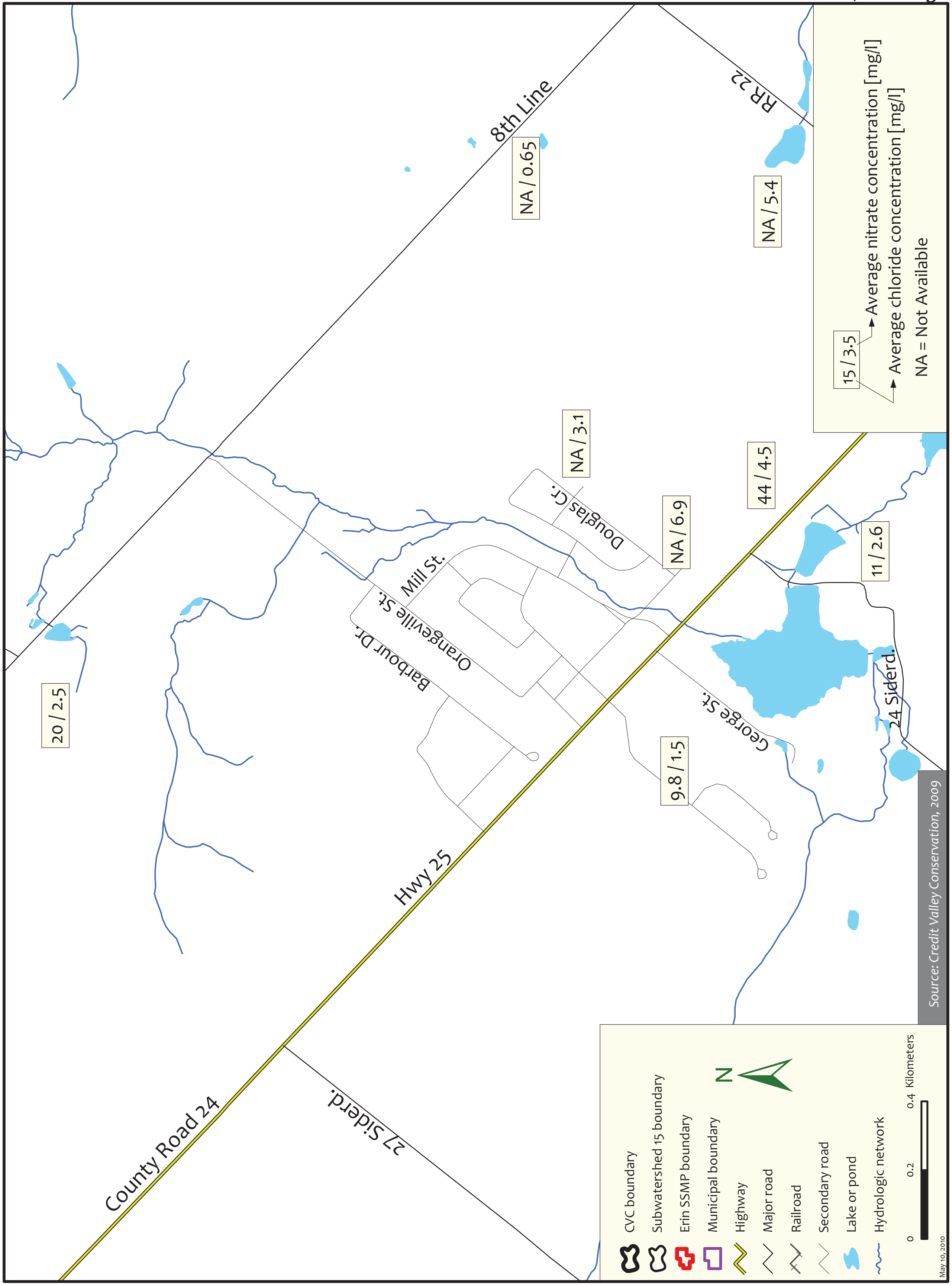
Source: Credit Valley Conservation, 2009

Figure 2.1.17 Historic Background Chloride and Nitrate Concentrations- Deep Groundwater, Erin



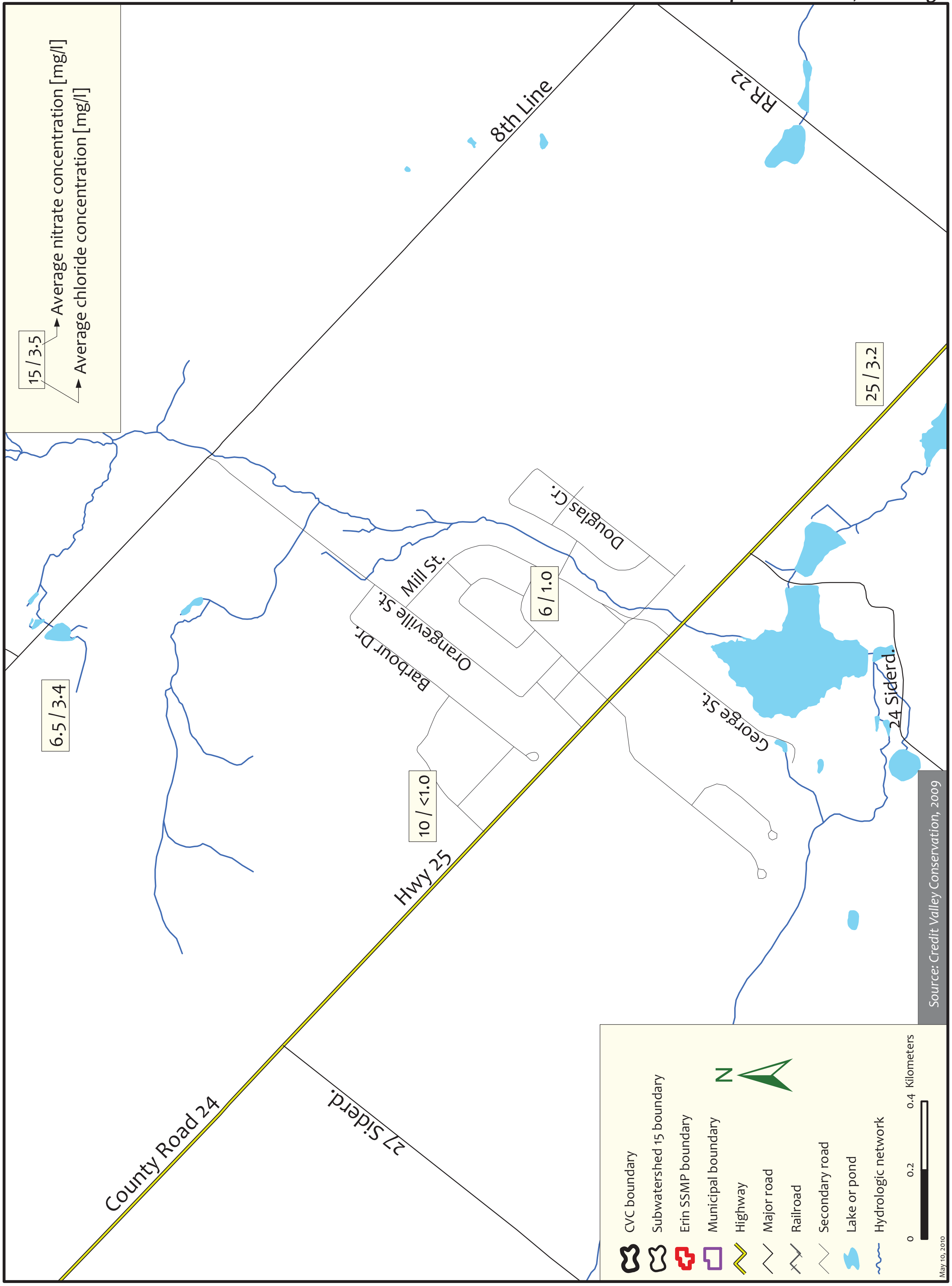
Source: Credit Valley Conservation, 2009

Figure 2.1.18 Historic Background Chloride and Nitrate Concentrations- Shallow Groundwater, Hillsburgh



Source: Credit Valley Conservation, 2009

Figure 2.1.19 Historic Background Chloride and Nitrate Concentrations- Deep Groundwater, Hillsburgh



Source: Credit Valley Conservation, 2009

2.1.6 Capture Zones and Aquifer Vulnerability

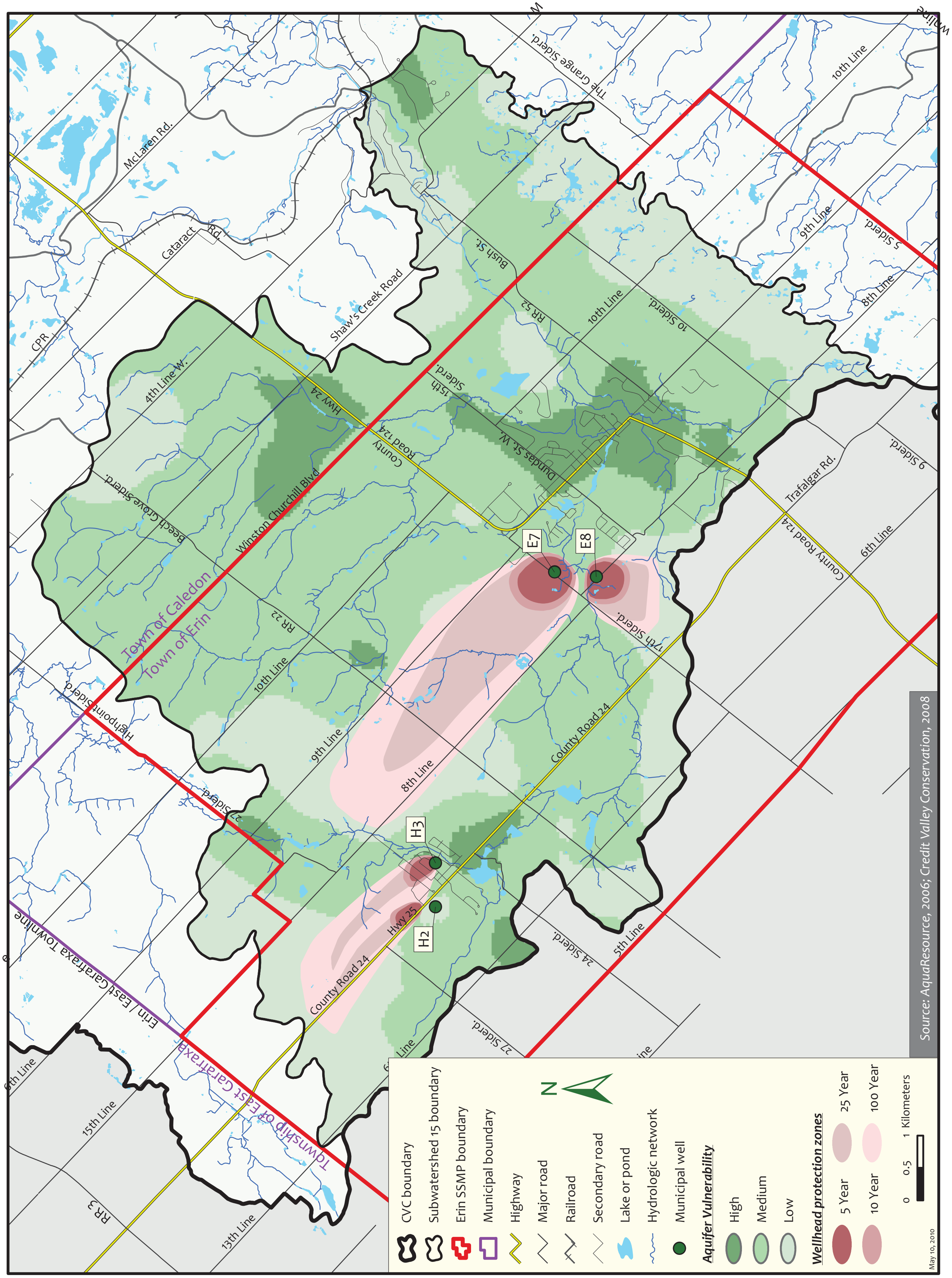
As part of the Town of Erin Groundwater Management Study (Blackport Hydrogeology Inc. 2005) a groundwater flow model was developed for much of the Town of Erin. The model was using the three-dimensional finite element model MODFLOW. As indicated previously, the Town of Erin Groundwater Management Study was conducted as part of the MOE Phase 1 Groundwater Studies, to develop groundwater protection strategies for all municipalities relying on groundwater. The studies were completed to characterize the hydrogeology on a subwatershed basis, develop wellhead protection areas around municipal water supply wells, and assess the vulnerability of these areas to potential sources of contamination from ground surface. The groundwater flow model was used to define “capture zones” for the municipal water supplies in Hillsburgh and Erin Village and develop wellhead protection areas around each well.

The area of influence within the groundwater system, as a result of pumping a well or well field is referred to as its zone of influence or capture zone. This area includes the area of groundwater upgradient of the well that will naturally migrate into the zone of influence and be "captured" by the well. The size and shape of the well capture zone depends upon the hydrogeologic characteristics of the aquifer system, and the design and operational characteristics of the well(s) used to pump water from the aquifer system. Capture zones were simulated for each of the municipal wells, using permitted pumping rates and hydrogeological data available during the study. Wellhead protection areas were developed based on the length of time of travel in the groundwater zone to the pumping well.

Phase 2 studies, initiated in 2003 and conducted by the County of Wellington, updated the individual Phase 1 studies that were conducted by individual municipalities throughout the County. The *County of Wellington Groundwater Protection Study* (MHBC et al. 2006) provides a detailed discussion of the updated studies and findings and only a general discussion is presented in this report. The existing groundwater flow model was updated and reconstructed in the County study using updated hydrogeological data and a revised pumping rate, based on actual and projected water supply usage using population growth forecasts.

Figure 2.1.20 shows the well field capture zones, as developed from the *County of Wellington Groundwater Protection Study*, and the aquifer vulnerability as interpreted in the Source Water Protection, *Interim Watershed Characterization Report for the Credit River Watershed* (CVC 2007). The time of travel (TOT) is based on the MOE Technical Terms of Reference (MOE 2001[a]). These zones were developed by releasing “particles” at the pumped wells and having them track backwards to the source of recharge. The capture zone for each time represents a two-dimensional projection to ground surface from travel within the aquifer. This does not mean that contaminants at ground surface in this area would reach the well in the specified time, as it would have to travel through overlying geologic units.

Figure 2.1.20 Well Field Capture Zones and Aquifer Vulnerability



Source: AquaResource, 2006; Credit Valley Conservation, 2008

May 10, 2010

Aquifer vulnerability or susceptibility is a relative measure of physical properties that overlie an aquifer and provide protection from contamination if a contaminant was released at, or just below, ground surface. An aquifer is least susceptible to contamination or has the greatest protection where it is overlain by a thick layer of low permeability material. Numerous methods have been developed for mapping aquifer vulnerability. **Figure 2.1.20** shows the aquifer vulnerability based on the use of the Aquifer Vulnerability Index (AVI) from CVC (2007). The bedrock aquifer was used for the assessment as the municipal wells are all located in the bedrock aquifer. Following the Technical Terms of Reference from MOE (2001), the vulnerability was classified into one of three groupings; high (<30), medium (30 to 80), or low (>80) susceptibility.

It is noted that the aquifer vulnerability mapping is currently being updated using a different method of assessment as part of the current Source Protection studies for CVC. At the time of writing this report, the results were in draft form and not yet available. Capture zone delineation and vulnerability mapping was also performed for the Bel-Erin wells in the most recent studies. The draft results indicate that there are minor differences in vulnerability mapping between the two studies. This information will be updated when the Source Protection study is completed, however based on the previous mapping shown in **Figure 2.1.20**, the following is highlighted with respect to capture zones and aquifer vulnerability in the Town of Erin:

- The 25-year capture zone for Erin Well E7 extends about 5 km to the northwest, following the general groundwater flow direction southeast (**Figure 2.1.20**). The 25-year capture zone for Erin Well E8 is much smaller extending, to the south about 1.5 km. Locally, groundwater flow is from the south towards the well, and there is a groundwater divide to the south, influencing the shape of the capture zone.
- Much of the south and eastern portion of the Village of Erin is highly susceptible to surface contamination. It is noted that most of the abandoned municipal wells in Erin Village were within the area of high aquifer vulnerability.
- The 25-year capture zones for the Hillsburgh wells extend about 3 km upgradient of the wells and merge, given their proximity to each other.
- An area of high aquifer vulnerability is noted in the 2-year capture zone of Well H3, however water quality data for H3 does not indicate any surface source of contamination. The area of high aquifer vulnerability to the south of Well H3, correlates with water quality data discussed in Section 2.1.5, showing impacts from surface source of contamination in both the shallow aquifer (**Figure 2.1.18**) and the deep aquifer (**Figure 2.1.19**).
- Most of the study area within the Town of Erin has a low or medium susceptibility to groundwater contamination.

2.1.7 Hydrogeological Characterization

The following is highlighted with respect to the hydrogeological characterization of the study area:

- There are three main recharge areas: the sands and gravels north of Hillsburgh, which form part of the Orangeville Moraine; the outwash gravels surrounding the Village of Erin; and, the Paris Moraine area southeast of the Village of Erin.
- The study area provides significant baseflow to the West Credit River, through groundwater discharge. Baseflow contribution is highly variable from each of the subcatchment areas in the subwatershed. There is a loss of baseflow through the core area of Hillsburgh and then a substantial gain - downstream of Hillsburgh. Baseflow through Erin Village is variable, while there appears to be a considerable gain, downstream of Erin Village. The greatest relative gain in baseflow is in the extreme downstream subcatchments of the West Credit River where there appears to be regional groundwater discharge, controlled by a regional bedrock valley exiting the Town of Erin in this area.
- The main aquifer system is the bedrock aquifer found throughout the entire study area. There are locally significant water bearing zones in the shallow bedrock, however the major water bearing zones are typically found in the deeper bedrock of the Amabel Formation.
- Much of the bedrock aquifer system in the study area appears to be reasonably well-protected by natural geologic conditions. Water quality is good at the existing municipal wells.
- In areas where there is a higher aquifer vulnerability to contamination, existing water quality data shows evidence of impacts from surface sources of contamination, in particular in the eastern and southern portion of Erin Village and in the southern portion of Hillsburgh.

2.1.8 Next Steps

The assessment of the groundwater system, as described above, must be combined with the other environmental components to determine the overall sensitivities of the features, functions, and linkages with the Erin SSMP study area. This analysis will form the basis for the assessment of potential impacts from future land use changes and servicing. In particular, the understanding of the groundwater flow system should be enhanced in relation to baseflow assessments in the vicinity of Erin and to a lesser degree, Hillsburgh, with respect to the potential assimilative capacity of the West Credit River. Understanding the local groundwater conditions (e.g., local recharge and discharge) is important in assessing the impact on groundwater quality as a result of potential land use changes and potential servicing options. More detail regarding additional data collection is discussed in Section 2.8, Septic Impact Assessment.

As part of the groundwater assessment, related both to environmental components and servicing options such as additional water supply wells or changes to septic systems, the existing groundwater flow model could be refined to assess the sensitivity of various servicing alternatives.

2.2 HYDROLOGY AND HYDRAULICS

Hydrology is an earth science, which deals with all of the waters of the Earth. It includes the occurrence, distribution, movement, and circulation of water as well as its physical and chemical properties. Hydraulics is the science concerned primarily with the flow of liquids. Furthermore, both hydrology and hydraulics involve the interaction of water with the physical and biological environment including how water influences human activity.

For this study hydrology and hydraulics look at the characteristics of flow along the watercourse (channel and floodplain), and the environmental (natural, social, and economic) impacts that result from development changes. Hydrologic characteristics include precipitation, evaporation, recharge rates, runoff volume/rates, and infiltration volumes/rates. Hydraulic characteristics include water levels, floodplain and channel storage, flow capacities, flow velocities, flow depths, and flow widths.

Hydrologic and hydraulic characteristics are influenced by runoff volumes/rates, topography, vegetation, erosion, and by social development (urban and rural). Social development includes watercourse crossings, floodplain uses, storage facilities (i.e., dams), channels etc. Crossings (roads and railways) and floodplain uses can have a significant impact on flow rates, flow velocities, and water levels.

2.2.1 General Description of the Subwatershed and Watercourses

The West Credit River subwatershed covers an area of approximately 126.1 km^2 and drains significant portions of the Township of Erin and the Town of Caledon and flows through the Villages of Hillsburgh, Erin, and Belfountain. In terms of land use, the Erin SSMP study area is dominated by agriculture and natural areas. About 46.4% of the study area is used for agriculture, 16.1% is forests (including 6.0% plantations), and 13.4% of the area is made up of wetlands. The subwatershed has 4.2% of its area classified as urban development and 3.8% as rural development. Land use within the Erin SSMP study area and surrounding buffer area are presented in **Figure 1.1.3** and **Table 2.3.1**.

The West Credit River subwatershed is a key headwater system for the Credit River. Because of the soil types that predominate, when it rains a significant portion of water percolates through to the aquifers below the surface. Some of this groundwater then moves laterally and upwards to feed wetlands and streams (provide baseflow). The flow from the West Credit River subwatershed is vitally important to river levels in the areas downstream. This cold baseflow also helps to keep the temperature cool enough in streams to sustain coldwater fisheries such as brook trout.

There are many important wetlands in the West Credit River subwatershed, which sustain terrestrial and aquatic communities. These wetlands also play an important hydrologic role by regulating flows of water and removing contaminants from water. Many of the wetland complexes and woodlands are found along the floodplain of the West Credit River and its tributaries. This intact vegetated riparian zone (the land adjacent to a river), in combination with limited urbanization, contributes to a river system that can be characterized as relatively healthy and stable.

2.2.2 Factors Influencing Surface Water Conditions

2.2.2.1 Introduction and Purpose

The purpose of the surface water characterization is to describe the dominant subwatershed characteristics that influence surface water flow. Water in a stream is the result of precipitation that has fallen on the subwatershed over time. Water resulting from precipitation gains entry to the stream following three main paths: by directly falling on the stream surface; by running over the land surface to the stream (surface runoff); or by infiltrating into the ground and reappearing as groundwater discharge (springs or seeps) along the stream.

It is important to note that not all of the precipitation that falls on the subwatershed makes it to the stream. A portion of the precipitation that falls, returns to the atmosphere by evaporation from open water sources, or is used by plants through transpiration. A portion of the water infiltrates into the ground and may leave the subwatershed and be discharged or used by plants in an adjacent subwatershed.

The path water follows in a subwatershed will determine to a great extent how the subwatershed responds to precipitation. The local climate and physiography (surficial geology, topography, and land use) are dominant factors that influence how water is delivered to the streams and rivers that form a subwatershed. Streamflow is the response to how water is delivered to the streams and creeks forming the drainage network of a watershed. Each of these factors needs to be considered when describing the surface water characteristics of a subwatershed. For example the abundance of impervious cover in urbanized watersheds fundamentally alters the proportion of precipitation that infiltrates into the ground, that evaporates back into the atmosphere, and that enters drainage features as surface runoff. In particular, there can be a 3 to 5 fold increase in the amount of runoff reaching streams, with a corresponding reduction in infiltration of water into the ground.

2.2.2.2 Climate Setting

The climate of Southern Ontario is characterized as having warm summers, mild winters, a long growing season, and usually reliable precipitation. The climate within Southern Ontario differs somewhat from one location to the other and from one year to the next.

Spatial variations are caused by the topography and varying exposure to the prevailing winds in relation to the Great Lakes.

According to Brown et al. (1974), the Credit River watershed is located within four climatic regions: the Huron Slopes, South Slopes, Simcoe and Kawartha Lakes, and Lake Ontario Shore. Figures showing the long-term monthly precipitation and air temperature for selected climate stations within and surrounding the West Credit River subwatershed are given in several texts (Brown et al. 1974; Hare and Thomas 1979; OMNR 1984). These figures show the typical variability in rain and snowfall amounts and spatial variations in mean annual precipitation, snowfall, and air temperature.

The mean annual precipitation in the West Credit River subwatershed is about 892 mm, of which 18% appears as snowfall (or 160 cm in depth). Total precipitation is distributed such that June, August, September, and November are the wettest months, and January and February are the driest months. The lowest total precipitation (51 mm) occurs in February, whereas the highest precipitation amount occurs in August (96 mm). Frozen ground conditions are persistent between mid-November to late March, yielding high runoff potential for all soil types (Meteorological Service of Canada, Climate Normals 1971-2000, Orangeville MOE station). The mean annual runoff for this region is estimated to be approximately 338 mm (Ontario Flow Assessment Technique, Version 1.0, OMNR 2002).

The mean annual evapotranspiration in the northern part of the watershed is about 530 mm as deduced from isohyetal maps for Southern Ontario (Brown et al. 1974; OMNR 1984). However, from water balance analyses using observed streamflow data, Singer et al. (1994) computed mean annual evapotranspiration for the area to be about 647 mm. This value is higher than that of the surrounding area, which suggests that a significant amount of water must be available in ponds, swamps, and marshes, or held in soil-water storage. The northern part of the Credit River watershed, including the West Credit River subwatershed, has an annual frost free period of 135 days and the growing period is about 195 days. The mean annual air temperature is 6 ^{o}C, where the mean daily temperature in February is about –7.3 ^{o}C and 19.1 ^{o}C in July (Meteorological Service of Canada, Climate Normals 1971-2000, Orangeville MOE station).

Although June and August tend to be the wettest months, the annual maximum streamflows usually occur in the March to April period resulting from snowmelt or rainfall on frozen ground or a combination of both.

Although the precipitation is generally evenly distributed throughout the years, during the summer period there is a net deficit in the amount of precipitation that falls and is lost through evapotranspiration. The potential evapotranspiration amounts (e.g., lake evaporation) are higher than the total precipitation input for May through August. Mean annual lake evaporation for this region of the watershed is estimated to be approximately 800 mm per year (Ontario Flow Assessment Technique, Version 1.0, OMNR 2002).

2.2.2.3 Streamflow

Monitoring of streamflow has been conducted on the West Credit River at 8th Line and 17th Sideroad, upstream of the Village of Erin, since April of 1983. Officially, Water Survey of Canada has called this gauge *Credit River at Erin Branch, Above Erin (02HB020)*, but in this report it will be referred to as the West Credit River at Erin Branch gauge. Refer to **Figure 2.2.2** for this gauge's location. This gauge measures 30% of the flow in the upper West Credit River, with a catchment area comprising 32.30 km^2. The mean monthly flows for the period of record (1983-2008) were determined and are illustrated in **Figure 2.2.1**. This confirms that the annual maximum streamflows occur in the March to April period resulting from snowmelt or rainfall on frozen ground or a combination of both. **Figure 2.2.1** gives the mean monthly flows in the West Credit River along with the maximum, minimum, median, upper, and lower quartile to the Erin Branch above Erin gauge. Notice that the flows are highest during the spring freshet and lowest during the summer months.

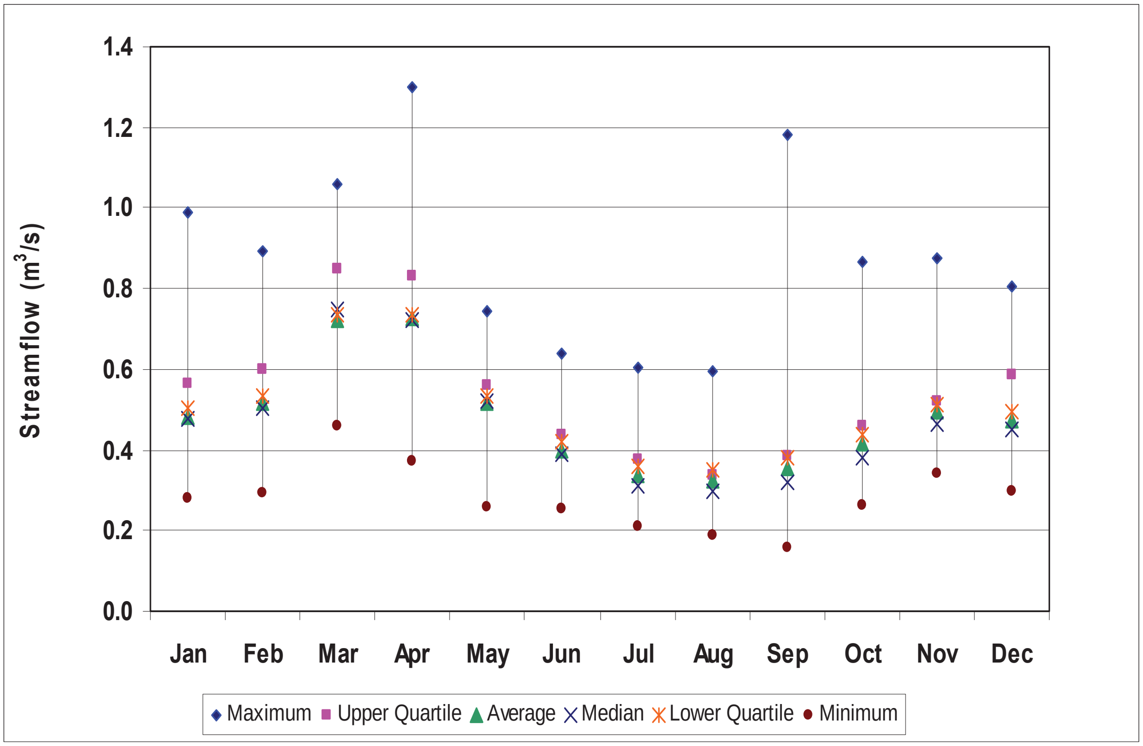
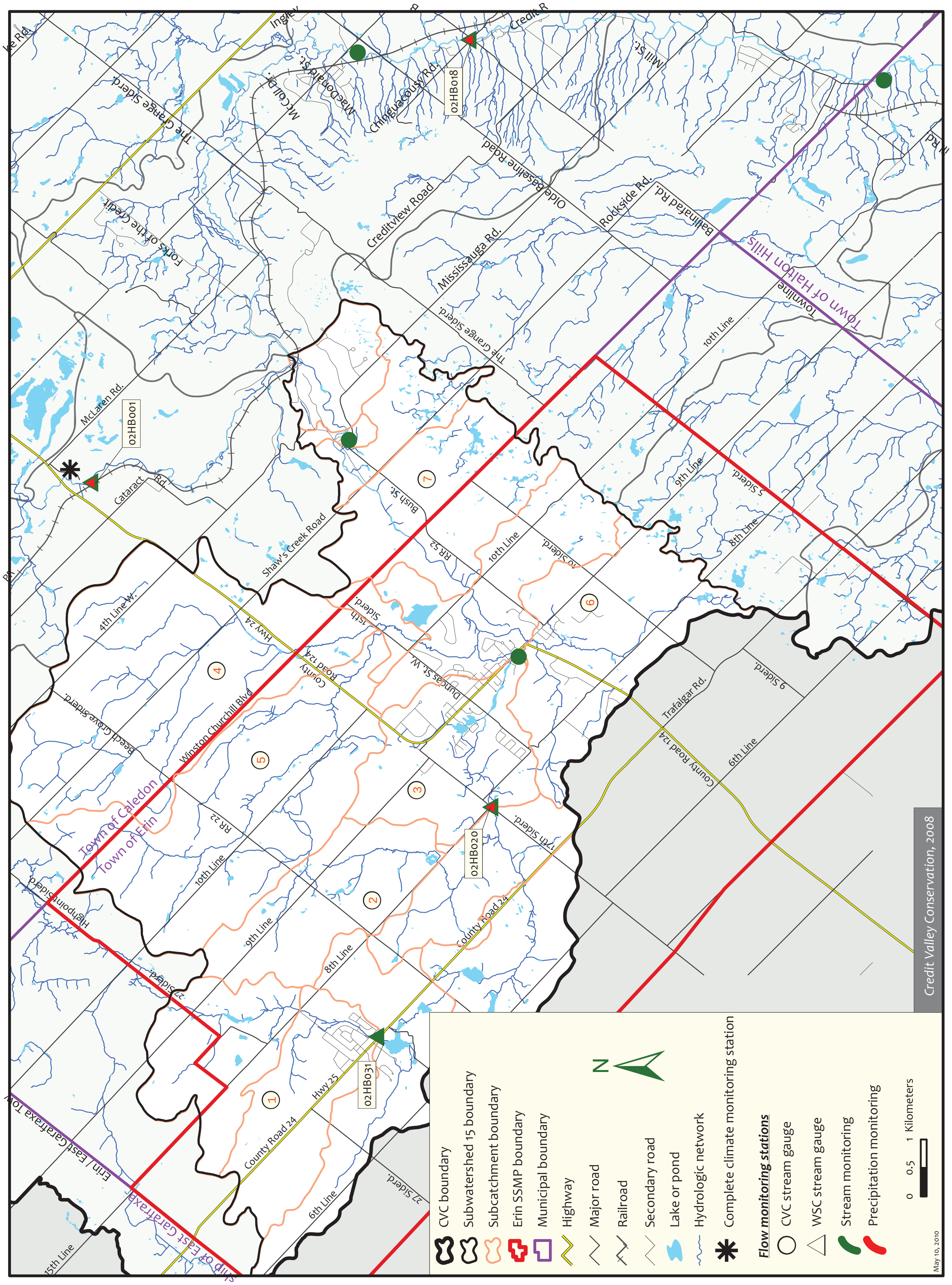


Figure 2.2.1 Mean monthly flows West Credit River at the Erin Branch, above Erin Gauge Station (02HB020) 1983 to 2008

Flow characteristics for the areas above the Niagara Escarpment are very different from those below or downstream of the Escarpment (Chapman and Putnam 1984; Singer et al. 1984), as illustrated by the daily hydrograph plots obtained for two event periods, March 28th to May 1st, 2008 and July 2nd to August 4th, 2008 at the Erin Branch gauge (**Figure 2.2.3** and **Figure 2.2.4**). Areas above the Niagara Escarpment are often dominated by hilly moraines, porous soils, and swampy valley lands. As a result, these factors have a

Figure 2.2.2 Subcatchments and Climate and Stream Gauge Stations



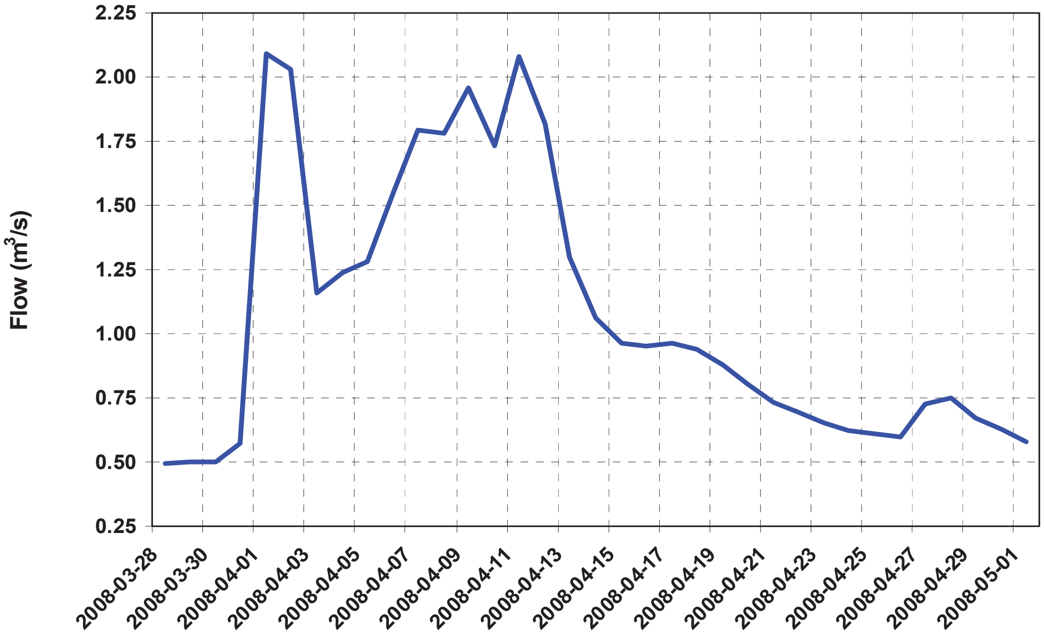


Figure 2.2.3 Typical snowmelt event, West Credit River at Erin Branch, above Erin Gauge Station (02HB020) March 28th to May 1st, 2008

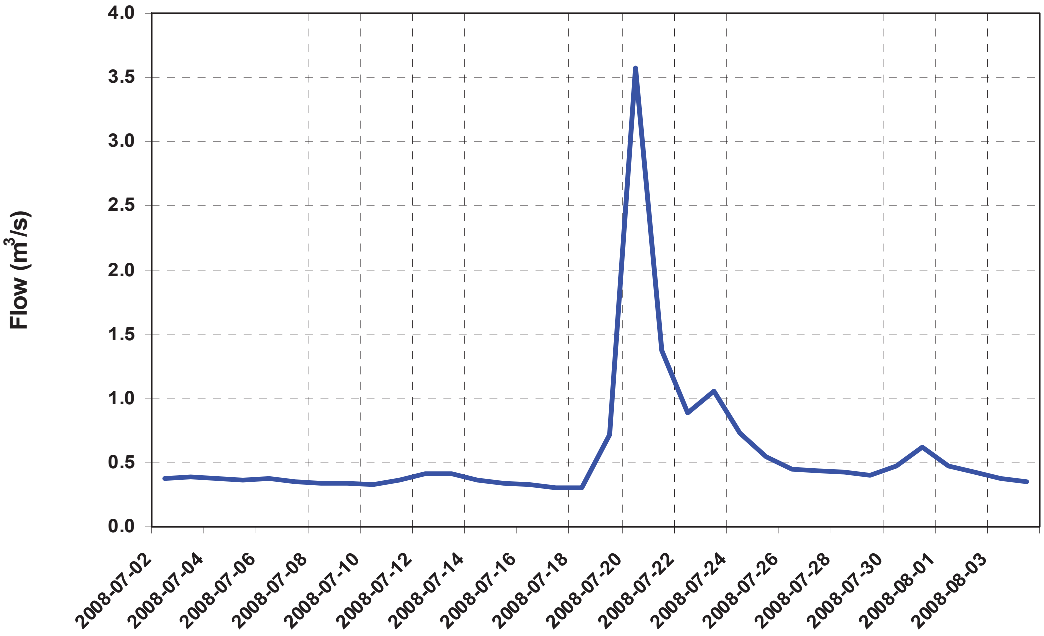


Figure 2.2.4 Typical rainfall event, West Credit River at Erin Branch, above Erin Gauge Station (02HB020) July 2nd to August 4th, 2008

direct influence on the streamflow response. The damp response from the rural areas in West Credit River subwatershed can be seen in the July 2008 plot, **Figure 2.2.4**. In addition, the base time for a typical snowmelt event (see **Figure 2.2.3**) is much longer than for a typical rainfall event (see **Figure 2.2.4**).

Further evidence for climate influences on the streamflow response of the West Credit River can be seen in **Figure 2.2.5**, which gives the time-series of annual maximum flows at the Erin Branch gauge for the period 1983 to 2008. Here we see lower peak flows during 2002 and the highest peaks during the early 1990’s. An examination of the time of occurrence of maximum flows indicated that within the period of record for the Erin Branch gauge (1983 to 2008) 90% of the annual maximum flows in the West Credit River occurred during the ‘spring freshet’ during the months of January (late), February, March, and April, when flood flows result from snowmelt or a combination of rain and snowmelt on frozen ground conditions. Flood flows in the late summer and early fall period are typically caused by tropical storm systems, a period when the infiltration capacity for most soils is reduced to 25 to 30% of their mid-summer values. During this time the runoff potential is at it’s highest without a snow pack. Recall that the highest 24 hour rainfall total that has occurred in the West Credit River was during the August to November period.

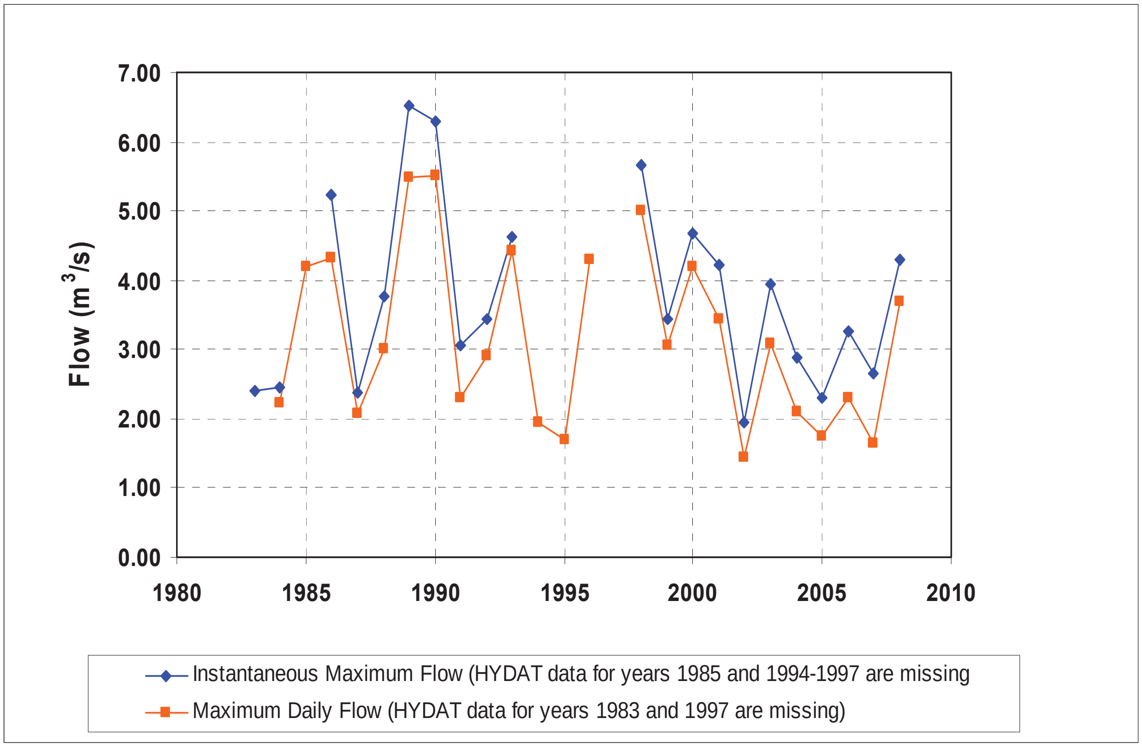


Figure 2.2.5 Time-series of annual maximum flows in the West Credit River at Erin Branch, above Erin Gauge Station (02HB020)
Note: Instantaneous maximum flow or peak flow is the maximum discharge of a stream or river at a particular instant of time; Annual maximum daily flow is the highest daily mean discharge of a stream or river in the particular year at a given location.

Figure 2.2.6 illustrates the time-series annual minimum daily flows at the Erin branch gauge for the period 1983 to 2008. Annual minimum daily flow is the lowest daily mean discharge of a stream or river in the particular year at a given location. Generally, this plot shows some of the same climate variability that was evident in a similar plot for annual maximum flows. The highest minimum flow occurred in 2008 and the lowest minimum flow occurred in 1989 during the drought of the late 80's, with recovery in baseflow in 1990. An examination of the time of occurrence of minimum low flows indicated that within the period of record for the Erin Branch gauge (1983 to 2008) 90% of the annual minimum flows in the West Credit River occurred during the late summer and early autumn period (July to September).

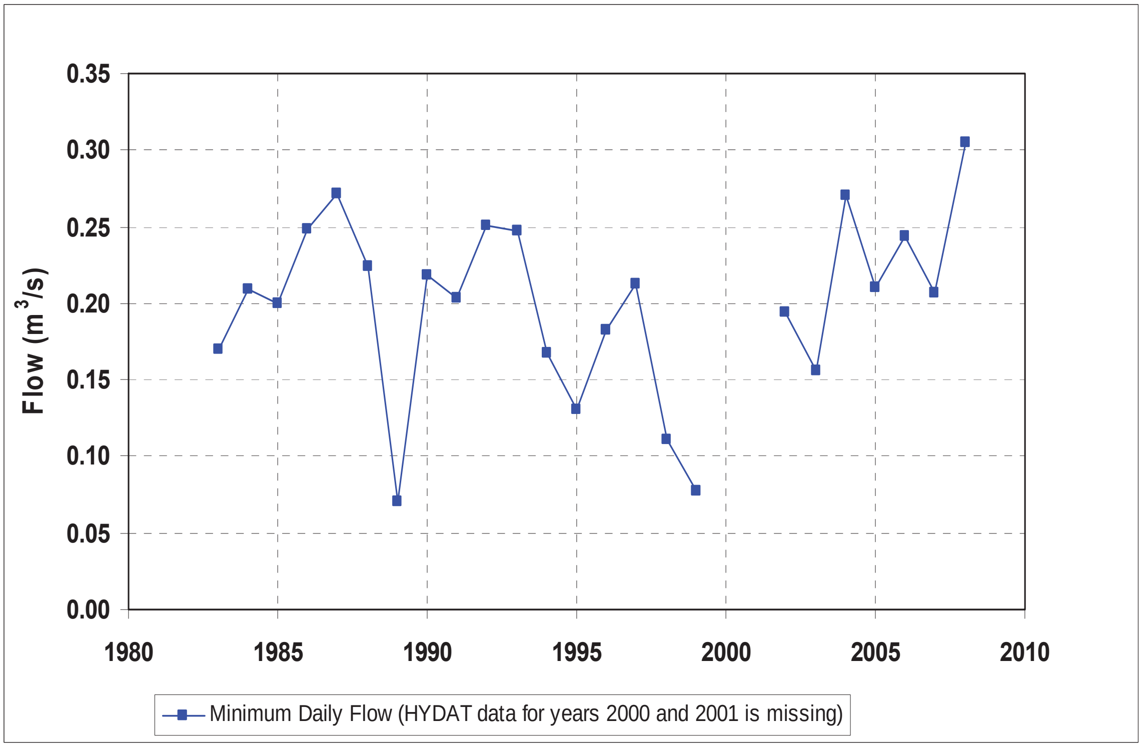


Figure 2.2.6 Time-series of annual minimum daily flows in the West Credit River at Erin Branch, above Erin Gauge Station (02HB020)

A comparison of unit area frequency peak flows within the West Credit River with other areas in the Credit River watershed is presented in **Figure 2.2.7**. Much lower unit flood flows are produced by the Upper Credit River watershed, headwaters area (Melville) than within the West Credit River. The unit area flood flows at Cataract for the 100 years Return Period are about 30% higher than corresponding unit flows at Melville. These differences in the unit flood flows are indicative of the differing physiography and climate occurring within the Credit River watershed.

Figure 2.2.7 Comparison of unit area peak flows in the West Credit River with other areas

A comparison of unit area low flows within the West Credit River with other areas in the Credit River watershed is presented in **Figure 2.2.8**. The unit area low flows for the Erin Branch station are higher due to greater recharge amounts attributed to soils with higher infiltration capacity and hummocky topography. Furthermore, the Melville low flows are higher than the Cataract due to the presence of the Orangeville Moraine which is made up primarily of sands and gravels, resulting in higher recharge amounts.

The low flow or dry weather flows can be characterized by examining the flow duration curves for the Erin Branch gauge within the study area. **Figure 2.2.9** gives the 'all year' and 'summer only' (June 21st to September 20th) flow duration curves for the Erin Branch gauge. Flows with less than 10% duration represent the flood flow portion of the curve. The summer flow curve flattens out for durations greater than 20%. As suggested by Schroeter and Boyd (1998), the flow duration curves are highly correlated with the physiography of an area. In this regard, the West Credit River subwatershed is located above the Niagara Escarpment where more pervious soils dominate among wetland and depressional storage features associated with hummocky terrain. As a result, the flow duration curves for the Erin Branch gauge are indicative of the physiographic features of the subwatershed.

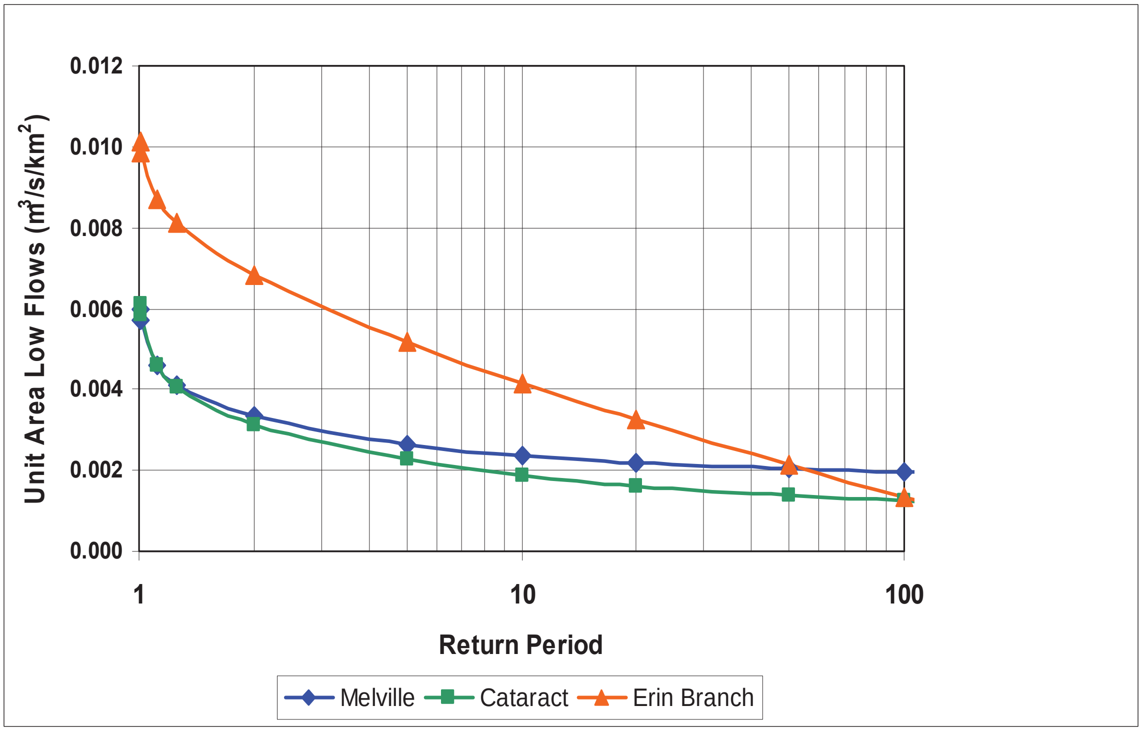


Figure 2.2.8 Comparison of unit area low flows in the West Credit River with other areas

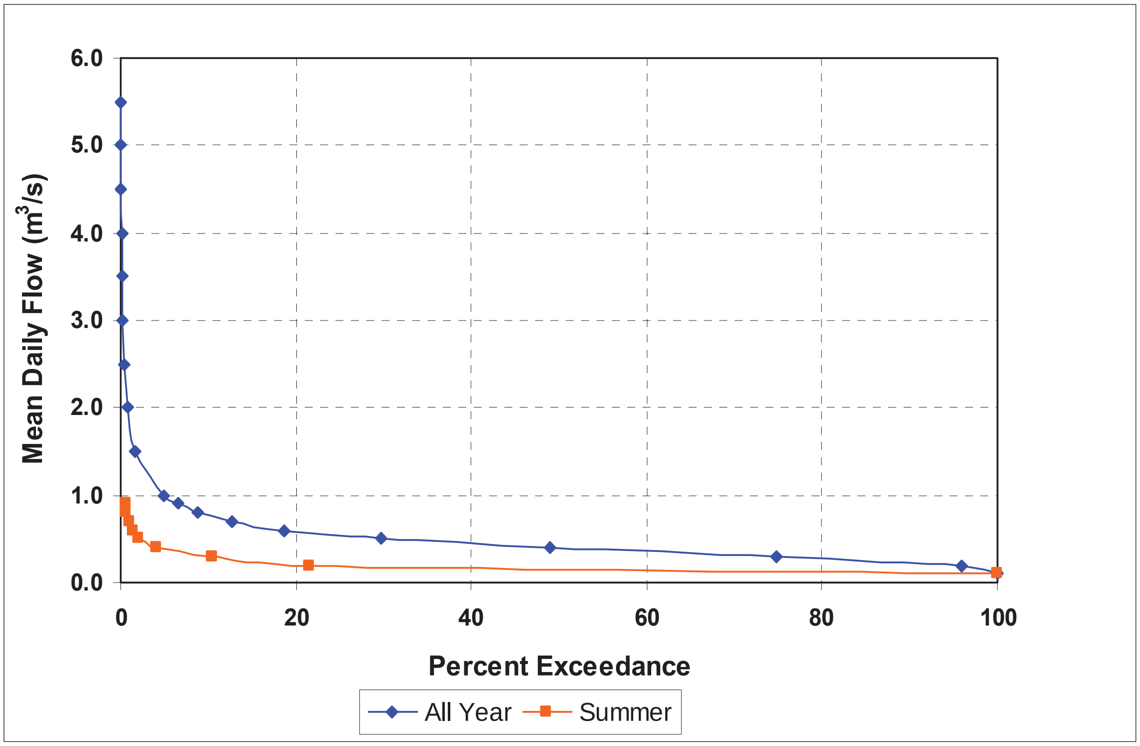


Figure 2.2.9 Flow duration curves for the West Credit River at Erin Branch, above Erin Gauge Station (02HB020)

2.2.3 Low Flow and Flood Flow Frequency Analysis

2.2.3.1 Low Flow Frequency Analysis

Runoff from a watershed is a natural process, which is subject to large daily and monthly fluctuations, which cannot be predicted to occur at any specific time. Minimum mean daily flow rates at the West Credit River at Erin Branch Above Erin gauge were used to carry out a low flow frequency analysis. Streamflow originates from a drainage area of approximately 32.3 km^2. As noted earlier, Water Survey of Canada has measured levels at the gauge since April of 1983.

The objectives of the low flow analyses are to determine the minimum flow rates for various durations and return periods. The low flow analysis determines streamflow rates that can be expected to occur on average once every 1.005 through 500 years. A separate low flow frequency analysis was carried out for each duration of 7, 15, and 30 days. The minimum streamflow rates for the various return periods are best determined using data recorded over long periods (50 to 100 years) from the basin where the predicted runoff rates are required. Less accurate results would be expected for shorter periods of record or flow rates recorded on adjacent basins. The low flow frequency analysis was carried out with the aid of the Low Flow Frequency Analysis Package (LFA) of Environment Canada. The detailed methodology and results of this analysis are presented in Section 1.0 of the Hydrology and Hydraulics Appendix. The results of the low flow frequency analysis for the Erin Branch Gauge are illustrated in **Table 2.2.1**. These values from the Erin Branch gauge station are transposed to determine the low flow frequency values for each duration series 7-day, 15-day and 30-day and return periods 1.005 to 500 years at 4 other monitoring stations, Beech Grove Sideroad, 17th Sideroad, 10th Line, and Winston Churchill Boulevard. These results are presented in Tables 1.2 to 1.5 of the Hydrology and Hydraulics Appendix.

Table 2.2.1 Low flow frequency analysis (durations of 7, 15, and 30 days) for the station, West Credit River at Erin Branch above Erin (period of record 1983 to 2008)

Return Period (years)	Avg. Min. 7 Day Flow Rate (m3/s)	Avg. Min. 15 Day Flow Rate (m3/s)	Avg. Min. 30 Day Flow Rate (m3/s)
1.005	0.366	0.390	0.452
1.01	0.352	0.375	0.430
1.11	0.294	0.307	0.339
1.25	0.268	0.279	0.303
2	0.216	0.226	0.242
5	0.165	0.178	0.192
10	0.140	0.156	0.173
20	0.120	0.140	0.160

Return Period (years)	Avg. Min. 7 Day Flow Rate (m3/s)	Avg. Min. 15 Day Flow Rate (m3/s)	Avg. Min. 30 Day Flow Rate (m3/s)
50	0.100	0.125	0.149
100	0.088	0.117	0.144
200	0.079	0.111	0.140
500	0.069	0.105	0.137

2.2.3.2 Flood and Low Flow Frequency Analysis

The objective of the flood and low flow frequency analysis is to determine the maximum annual instantaneous peak flow rates and annual minimum flow rates that will occur on average at various return periods. Runoff from a subwatershed is a natural process, which is subject to large daily and monthly fluctuations, which cannot be predicted to occur at any specific time. However, using past occurrences of runoff rates, it is possible to predict on average when a specific runoff rate will occur. The analysis determined streamflow rates that can be expected to occur on average once every 2 through 100 years.

The analyses involved first the determination of a series of annual maximum instantaneous flow rates and annual minimum flow rates for each year and then performed a frequency analysis of the maximum and low flow rates.

The frequency analysis on peak flows was carried out with the aid of the Consolidated Frequency Analysis Package (CFA88) of Environment Canada. Similarly, frequency analysis on annual low flows was carried out with LFA program of Environment Canada. The CFA88 program determines return period values for the four (4) frequency distributions shown in **Table 2.2.2**. The user must determine which frequency distribution best fits the data. In the case of the Erin Branch Above Erin gauge, experience has shown that the 3-Parameter Log Normal Frequency Distribution best fits the data (**Table 2.2.2**). These peak flow values for the Erin Branch station based on the 3-Parameter Log Normal Distribution were than transposed to four monitoring locations, Beech Grove Sideroad, 17th Sideroad, 10th Line, and Winston Churchill Boulevard. These results are tabulated in **Table 2.1** of the Hydrology and Hydraulics Appendix. This appendix also provides details of the methodology used.

Table 2.2.2 Flood flow frequency analysis (instantaneous peak flow rates) for the station, West Credit River at Erin Branch above Erin (period of record 1983 to 2008)

Return Period	Exceedance Probability (m^3/s)	Distributions			
		Generalized Extreme Value (m^3/s)	3 Parameter Log Normal Distribution (m^3/s)	Log Pearson Type III Distribution (m^3/s)	Wakeby Distribution (m^3/s)
1.003	0.997	1.16	**1.67**	1.59	1.64
1.050	0.952	1.88	**2.09**	2.09	1.90
1.250	0.800	2.59	**2.63**	2.66	2.54
2.000	0.500	3.53	**3.47**	3.49	3.51
5.000	0.200	4.82	**4.78**	4.73	4.91
10.000	0.100	5.68	**5.73**	5.61	5.80
20.000	0.050	6.52	**6.70**	6.51	6.57
50.000	0.020	7.61	**8.04**	7.74	7.42
100.000	0.010	8.43	**9.11**	8.73	7.97
200.000	0.005	9.26	**10.20**	9.78	8.44
500.000	0.002	10.4	**11.80**	11.30	8.96

2.2.4 Hydrologic and Hydraulic Issues

Land use changes, and urbanization in particular, can have significant impacts on topography, ground cover, contaminant loadings, and surface drainage, and can lead to diminished water quality, increased stream bank erosion, loss of terrestrial and aquatic biota, and loss of recreational resources. Increased urbanization in the West Credit River subwatershed would have the most impact in three areas: flooding, domestic water supply, and aquatic habitat.

There are three "flood damage centres" (areas susceptible to flooding during storms) located along the main branch of the West Credit River. These are located at Hillsburgh, Erin Village, and Belfountain. During the Regulatory Storm (a storm of Hurricane Hazel's magnitude), approximately 28 buildings in Hillsburgh, 38 buildings in the Erin Village, and 3 buildings in Belfountain would be inundated. Most of these buildings are residential. Increases in runoff resulting from land use changes or activities would increase actual and potential flood damages within these communities.

With respect to the domestic water supply, drinking water within the subwatershed is provided by groundwater. Traditionally, urbanization reduces infiltration dramatically through the creation of hard surfaces (paved or impervious roads, parking lots, rooftops, etc.) Reductions in infiltration will result in reductions in the amount of available drinking water supply. Urbanization also typically generates contaminants which, if not properly treated, can infiltrate to groundwater and nearby streams. In extreme cases, this can lead to aquifers that are too contaminated to be used for drinking water.

Significant impacts to aquatic habitat can be caused by land use changes that eliminate riparian vegetation and alter water quality and the quantity and quality of flows. Reductions in infiltration resulting from urbanization will eventually reduce summer streamflow rates and water depths that are required to sustain certain species. As previously described, changes to the flow-duration relationship will accelerate stream bank erosion and cover spawning beds with sediment. Increased water temperatures caused by online ponds have already changed species composition and habitat in the West Credit River subwatershed.

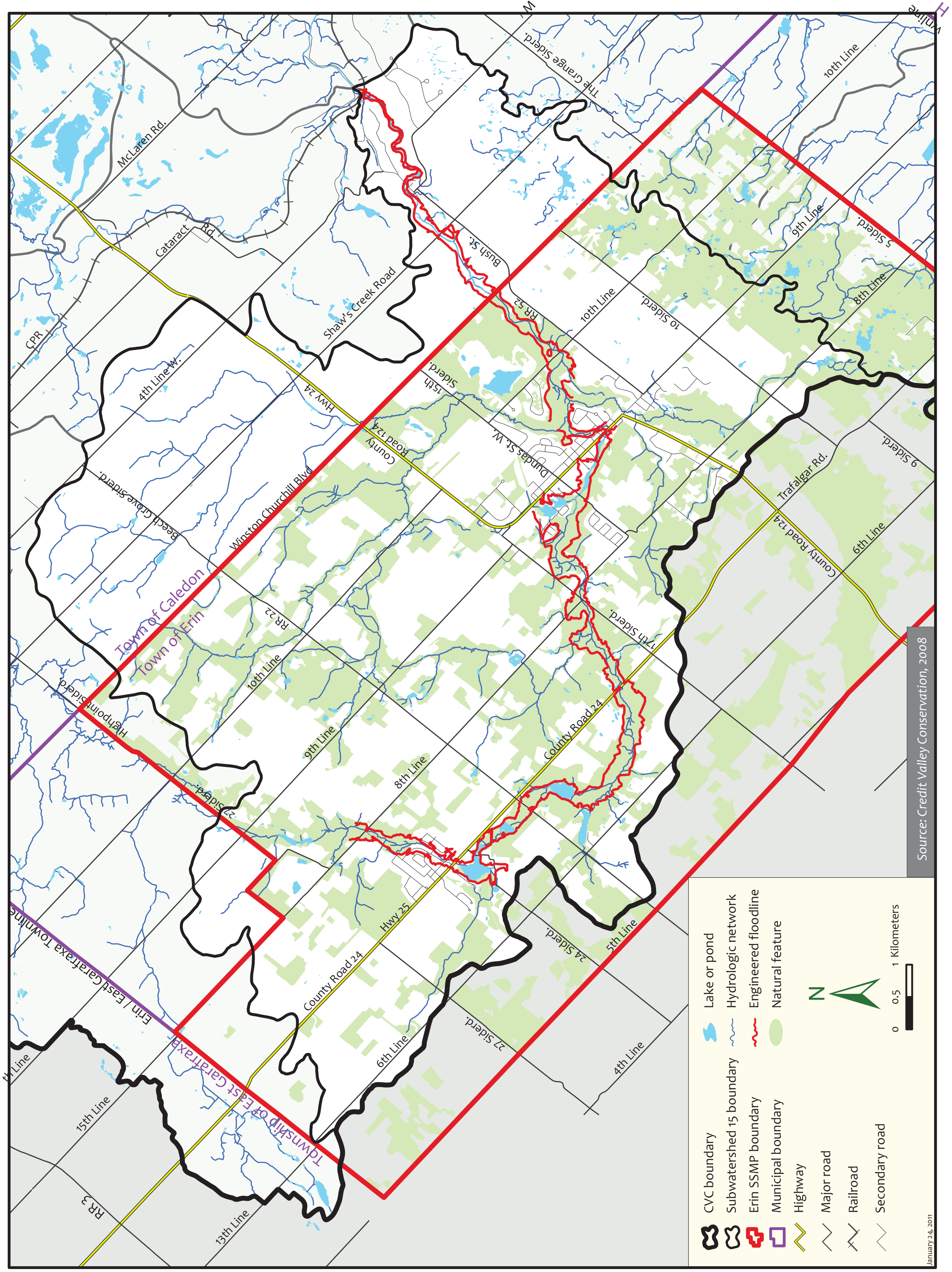
2.2.5 Floodplain and Watercourse Characteristics

The main branch of the West Credit River is perennial, meaning water flows in it all year. However, many of the smaller first order streams that feed into the main branch only convey water for a few weeks of the year, typically during the spring freshet. The main branch can be characterized as having little erosion and stable banks. The gravely soils in the West Credit River subwatershed allow water to percolate into the ground and make its way slowly to the river as well as into deeper groundwater. When water moves slowly to the river, there is little bank erosion, and flooding is infrequent. The subwatershed is able to store water and release it to the river slowly, except in very wet conditions. The floodplain mapping can be seen in detail in **Figure 2.2.10**

There is little urban activity in the subwatershed, and therefore storm runoff is contained in three nodes: the Villages of Hillsburgh, Erin, and Belfountain. At present, the runoff is not significant enough to cause increased bank erosion, with the exception of Reach 15-035 in Erin Village which is showing instability (refer to **Figure 2.4.2** for the location of this reach). In the urban areas, encroachment onto the floodplain and in the riparian zone limits the area the river can move around in, and to counteract potential river migration, there is some hard lining on the banks adjacent to road crossings and private properties.

There are some disturbances to the West Credit River subwatershed's watercourses, especially in areas where beaver activity is common (between the Villages of Erin and Hillsburgh). The beaver dams trap water, flooding riparian areas and drowning adjacent trees, causing them to topple. Beavers also use the trees in the riparian zone for food and lodging. The result is a reach of river with little cover and vegetation to stabilize the banks. At the present time, this does not appear to be having a drastic impact on the morphology of the river. Please refer to Section 2.4.4, Fluvial Geomorphology for further details on the study area’s watercourse characteristics.

Figure 2.2.10 Floodplain Mapping



Source: Credit Valley Conservation, 2008

2.2.6 Dams

The presence of dams and online ponds within a subwatershed can have a direct impact on water quality (i.e., temperature) and quantity, which in turn, can affect species composition and habitat. In total, eleven (11) dam structures have been identified within the West Credit River subwatershed. They include Roman Lake Dams 1 and 2, Fish Club Dam, Hillsburgh Dam, Ainsworth Dam, Stanley Park Ponds, Church Street Dam, Charles Street (Hall's) Dam, Forks of the Credit Dam, Belfountain Dam, and one dam name unknown (**Figure 2.6.6**). Each of the dam structures is privately owned with the exception of Belfountain Dam which is owned and operated by Credit Valley Conservation. The condition of each of these structures varies from site to site. Most of the Dams with the exception of the Belfountain Dam and Forks of the Credit Dam are earthen gravity dams with a concrete control structure. The latter two are concrete gravity dams. At one point the purpose of the Belfountain dams was to provide electrical power during milling operations, now the dam serves only for the purpose of recreation. The purpose of the Forks of the Credit Dam is to provide grade control on site. Drainage areas for the dam structures vary from as low as 177 ha (Roman Lake #2 Dam) to as high as 10,285 ha (Belfountain Dam). The storage area behind each of the structures varies from 0 ha (Forks of the Credit Dam) to 8.9 ha (Hillsburgh Dam). The storage area for the Belfountain Dam is 0.8 ha.

2.2.7 Hydrology and Hydraulic Characterization

The West Credit River subwatershed is a key headwater system for the Credit River. The flow from the West Credit River subwatershed is vitally important to river levels in the areas downstream. A summary of hydrology and hydraulic characteristics of the subwatershed is provided below:

- The mean annual precipitation in the West Credit River subwatershed is about 892 mm, of which 18% appears as snowfall (or 160 cm in depth). The mean annual runoff for this region is estimated to be approximately 338 mm.
- Monitoring of streamflow has been conducted on the West Credit River since April of 1983 by Water Survey of Canada at the gauge located on 8th Line, and named the West Credit River at Erin Branch, Above Erin Village (02HB020). This gauge measures 30% of the flow in the West Credit River, an area comprising 32.30 km^2.
- The Low Flow Frequency Analysis Package (LFA) and Consolidated Frequency Analysis Package (CFA88), computer programs maintained and distributed by the Water Resources Branch of the Inland Waters Directorate of Environment Canada, were used for analysis of the maximum and minimum flow series.
- 7-days annual minimum mean daily flow rates for the West Credit River at Erin Branch, above Erin Village (02HB020) for the following Return Periods (years) 1.005, 2, 5, 10, 20 and 100 are equal to 0.366, 0.216, 0.165, 0.140, 0.120 and 0.088 m^3/L respectively.

- Annual maximum instantaneous flow rates for the West Credit River at Erin Branch, above Erin Village (02HB020) evaluated by 3-Parameter Log Normal Frequency Distribution best fits the observed flows. For the following Return Periods (years) 1.05, 2, 5, 10, 20 and 100 the peak flows are 2.09, 3.47, 4.78, 5.73, 6.70 and 9.11 m^3/L respectively.
- The main branch of the West Credit River can be characterized as having little erosion and stable banks. The gravely soils in the West Credit River subwatershed allow water to percolate into the ground and make its way slowly to the river as well as into deeper groundwater.
- Eleven (11) dam structures have been identified within the West Credit River subwatershed. The presence of dams and online ponds within a subwatershed can have a direct impact on water quality (i.e., temperature) and quantity.

2.2.8 Next Steps

A number of small tributaries and headwater features of subwatersheds 10, 11 and 12 may be impacted by the servicing and future developments. The hydrologic functions of these tributaries should be studied in detail during site specific studies. In addition, a flood line mapping study should be conducted to delineate hazard limits, where applicable. Floodline mapping has been completed for the main branch and eastern branch of the West Credit River, and have been approximated for various tributaries. For those tributaries that have not been studied, delineations are determined at a site specific scale through CVC's site assessments as well as through an Environmental Assessment if required.

Currently there is no information on the operation of existing ponds, which is essential as their operation impacts peak flows. Therefore, a detailed analysis of land use, proposed locations of a Water Pollution Control Plant, and operations of existing ponds should be studied in detail to specifically address issues on increased flows and conveyance capacity of the existing downstream infrastructure.

Infiltration based Low Impact Development (LID) practices should be considered in the stormwater management plan to meet the flood quantity, quality, and pre-development water balance criteria as compared to the conventional stormwater management practices.

2.3 NATURAL HERITAGE

Natural heritage includes geological features and landforms, associated terrestrial and aquatic ecosystems, plant and wildlife species, populations and communities, and their habitats and sustaining environments. A *natural heritage system* includes the interactions that occur among and between these features. The natural heritage system is the resource base from which, and around which, human activities occur (e.g., education, recreation, and resource extraction). Achieving a balance between resource use and the protection of the quality of natural heritage features is a fundamental objective of sustainable development.

The "health" of a natural heritage system is often linked to the size, shape, and spatial arrangement of terrestrial habitat patches, including wetlands, woodlands, and meadows. Also an influence is the types of land uses that occur between these natural features. Generally, urban land uses such as housing, industrial, and commercial uses exert a negative impact on natural heritage features; while other land uses such as agriculture and public parklands exert a lesser impact. In general, the larger, more abundant, and more connected habitat patches (i.e., to each other and to surface and groundwater features) are, the more resilient the natural heritage system is to environmental change. In addition, the age of a natural community or a population can influence ecosystem health, as can the amount of disturbance an area is exposed to. While variables such as size, shape, spatial arrangement, and land use can be determined remotely (e.g., through air photo interpretation or digital orthophotography), site-specific field investigations confirm the determination of abiotic conditions, the presence/absence of unique species, the age of ecological communities (i.e., successional stage), and/or the "nativeness" of the community. Important benefits provided by a healthy natural heritage system include, but are not limited to: flood attenuation; protecting rivers, streams and other water bodies from sedimentation and temperature increases; promoting and protecting groundwater recharge and discharge areas; maintaining air quality; maintaining biological diversity and species abundance; and providing recreational and educational opportunities.

The natural heritage component of this study focuses on the natural areas within the Erin SSMP study area, as well as the floral and faunal species that rely on these areas. This section provides information on the communities and species noted in the study area, and notes some of the more interesting finds and trends. This section of the report will also identify the locations of high priority natural heritage features, such as those protecting groundwater recharge and discharge, those playing a role in flood control, those that are under-represented at a subwatershed, watershed, and provincial scale, and those habitats containing rare species. In doing so, we are able to establish the current condition of the natural features and functions of the study area.

2.3.1 Landscape Context

2.3.1.1 Ecoregion and Ecodistrict

The Erin SSMP study area is located within the Mixedwood Plains Ecozone that encompasses all of Southern Ontario. This Ecozone, occupying less than 10% of the province, is defined by the limestone and dolostone bedrock that occurs south of the Precambrian Shield. Vegetation is diverse, despite the conversion of many natural lands for agriculture and urban development. Mixed forests of deciduous and coniferous trees occur, as well as areas dominated by deciduous tree species as in Carolinian forests.

The study area is within the Great Lakes-St. Lawrence Forest zone which is characterized by mixed forests of White Pine, Red Pine, Eastern Hemlock and Yellow Birch as well as Sugar Maple, Red Maple, Red Oak, Basswood and White Elm (Rowe 1972).

Ontario was originally divided into Site Regions by Angus Hills (Hills 1959) to distinguish distinct ecological regions in the province based on a combination of landform and climate. Boundaries for these regions were modified based on more detailed mapping and interpolation of physiographic features (e.g., Jalava et al. 1997) which have come to be known as Ecoregions. The Erin SSMP study falls within Ecoregion 6E, the Lakes Simcoe–Rideau Site Region, which occupies the northern portion of Rowe's (1972) Great Lakes–St. Lawrence Forest Region. The underlying bedrock is primarily dolostone and limestone. In the study area, the ecoregion is draped with thick deposits of glacial and post-glacial sediments in the form of massive moraines (i.e., Oak Ridges) and broad till sheets. The Niagara Escarpment provides an exception to the otherwise relatively flat landscape. This area was once dominated by deciduous forest. However, the predominance of clayey gleysolic and grey brown luvisolic soils over a landscape that is generally flat and interspersed with rolling moraines resulted in extensive clearing for farming over the nineteenth century. This area is characterized by mixed forests of White Pine (*Pinus strobus*) and Red Pine (*Pinus resinosa*), Eastern Hemlock (*Tsuga canadensis*), Sugar Maple (*Acer saccharum*), Red Maple (*Acer rubrum*), Yellow Birch (*Betula alleghaniensis*), Red Oak (*Quercus rubra*), Basswood (*Tilia americana*) and White Elm (*Ulmus americana*). Other wide-ranging species include Eastern White Cedar (*Thuja occidentalis*), Largetooth Aspen (*Populus grandidentata*), Beech (*Fagus grandifolia*), White Oak (*Quercus alba*), Butternut (*Juglans cinerea*), and White Ash (*Fraxinus americana*) (Hills 1959; Rowe 1972).

Ecoregions provide a useful context for natural heritage planning in the Province and have been further subdivided into Ecodistricts by the Ontario Ministry of Natural Resources (OMNR), as described by Henson and Brodribb (2005). The Erin SSMP study area falls within the extreme eastern end of Ecodistrict 6E-1, whose physiography is described as smooth clay areas and gently rolling till moraines. The overall cover of wetlands and forests in Ecodistrict 6E-1 is currently estimated at 16% (Henson and Brodribb 2005).

2.3.2 Land Use and Ecological Community Characterization

The ecological communities have been mapped and described using Ecological Land Classification (ELC). Ecological Land Classification is a standardized hierarchal classification used for the description, inventory, and interpretation of ecological units. ELC provides resource managers with a "uniform and consistent way to identify, describe, name, map, manage and conserve important landscape patterns and communities" (Lee et al. 2001). Lee's 2008 classification system was not used because at the time of this study it was still considered a work in progress. Instead, a modified ELC vegetation community list was used, see Appendix C. The modified list was created by combining Lee's (2008) vegetation community list, along with additional vegetation communities from Toronto and Region Conservation Authority.

In the late 1990s, CVC staff mapped the terrestrial system of the Credit River watershed to the Community Series level using the *Ecological Land Classification for Southern Ontario* (Lee et al. 1998) and the *Credit Watershed Natural Heritage Project Detailed Methodology* (Credit Valley Conservation 1998^{b}). The Ecological Land Classification (ELC) was used to map and describe upland, wetland, and aquatic systems. The Natural Heritage Project (NHP) Methodology outlines the methods used to characterize the existing land use matrix of the watershed. Mapping of the study area was originally completed using 1996-spring aerial photography. The polygon boundaries drawn on the air photos were then transferred to 1:10,000 Ontario Base Mapping and digitized into GIS (Geographic Information System ArcView 3.3).

In 2009, land use and ELC mapping of the Erin SSMP study area was updated based on existing fieldwork (much of which was conducted in 2008) and 2007 digital ortho-rectified aerial photography. It should be noted that although field work permits the mapping of communities at the Vegetation Type level of ELC, due to issues of scale these communities are not displayed in this report. Vegetation Type level data was, however, used to characterize the subwatershed and to identify terrestrial priority areas and connections.

The following sections describe existing land use and the ecological communities present in the Erin SSMP study area. In addition these sections explain the role the communities play within the larger natural heritage system, the condition of these communities, and the significance of specific vegetation communities within the study area. Descriptions of the Community Series Classes used in this discussion appear in Section 1.0 of the Natural Heritage Appendix and subsequent mapping is found in **Figure 2.3.1**.

Table 2.3.1 shows a breakdown of the Existing Land Use categories and the Community Series classifications for forest, wetland, aquatic, and cultural communities. Statistics are also provided for the West Credit River subwatershed as a comparison to illustrate that the ecological communities within the study area are representative of the surrounding area despite the increase in urban area around Erin Village and Hillsburgh. The land uses are illustrated in Figure 1.1.2, within Section 1.1.

Figure 2.3.1 Ecological Land Classification

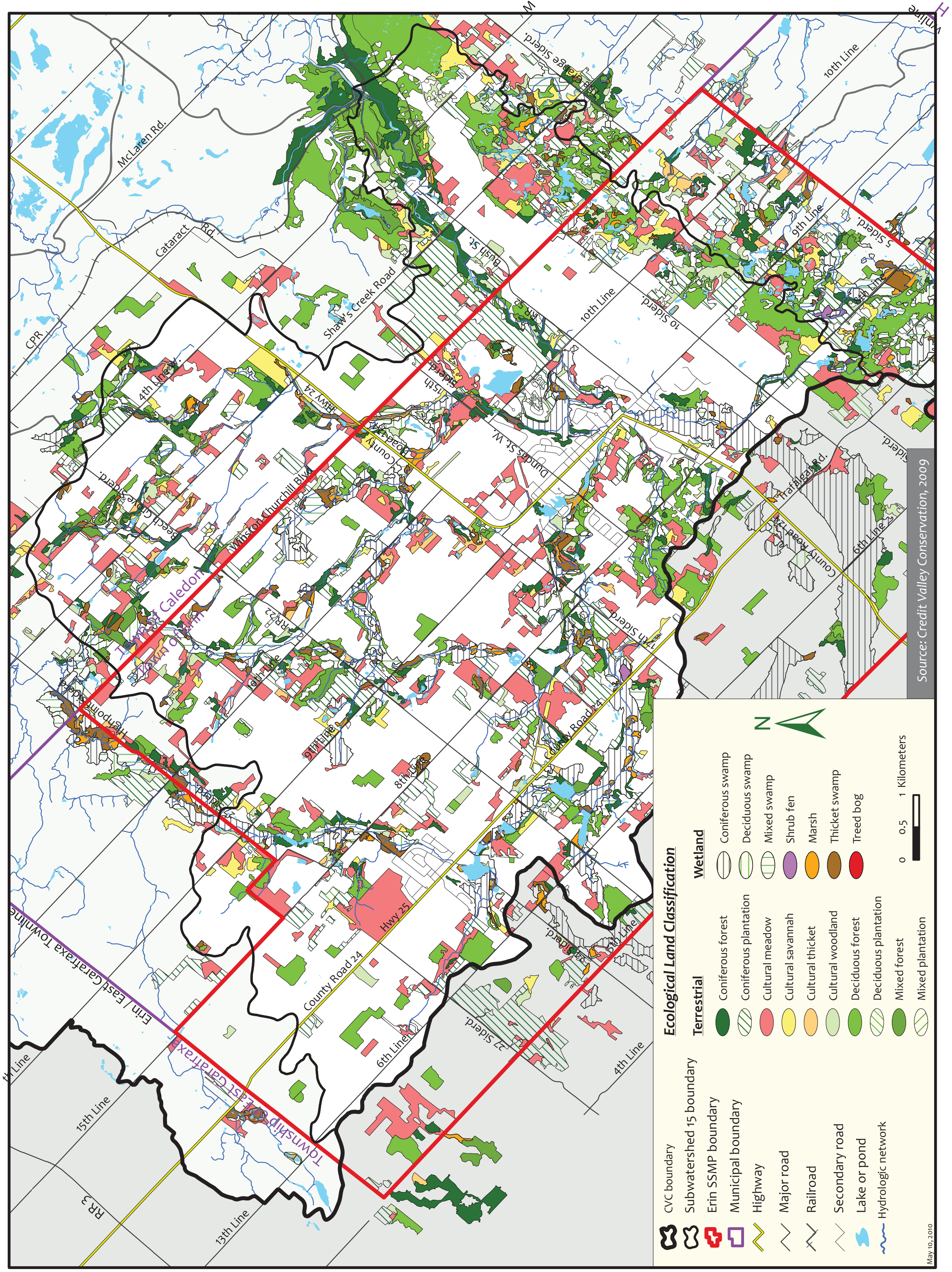


Table 2.3.1 Existing Land Use and Ecological Communities within the Erin SSMP Study Area

	Erin SSMP Study Area		**West Credit River Subwatershed**	
TYPE	**Hectares**	**% of Total**	**Hectares**	**% of Total**
Forest				
Coniferous forest	353.33	2.80	292.89	2.8
Mixed forest	168.19	1.33	193.44	1.8
Deciduous forest	751.91	5.96	699.76	6.6
Coniferous plantation	724.86	5.75	668.57	6.3
Mixed plantation	4.24	0.03	11.07	0.1
Deciduous plantation	23.87	0.19	5.63	0.1
TOTAL FOREST	*2026.41*	16.07	*1871.34*	*17.7*
Wetland				
Coniferous swamp	944.98	7.49	491.00	4.7
Mixed swamp	299.61	2.38	235.65	2.2
Deciduous swamp	171.34	1.36	164.97	1.6
Thicket swamp	144.69	1.15	129.25	1.2
Marsh	114.99	0.91	105.28	1.0
Fen	8.35	0.07	2.89	0.0
Treed bog	2.32	0.02	0.00	0.0
TOTAL WETLAND	*1686.28*	13.37	*1129.05*	*10.7*
Aquatic				
Aquatic	83.59	0.66	77.77	0.7
TOTAL AQUATIC	*83.59*	0.66	*77.77*	*0.7*
Cultural				
Cultural meadow	845.62	6.70	842.74	8.0
Cultural thicket	58.54	0.46	62.05	0.6
Cultural savannah	147.68	1.17	178.52	1.7
Cultural woodland	223.97	1.78	244.22	2.3
TOTAL CULTURAL	*1275.81*	10.12	*1327.53*	*12.6*
Existing Land Use				
Construction	0.00	0.00	0.26	0.0
Active aggregate	197.98	1.57	224.04	2.1
Inactive aggregate	15.55	0.12	16.27	0.2
Intensive agriculture	4452.21	35.30	3215.76	30.5
Non-intensive agriculture	1400.96	11.11	1318.28	12.5
Landfill	2.53	0.02	2.53	0.0
Manicured open space	131.07	1.04	122.56	1.2
Private Open Space	64.53	0.51	52.26	0.5
Major trail	1.10	0.01	0.95	0.0
Railroad	0.00	0.00	0.54	0.0
Regional Road	231.11	1.83	205.00	1.9
Rural development	481.27	3.82	356.70	3.4
Urban	523.09	4.15	584.62	5.5
Wet meadow	38.96	0.31	50.29	0.5
TOTAL CULTURAL	*7540.36*	59.79	*6150.05*	*58.3*
GRAND TOTAL	***12612.45***	***100.00***	***10555.74***	***100.00***

Within the Erin SSMP study area, 59.8% of the land is dominated by human use in the form of agriculture or urban/rural settlement (Table 2.3.1). Natural areas (40.2%) are comprised of forests (16.1%), wetlands (13.4%), lakes and ponds (0.7%), and cultural/successional communities (10.1%) make up the natural features.

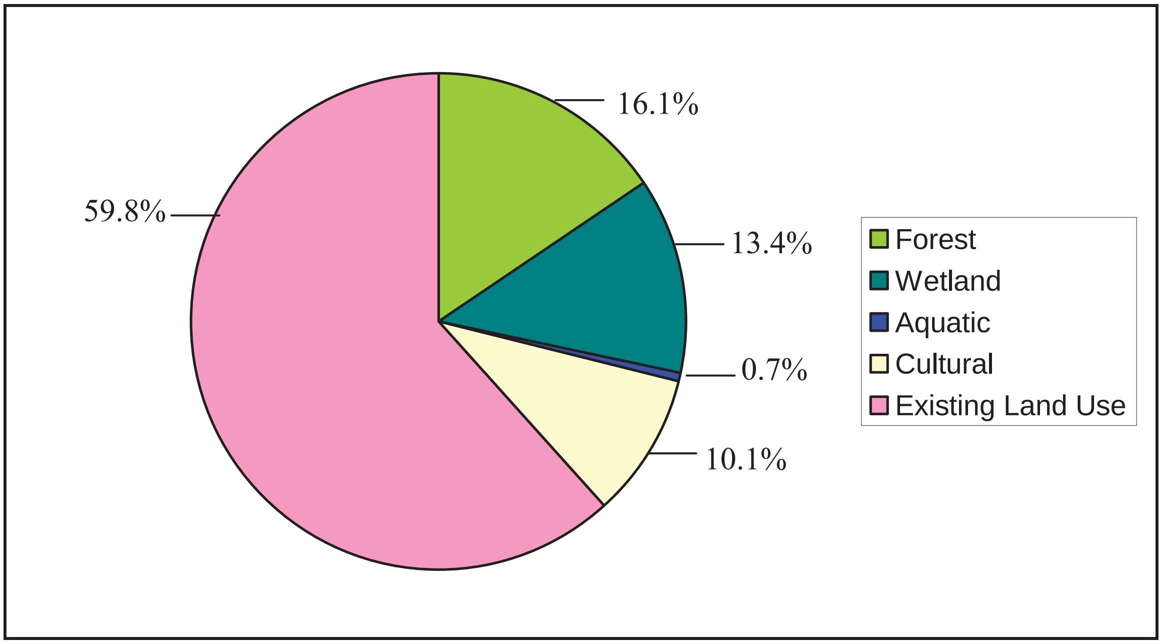


Figure 2.3.2 Percentage of existing land use and ecological communities within the Erin SSMP Study Area

2.3.2.1 *Existing Land Use*

The Erin SSMP study area includes two urban centres, Erin and Hillsburgh, surrounded by a natural rural area. The study area is located approximately 60 kilometres northwest of the city of Toronto and less than 20 kilometres from the proposed urban boundary of the City of Brampton. Other significant cultural features of the subwatershed include Highway 24, Trafalger Rd. (Wellington Rd. 24), and the Elora-Cataract Trailway.

Agriculture is the dominant land use within the study area (46.4%). This includes pasturelands, row cropping, livestock rearing, abandoned fields, and wet meadow. These agricultural areas can provide wildlife habitat, but have not been considered in this component of the study.

Urban and rural development comprises 9.5% of the land use (**Table 2.3.1**). This includes manicured open space, private open space, rural development, and urban development. Within Erin Village, there appears to be a trend for newer development to be located in scattered rural estate subdivisions. Several subdivisions occur within natural areas (e.g., Erinwood Dr., Patrick Dr., Pine Ridge Rd.), or immediately adjacent to a natural area (e.g., Erin Heights Dr.), which directly fragments habitat in the surrounding natural areas.

Human impacts such as encroachment, unsanctioned trail building, dumping, tree cutting, and underbrush clearing are evident in many of the forests within the town boundary. The Village of Hillsburgh is largely surrounded by agricultural lands, and natural areas within this urban boundary are limited to the large pond – wetland complex south of the Village on the west side of Highway 25. There is minor development within the natural area (e.g., George St.) and a new large-lot development, Upper Canada Dr., adjacent to the natural area.

2.3.2.2 Ecological Communities

Forest Communities

At the time of European settlement, over 70% of Southern Ontario was covered in upland forest communities (Larson et al. 1999). In comparison, only 16.1% of the Erin SSMP study area is currently covered with natural forests or plantations (**Table 2.3.1**). Of the upland forest cover, 6% is in plantation, which leaves only 10.1% in a relatively natural state of upland forest cover. Total forest cover for the study area increases to 27.3%, when swamps, also known as forested wetlands, are added to the calculation. This falls slightly short of the 30% forest cover guideline that has been recommended to maintain forest interior species and area sensitive species (Environment Canada 2004).

Of the natural forests, deciduous forests make up 59% of the cover, while coniferous (28%) and mixed (13%) forests make up the remainder. The vast majority of plantations are coniferous (96%).

Within the study area, forest cover is extensive along the Paris Moraine, south of Erin Village. It is important that this area remain well-forested in order to protect this important groundwater recharge area. The West Credit River, from the area downstream of its confluence with the main eastern branch to the point of entry into the main Credit River is also well-forested, although much of it is in plantation. The headwaters of the western tributary, also known as the West Credit River, are lacking forest cover; what remains is sparse and highly fragmented. Much of the eastern branch of the West Credit River, including the Binkham Tributaries, contains good forest cover.

Tableland forests are largely sugar maple (*Acer saccharum saccharum*) dominated deciduous forests, with associates of white ash (*Fraxinus americana*), black cherry (*Prunus serotina*) or American beech (*Fagus grandifolia*). The coniferous forests are almost exclusively dominated by white cedar (*Thuja occidentalis*). Forested floodplains in the study area support American white elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), trembling aspen (*Populus tremuloides)* and Manitoba maple (*Acer negundo*). Of particular note, woodlands containing a large concentration of the endangered butternut tree (*Juglans cinerea*) can be found along the slopes and bottomland of the forest communities adjacent to 8th Line, south of Dundas St. (outside of Erin Village).

Characteristically many forests associated with urban areas contained a significant component of non-native vegetation. Human disturbances related to encroachments, and off trail uses are evident in many forests where reduced regeneration and forest understory structure are evident. In the more rural areas of the study area, condition of these forests is much improved where historic human disturbance has been limited. However instances do occur of where poor management practices have been carried out such as overharvesting, and high grading of tree species at harvest time.

Some of the natural forests (i.e., terrestrial vegetation communities with at least 60% tree cover that are not the result of, or maintained by, cultural or anthropogenic-based disturbances) in the Erin SSMP study area receive some form of protection because they have been recognized as being regionally important. These woodlands are within or adjacent to Environmentally Significant Areas, and are therefore afforded some protection under CVC's Environmentally Significant Areas (ESAs) in the Credit River watershed policy (Credit Valley Conservation 1985). Please refer to Section 2.3.3.2, Environmentally Significant Areas, for more information on the ESAs in this area. Many of these woodlands are also protected under the Greenbelt Plan Policies.

Cultural / Successional Communities

The cultural communities identified through the ELC (**Figure 2.3.1**) can also be described as successional or old-field communities. These communities are no longer used for agriculture or other land use practices, and have been left to regenerate vegetation naturally. The vegetation of cultural communities is more abundant and diverse than that which is found on lands undergoing human uses. They reflect the stages of natural succession from field (i.e., cultural meadow) to sparse forest (i.e., cultural woodland). These communities are important sources of food, shelter, and movement corridors for wildlife. It is therefore important to consider these areas not just as culturally impacted lands, but as areas that work within the matrix of forests and wetlands to provide a niche for many species. How and when animals use successional habitats varies by species. It also varies seasonally and even within a single day. Some animals confine all of their activities to successional ecosystems while others use these "transitional" communities only a portion of the time (Bavrlic et al. 1999). The features of cultural communities that provide suitable wildlife habitat include cover, corridors for movement, amount of edge relative to the size of the old field, food source, and suitability of breeding areas. Examples of species that depend on cultural communities include meadow voles (*Microtus pennsylvanicus*), red foxes (*Vulpes vulpes*), savannah sparrows (*Passerculus sandwichensis*), and swallows.

Over 10% of the Erin SSMP study area is composed of cultural communities, and thus is in a stage of succession (**Table 2.3.1**). In the study area, most of these communities have arisen because agriculture or other land use practices have ceased and they have therefore begun to regenerate naturally. Cultural meadows are the predominant type of cultural community (**Table 2.3.1**), reflecting a landscape that has recently experienced farm abandonment.

Wetland Communities

Wetlands are areas of land that are saturated with water long enough to promote hydric soils or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation, and various kinds of biological activity that are adapted to wet environments. This includes shallow waters that are generally less than 2 m deep (Lee et al. 1998).

Wetland communities can include swamps, marshes, fens, and bogs. Swamps are classified to the Community Series level of the ELC as Deciduous, Mixed, Coniferous, or Thicket Swamp (**Figure 2.3.1**). Marshes are not mapped according to the Community Class level because it is difficult to determine the differences between Meadow Marsh and Shallow Marsh from aerial photography. Marshes are therefore mapped to the Community Class level of ELC as Marsh. Fens and Bogs are also difficult to interpret from aerial photography, and thus are not mapped through the process of air photo interpretation. Instead, Fens and Bogs have been identified and mapped based on fieldwork, Ontario Wetland Evaluations, Environmental Impact Studies, and other applicable research. For detailed descriptions of Community Series Classifications, please see Section 1.0 of the Natural Heritage Appendix.

Wetlands perform many important functions in a watershed. In terms of hydrology, wetlands play important roles in attenuating peak flows, removing contaminants and nutrients, preventing erosion, and recharging groundwater. The biological values of wetlands are usually assessed with respect to productivity (the amount of plants and animals sustained), biodiversity, system age, size, and rarity. Wetlands provide critical habitat for fish, reptiles, amphibians, invertebrates, birds, and mammals. They also allow for recreational opportunities such as nature appreciation, fishing, hunting, hiking, canoeing, bird watching, and aesthetics.

Environment Canada (2004) provides the following guidelines regarding wetland size, location, and the amount of wetland coverage that should exist at the watershed and subwatershed level for ecosystem health:

- *Wetland size:* Wetlands of a variety of sizes, types, and hydroperiods should be maintained across a landscape. Swamps and marshes of sufficient size to support habitat heterogeneity are particularly important.
- *Wetland location:* Wetlands can provide benefits anywhere in a watershed, but particular wetland functions can be achieved by rehabilitating wetlands in key locations such as headwater areas for groundwater discharge and recharge, floodplains for flood attenuation, and coastal wetlands for fish production. Special attention should be paid to historic wetland locations or the site and soil conditions.
- *Percent wetlands in watershed and subwatershed:* Greater than 10% of each major watershed should be in wetland habitat; greater than 6% of each subwatershed in wetland habitat; or restore to original percentage of wetlands in the watershed.
- *Amount of natural vegetation adjacent to the wetland:* For key wetland functions and attributes to be protected the guidelines recommend a minimum critical

function zone to be maintained around each wetland. Marsh, Swamp, and Fen = 100 m; Bog = total catchment area.

Wetlands within the Erin SSMP Study Area

Wetlands make up 13.4% of the Erin SSMP study area (**Table 2.3.1**). **Figure 2.3.1** shows their distribution and classification. This number meets Environment Canada's recommended guideline for wetland coverage at the subwatershed level. However, at a watershed level, the Credit River watershed has approximately 6.0% coverage, which does not meet the recommended guideline of 10% for a watershed. CVC therefore recommends the retention of current amount of wetland cover in the subwatershed, and restoration activities to increase the amount of wetland area.

Based on CVC's ELC mapping, swamps (forested wetlands) are the dominant wetland type in the Erin SSMP study area (92.5%), though marshes (6.8%), fens (0.5%), and bogs (0.1%) are also present. Refer to **Figure 2.3.1** for the location of these communities.

Fens and bogs are extremely rare features within the Credit River watershed, yet two distinct areas were discovered to have fen/bog complexes during the 2008 field season. One of these areas, located on the Paris Moraine between 8th and 9th Line, north of 5th Sideroad, supports two depressions with fen and bog communities. There are several similar depressional areas apparent on air photos in the surrounding areas, and it is anticipated that several of these features are likely fens or bogs. CVC will attempt to visit the surrounding properties in the future to map and evaluate these special features. The second fen patch was located northwest of Erin Village, on the east side of County Rd. 24 immediately north of 17th Sideroad. Fens and bogs support a variety of highly specialized and rare plant and odonate (dragonfly and damselfly) species, therefore a more detailed vegetation and wildlife inventory was completed in the confirmed fen/bog areas in 2009 (the entire data set was not yet available at the time this report was written).

Conifers are a large component of the swamp communities. Coniferous and mixed swamps are the predominant treed wetlands in the study area, while deciduous swamps are a relatively small component (**Table 2.3.1**). While white cedar (*Thuja occidentalis*) is the dominant coniferous species, balsam fir (*Abies balsamea*) is commonly observed. Black spruce (*Picea mariana*) is seldom seen in the Credit River watershed, yet it is recorded in a number of wetlands within the Erin SSMP study area. Deciduous swamps are comprised of associates of black ash (*Fraxinus nigra*), poplars (*Populus tremuloides* and *P. balsamifera*), white birch (*Betula papyrifera*) and occasionally red maple (*Acer rubrum*).

With respect to wetland substrate, organic "soils" were commonly recorded for many of the wetlands, possibly owing to the vast amounts of groundwater discharging throughout the study area. The cool and often saturated conditions associated with groundwater discharge often results in the formation of organic soils. In the fen and bog communities, there were significant accumulations of peat.

Provincially Significant Wetlands

Evaluated wetlands are classified using the *Wetland Evaluation System for Ontario - South of the Precambrian Shield* developed by the Environment Canada and Ontario Ministry of Natural Resources (1984). This system evaluates wetlands based on their biological, hydrological, and socio-economic values, while accounting for unique or rare features and functions. Based on this assessment, the Ministry of Natural Resources can determine a wetland to be "Provincially Significant." According to the Provincial Policy Statement issued under Section 3 of the *Planning Act*, development and site alteration shall not be permitted in Provincially Significant Wetlands. In addition, lands adjacent to Provincially Significant Wetlands are protected from development and site alteration unless it can be demonstrated that there will be no negative impacts on the natural features or their ecological functions. Wetlands not identified as Provincially Significant Wetland often play important regional roles in terms of hydrology and biology. These wetlands can be protected as "Locally or Regionally Significant Wetlands" by the municipality.

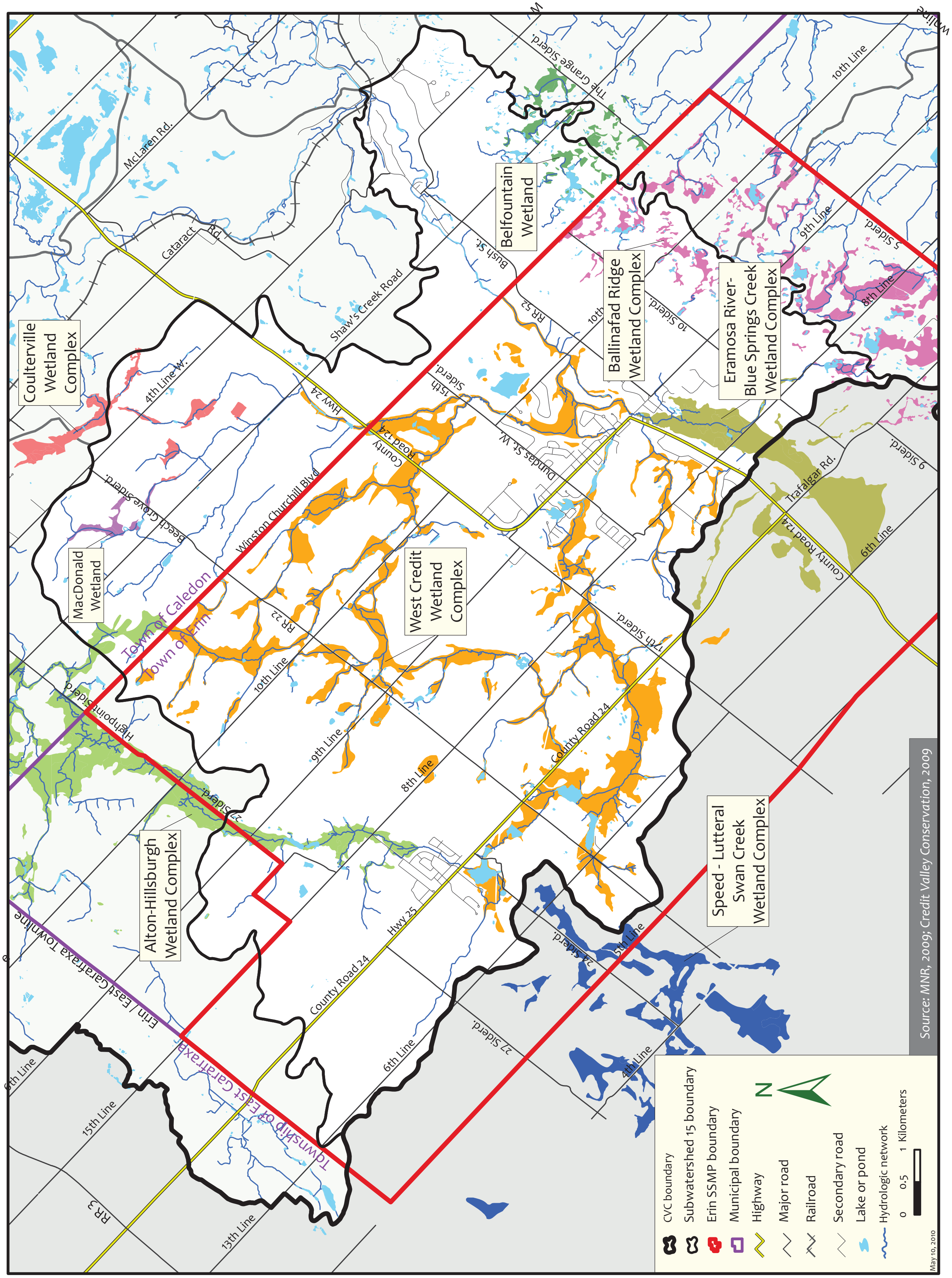
There are five wetland complexes (**Figure 2.3.3**) within the Erin SSMP study area and all are considered by OMNR to be Provincially Significant:

- Alton–Hillsburgh Wetland Complex,
- Ballinafad Ridge Wetland Complex,
- Eramosa River–Blue Springs Creek Wetland Complex,
- Speed–Lutteral–Swan Creek Wetland Complex, and
- West Credit Wetland Complex.

Other Wetlands

Several new wetland communities were mapped during the 2008 field season. At the present time, these wetlands are considered unevaluated, but information on these wetlands will be sent to OMNR for consideration to append them to existing wetland complexes. Because these wetlands are in close proximity to existing Provincially Significant Wetland complexes, it is anticipated that these new wetlands will also eventually be provincially significant. In addition, new updated wetland mapping was obtained from OMNR in September 2009. In the upcoming year CVC will review this new OMNR mapping against our ELC wetland polygons to identify any unresolved wetlands that need to be incorporated into the provincial mapping or those that still require an evaluation. Any changes will also be reflected in CVC's regulation line mapping.

Figure 2.3.3 Provincially Significant Wetlands



Source: MNR, 2009; Credit Valley Conservation, 2009

Aquatic Communities

The aquatic communities in the Headwaters Subwatershed Study area were identified through Ecological Land Classification mapping. As with the terrestrial and wetland systems, mapping of watercourses, lakes, and ponds was originally done using 1:10,000 Ontario Base Mapping and have been updated based on digital ortho-rectified aerial photography and fieldwork. These updates include previously unmapped lakes and ponds greater than 0.5 hectares in size, as well as sections of watercourses where there have been significant changes in the watercourse's size and location.

Watercourses, Lakes, and Ponds

Approximately 84 ha (or 0.7%) of the study area are considered to be a part of the aquatic system. This system consists of natural waterways, modified waterways, lakes, and ponds. Detailed descriptions of aquatic community classifications can be found in Table 1.2 of the Natural Heritage Appendix.

There are an estimated 270 ponds and impoundments documented within the West Credit River subwatershed (CVC et al. 2004). The location of major impoundments can be found on **Figure 2.6.6**. Ponds have been historically constructed for water supply purposes and aesthetics without broader ecological considerations. Pond littoral zones and shorelines are often excessively manicured, causing unwanted algal growth, and destruction of shoreline habitat for amphibians and other wildlife. In addition, ponds are often created by blocking or redirecting a watercourse, digging in an existing wetland, or exposing a high water table, all which can be considerable impacts to natural heritage features. Biodiversity is often lower in and around artificial ponds in comparison to naturally formed/vegetated ponds, yet they do offer a unique habitat for a suite of species that rely on open water habitats.

There has been little focus on inventories of aquatic communities, particularly open water ponds. CVC recognizes the importance of these features to wildlife such as waterfowl, amphibians, and odonates, in addition to specialized aquatic vegetation, and has committed to further studies in the near future.

Notable artificial ponds within the study area include the Hillsburgh Pond (9 ha), the Unknown (Olesovsky) Pond (7 ha), Roman Lake (5.8 ha), the two Stanley Park Ponds (6 ha), and the impoundments at Church St. and Charles St. in Erin Village (1.4 ha). Refer to **Figure 2.6.6** for the location of these ponds. Large open water features also occur on the Paris Moraine south of Erin Village, several of which are greater than 2 ha. Contrary to the ponds mentioned above, these "ponds" are naturally formed in morainal depressions (in some cases with some alterations from landowners). One of these large ponds has been confirmed to be a fen and we suspect the others are covered in floating peat as well.

The Riparian System

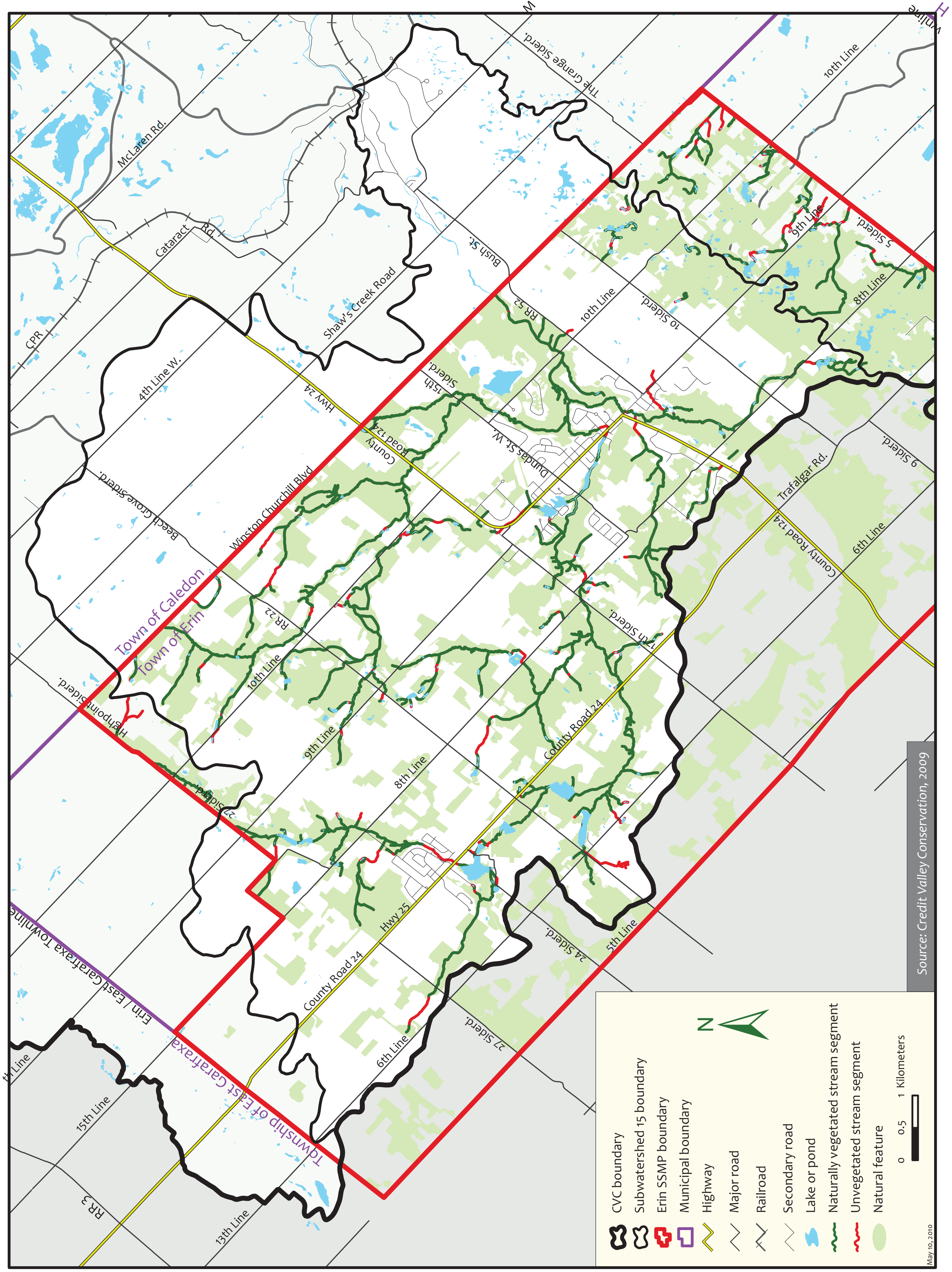
The riparian system includes those zones along a river that are flooded at least once every 20 years, and/or those zones which have high water tables connected to the stream channel and contain species of plants that can tolerate saturated conditions for extended periods. The quantity and quality of vegetation in the riparian zone is fundamentally connected to channel form and shape (geomorphology), aquatic habitat, water quality, and temperature. Well-vegetated riparian stream banks help to control the form and shape of channels. Vegetated stream banks are fairly resistant to scouring: in such a system, streams are narrow, pools are deep, and total sediment eroded into the channel system is low because root systems protect the soil. In these well-vegetated streams, the pools, riffles, and banks, as well as the overall water quality, provide high quality fish habitat. In streams without extensive riparian vegetation, stream width increases, pools get shallower, and more material is eroded from banks. Streams with lush riparian vegetation — shrubs and grasses or trees and shrubs — have better pools and other habitats in them than streams with thinly grassed banks and active bank erosion.

Environment Canada (2004) provides the following guidelines regarding riparian vegetation:

- *The percentage of the stream naturally vegetated* should be 75% of the stream length.
- *The amount of natural vegetation adjacent to streams* should be a minimum of 30 m wide on both sides, greater depending on site conditions.

CVC's 1:10 000 scale and 1:8,000 scale aerial photographs are not suitable for accurate and detailed mapping of riparian vegetation (i.e., the vegetation that is typically within 30 metres of the channel bank). We can, however, conduct a coarse scale analysis using ELC mapping to determine the percentage of stream length that flows through naturally vegetated vs. non-natural communities. **Figure 2.3.4** shows the analysis of the ELC communities adjacent to watercourses in the Erin SSMP study area. Of the 141 km of total stream length in the study area, 118 km (84%) is considered naturally vegetated. This surpasses Environment Canada's guideline for 75% riparian cover, supporting the statement that stream corridors in the study area are well-vegetated. [At this time, we have not been able to complete the second analysis for 30 m wide vegetated stream buffers.]

Figure 2.3.4 Riparian Vegetation



Source: Credit Valley Conservation, 2009

2.3.3 Core Natural Areas and Significant Natural Heritage Features

2.3.3.1 Areas of Natural and Scientific Interest (ANSI)

ANSIs are areas of land and water that represent significant geological (earth science) and biological (life science) features, as identified by the OMNR. There are two types of Areas of Natural and Scientific Interest (ANSI):

1. Life Science ANSIs, which are significant representative segments of Ontario's biodiversity and natural landscapes; and
2. Earth Science ANSIs, which are significant representative examples of bedrock, fossil, and landform records of Ontario.

OMNR identifies ANSIs that are "provincially significant" by surveying regions and evaluating sites to decide which have the highest value for conservation, scientific study, and education. Provincially significant ANSIs are specified in the Provincial Policy Statement (2005) as areas that must be protected.

Three Life Science ANSIs and one Earth Science ANSI are found within the Erin SSMP study area (**Table 2.3.2**; **Figure 2.3.5**).

2.3.3.2 Environmentally Significant Areas (ESAs)

In 1984, Credit Valley Conservation designated areas where ecosystem functions or features warrant special protection as Environmentally Significant Areas (ESAs). CVC adopted a series of policies to aid in the protection of these features and their associated functions. To be designated, an area would have to meet one or several criteria that reflected its ecological importance within the watershed. Criteria included that the area: was part of a distinctive or unusual landform; served a significant hydrological function; provided critical wildlife habitat; contained provincially or regionally rare species or communities; had a particularly high species diversity; and had high aesthetic value in the context of the surrounding landscape. With improvements in orthoimagery, it is possible to map boundaries at a much lower resolution than was possible in the 80's and so ESA boundaries were reviewed in 2005 by CVC staff. In instances where it was thought that the ESA boundary should be adjusted to include a larger area, these were mapped as "Potential ESA."

Six ESAs are found in the Erin SSMP study area (**Figure 2.3.6**) and are described below. There are also six areas (or Potential ESAs) that are suggested additions to the existing ESAs.

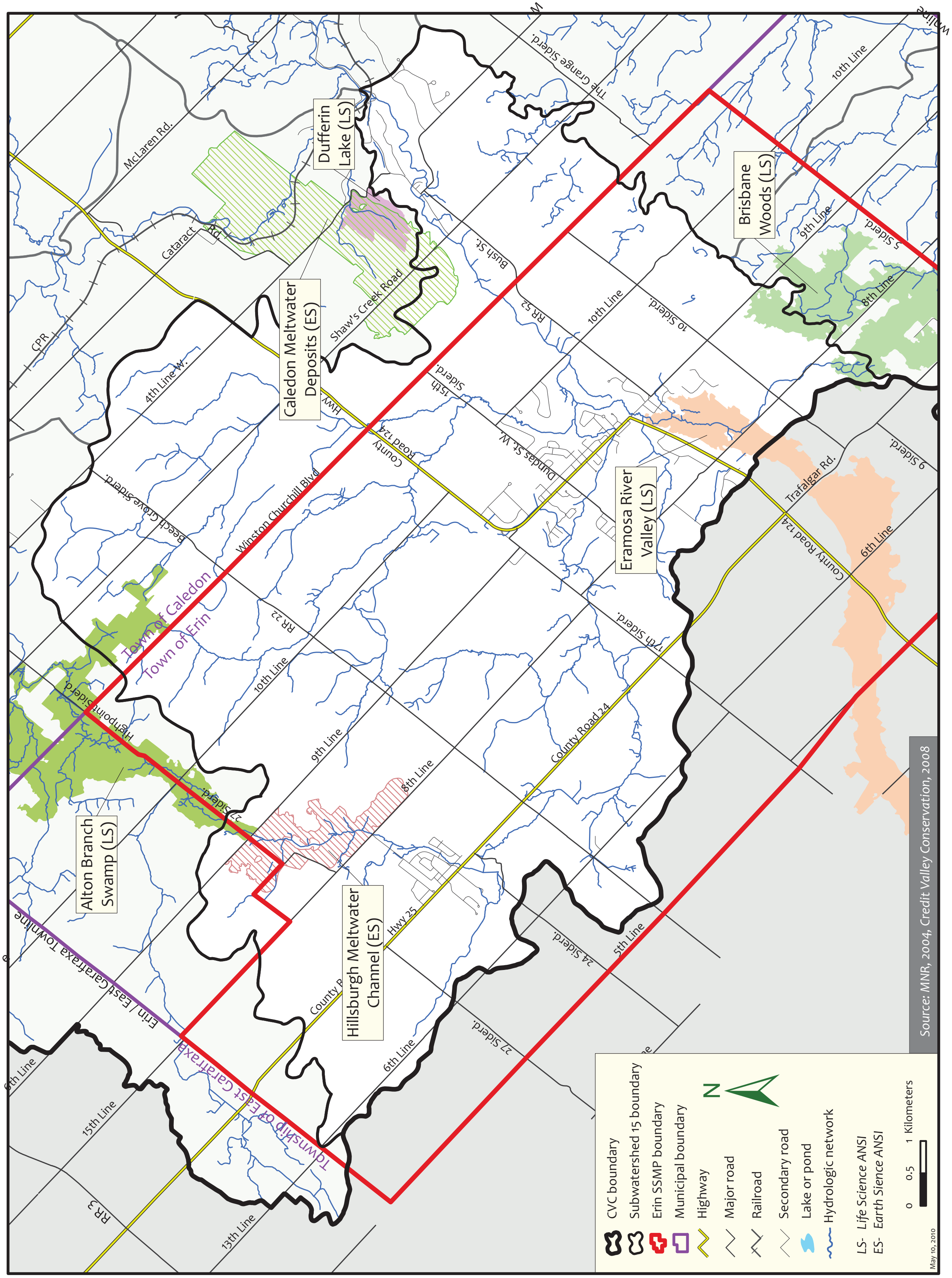
a) Brisbane Swamp

Brisbane Swamp is located in the south-western portion of the subwatershed and is the headwater area for tributaries of the West Credit River and the Eramosa River. It

Table 2.3.2 Life Science and Earth Science Areas of Natural and Scientific Interest

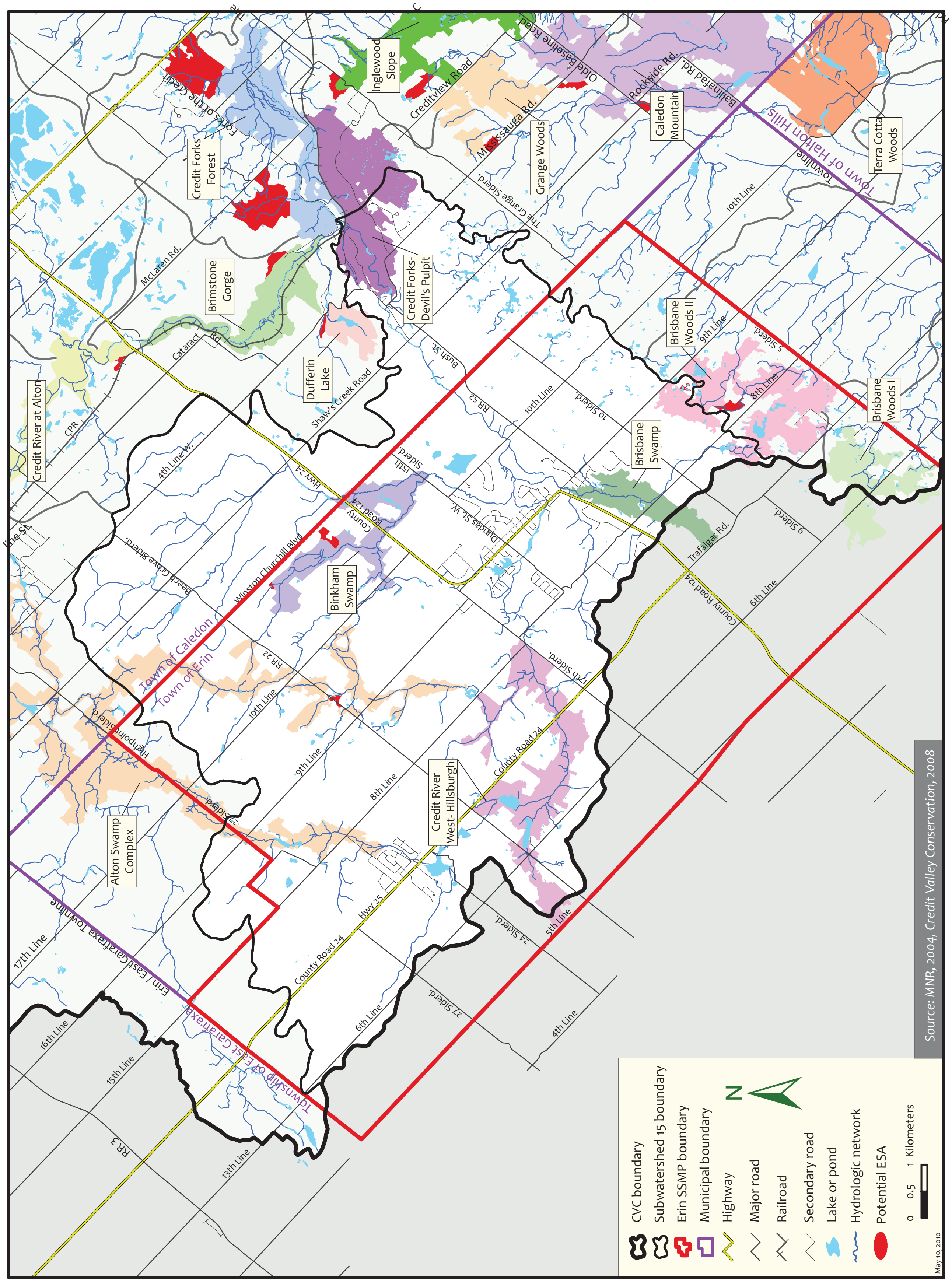
ANSI Type	Name	Significance	Location Within Study Area	Feature Description
Life Science	Eramosa River Valley	Provincial	Southern edge of Erin Village	One of the two best examples of river valley systems in Site District 6-1. Contains high-quality sections of braided stream, gravel terraces, rapids, and limestone potholes. The site offers a high diversity of wetland vegetation types, floodplain forests, uplands forests, valley slopes, and rims (Klinkenburg 1984).
	Brisbane Woods	Regional	Paris Moraine, south of Erin Village	Swamp-forest complex on the Paris Moraine (a till moraine). The headwaters of two streams and a groundwater recharge area. Rolling uplands of beech-maple forest surround the swamps and beaver ponds. Supports significant species and significant vegetation communities (e.g., bogs and fens).
	Alton Branch Swamp	Regional	Northeast of Hillsburgh	A very small portion reaches into the Erin SSMP study area. Part of a swampy spillway valley stretching from Orangeville to Hillsburgh. Major source area of the Credit River (Alton Branch). Supports boreal and regionally rare species. Supports regionally rare vegetation communities (bog).
Earth Science	Hillsburgh Meltwater Channel	Provincial	North of Hillsburgh	Situated in the Orangeville Moraine. This site is significant to the geologic interpretation of the retreat of the Ontario ice lobe and has been proposed as a candidate nature reserve (OMNR 1983).

Figure 2.3.5 Areas of Natural and Scientific Interest (ANSIs)



Source: MNR, 2004, Credit Valley Conservation, 2008

Figure 2.3.6 Environmentally Significant Areas (ESAs)



Source: MNR, 2004, Credit Valley Conservation, 2008 is a large relatively undisturbed boreal swamp/bog complex with an unusually high diversity of species.

b) Brisbane Woods I
Brisbane Woods I, which is located on the Paris Moraine, is the source area for an unnamed tributary of Black Creek and 2 tributaries of Eramosa River. Scattered depressional swamps give way to hummocky topography and a high diversity of forest types and habitats.

c) Brisbane Woods II
Brisbane Woods II is the source area of several small streams that feed the west branch of Silver Creek, having a large influence on the quality of groundwater and surface water in the region. Connecting with Brisbane Woods I, it provides a large continuous forested area, important habitat and high species diversity.

d) Alton Swamp Complex
Alton Branch Swamp is a major source area of Shaw's Creek and an important storage area. It contains an extensive undisturbed coniferous swamp comprised of several species associations, a sphagnum bog, which is a rare habitat in the watershed, and high species diversity including locally rare species.

e) Credit River West at Hillsburgh
Credit River at Hillsburgh is characterized by an undisturbed forested valley with coniferous swamp associations. This area, which is part of the West Credit River Wetland Complex, provides important groundwater discharge for the West Credit River and important habitat for rare species.

f) Binkham Swamp
Binkham Swamp is an irregularly shaped forest/wetland complex containing two tributaries of the West Credit River, which join together at the southern boundary of the ESA. As part of the Alton-Hillsburgh Wetland Complex, it provides significant hydrological function and supports a diversity of important habitats and species.

2.3.3.3 Provincially Significant Wetlands

Provincially significant wetlands are wetlands evaluated under the *Wetland Evaluation System for Ontario - South of the Precambrian Shield* and determined to be "Provincially Significant." (Environment Canada and OMNR 1984). This system evaluates wetlands based on their biological, hydrological, and socio-economic values, while accounting for unique or rare features and functions. Based on this assessment, the Ministry of Natural Resources can determine a wetland to be "Provincially Significant." See Section 2.3.2.2 above for a discussion on the Provincially Significant Wetlands within the Erin SSMP study area.

2.3.3.4 Provincially Rare Vegetation Communities

Just as individual species can be considered provincially rare [Natural Heritage Information Centre (NHIC) rank of S1-S3], vegetation communities can also be classed as provincially rare. One vegetation community was discovered during the 2008 field work which may potentially be provincially rare.

One community, classified tentatively as a Leatherleaf Shrub Kettle Peatland (BOT2-1), has an S-rank of S3 (**Figure 2.3.7**). An S-rank of S3 indicates that this community is vulnerable in the nation or state/province due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation (OMNR 2009). It needs to be determined if this community is indeed a kettle depression in order to confidently deem it provincially rare. Currently, NHIC indicates this community type is presently restricted to Ecoregion 7E and has not been documented in Ecoregion 6E. Despite this, we feel it warrants further investigation.

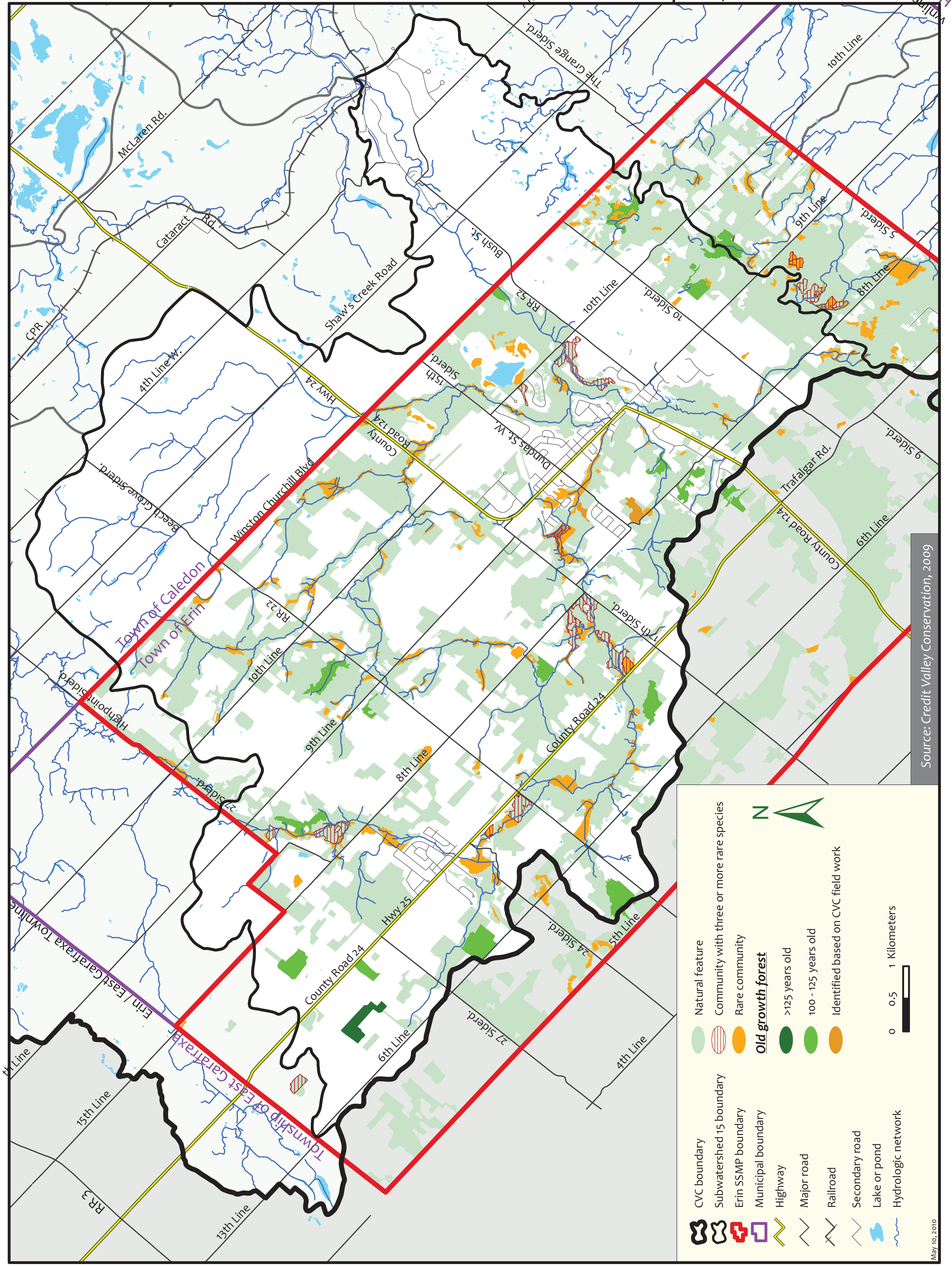
2.3.3.5 Subwatershed Rare Communities

Rare vegetation communities are those natural communities that are the most uncommon in a given jurisdiction, and therefore should be considered a high priority for protection. Although some species of plants and wildlife are able to migrate between and survive within a variety of habitat types, other species are very reliant on specific conditions and/or resources only available within certain habitat types. If already-scarce vegetation communities in the landscape are not protected and disappear, the species that rely specifically on these communities will become locally extirpated.

Using the Ecological Land Classification Mapping it is possible to identify the community types that are uncommon within the Erin SSMP study area. On this basis, those ELC community types that make up 5% or less of the natural area have been identified as rare in the study area (**Table 2.3.3**; **Figure 2.3.7**). Generally these statistics are calculated based on a subwatershed boundary, so the analysis based on the West Credit River subwatershed is given as a comparison. Comparing the Erin SSMP study area with the subwatershed area, we see that there are no major differences in what communities are considered uncommon. The only exception are thicket swamps, which are considered rare in the study area, but not in the subwatershed (although, only marginally).

Communities that are considered to be rare in the landscape within the Erin SSMP study area include Aquatic (2.8%), Fen (0.3%), Marsh (3.8%), Thicket Swamp (4.8%), and Treed Bog (0.1%). These communities are considered to be “Special Features” as part of the Terrestrial Analysis.

Figure 2.3.7 Rare Communities, Communities with Four or More Rare Species, and Older Growth Forests



Source: Credit Valley Conservation, 2009

Table 2.3.3 General Summary of Natural Community Types in Erin SSMP Study Area, illustrating Communities that make up <5% of the Natural Areas in the Study Area

Community Type	Erin SSMP Study Area		West Credit River Subwatershed	
	Hectares	Percent of Total	Hectares	Percent of Total
Aquatic	83.59	**2.75**	77.77	**3.25**
Coniferous forest	353.33	11.61	292.89	12.24
Coniferous swamp	944.98	31.05	491.00	20.52
Deciduous forest	751.91	24.71	699.76	29.24
Deciduous swamp	171.34	5.63	164.97	6.89
Fen	8.35	**0.27**	2.89	**0.12**
Marsh	114.99	**3.78**	105.28	**4.40**
Mixed forest	168.19	5.53	193.44	8.08
Mixed swamp	299.61	9.84	235.65	9.85
Thicket swamp	144.69	**4.75**	129.25	5.40
Treed bog	2.32	**0.08**	0.00	0.00
Total	***3043.30***	***100.00***	***2392.90***	***100.00***

2.3.3.6 Communities with a Significant Number of Rare Plant Species

The most comprehensive source of information on vascular plants in the Credit River watershed is *The Vascular Plant Flora of the Region of Peel and the Credit River Watershed* (Kaiser 2001). This document identifies CVC/Peel Region Rare Species as species with 10 or fewer locations or distinct “plant stations” in the Credit River watershed and/or the Region of Peel. A location or plant station is defined by an exclusion zone with a 1 km radius around each known location for a given species.

Based upon an analysis of 215 vegetation community samples in the study area with 357 rare plant occurrences, it was determined that any community with four or more rare species[2] was sufficiently unusual to be considered a Special Feature as part of the Terrestrial Analysis. This analysis identified 23 vegetation communities with four or more species that are considered rare in the Credit River watershed (**Figure 2.3.7**). These communities are considered to be “Special Features” as part of the Terrestrial Analysis. A list of rare flora found within the study area can be found in Table 2.0 of the Natural Heritage Appendix.

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[2] Rare species included those that were provincially rare, regionally rare, locally rare or some combination (with local & regional rarity determined using Kaiser 2001).

2.3.3.7 Older Growth Forests

The concept of “old-growth” has an inherent complexity and no universal definition (Riley and Mohr 1994). Old growth forests are more complex in their vertical structure than younger forest communities. Usually an old growth forest will exhibit well-defined vegetation layers, resulting in enhanced community, species, and genetic diversity. Although not pristine, older-growth ecosystems provide some of the best examples of pre-settlement landscapes, and are often targets for conservation, based on ecological, and ethical grounds (Riley and Mohr 1994). They provide habitats for numerous rare plants and animals, and can act as reserves of genetic variation, preserving examples of life forms that may have value for the future because their genes enabled them to survive under severe conditions and to achieve longevity.

Before European settlement, most woodlands in Southern Ontario were relatively mature; that is, replacement of canopy trees would have occurred mostly through gap regeneration (Frelich and Reich 1996). Large-scale disturbances were relatively rare, so older-growth forests were fairly abundant. Currently, only 0.07% of the landbase south and east of the Canadian Shield is estimated to remain as old-growth production stands older than 120 years (Federation of Ontario Naturalists 2001).

Based on a combination of Forest Resource Inventory Mapping (FRI) prepared by the Ministry of Natural Resources (1976) and CVC field work, this Erin SSMP study has identified 25 communities as having trees greater than 100 years of age (**Figure 2.3.7**). A number of structural indicators are used in the field to assess old growth, such as minimal anthropogenic disturbance, presence of slow colonizing species, large numbers of snags of large diameters, highly decomposed downed logs, a multi-layered canopy, soils showing pit and mound microrelief, an abundance of fungi, lichens, mosses and ferns, and individual trees that are very large and old.

2.3.3.8 Forest Patch Area and Interior Forest Core Habitat

It is generally accepted that plant and animal diversity increases as the size of an area increases (Riley and Mohr 1994, Environment Canada 2004). Interior habitats are generally free from the often-negative effects found in edge habitats such as increased predation, competition, pollution, and wind. The literature suggests that on average, edge effects are felt at least 100 metres into a forest patch. Some species require a 200-metre buffer from the edge of the forest patch (this area is also referred to as deep core). Interior habitat is critical to the survival of many species, particularly "forest-interior" birds. Discussion and literature relating to forest patch size and interior forest core is best summarized in *How much Habitat is Enough – A Framework for Guiding Habitat Restoration in Great Lakes Areas of Concern* (Environment Canada 2004). From this document, Environment Canada provides the following recommendations:

- Each watershed should have at least one 200 ha forest patch with a minimum 500 m width;

- The proportion of forest cover 100 m or further from the forest edge should be greater than 10%; and
- The proportion of forest cover 200 m or further from the forest edge should be greater than 5%.

Figure 2.3.8 illustrates forest patches containing 100 m and 200 m core interior forests. **Table 2.3.4** summarizes how the Erin SSMP study area measures up to Environment Canada's guidelines. Within the Erin SSMP study area, there is one forest patch that comes extremely close (197 ha) to the 200 ha forest patch guideline. The site is located on the Paris Moraine, south of Erin Village between 8th and 9th Line. The adjacent forest patch immediately to the west is 167 ha. Interestingly, the larger forest patch is the same site where the hooded warbler, a species at risk dependent on large, undisturbed interior forest habitat was recorded. The forest patch in the vicinity of Roman Lake is also quite large (166 ha) and it is recommended that there be no further loss of forest in this area. With respect to interior forest habitat 100 m and 200 m from the forest edge, the habitat available within the study area falls well short of these recommendations, having only 4.6% and <1% of 100 m and 200 m forest interior, respectively. While many of these targets are interpreted at the watershed level, even at the study area level they have relevance as each subwatershed should be expected to contribute its ecological benefits to the overall watershed to ensure an even distribution of ecological services and function across the landscape.

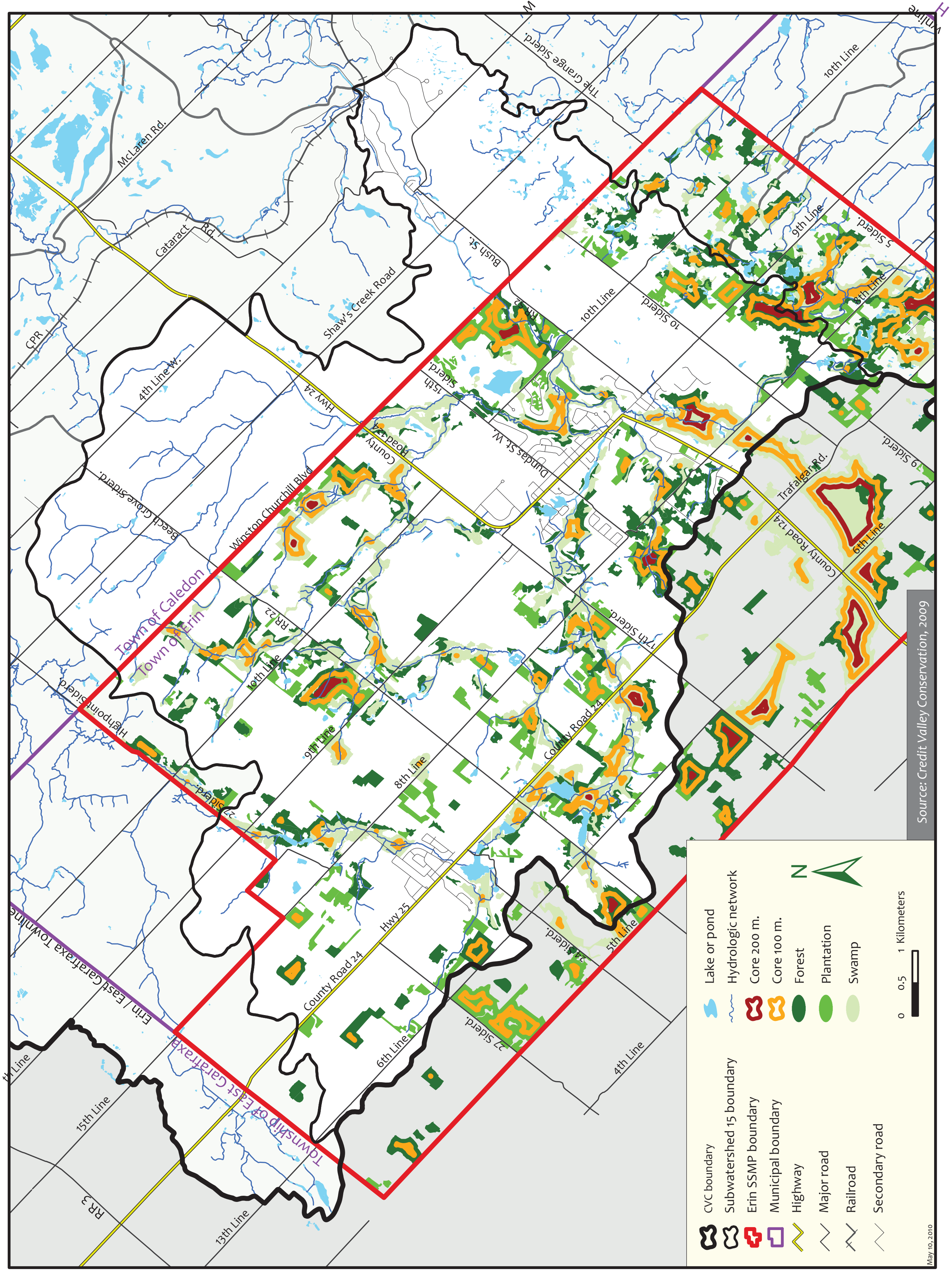
Table 2.3.4 Environment Canada Guidelines for Forest Cover in the Erin SSMP Study Area

Measure	Erin SSMP Study Area	Guideline
Percent of forest cover	27.3%	30%
Number of forest patches over 200 ha	1	At least 1
Percent of forest cover with over 100 m interior	4.6%	>10%
Percent of forest cover with and over 200 m interior	<1%	>5%

2.3.3.9 Habitat for Species at Risk

Six federally or provincially listed species at risk have been recorded within the study area (**Table 2.3.5**). In addition, three species considered provincially rare (S1-S3) have also been recorded. Species at Risk have legal protection, while provincially rare species (S1-S3) generally do not; however municipalities and other agencies can implement policies for best management practices to ensure these species are also protected.

Figure 2.3.8 Interior Forest Habitat



Source: Credit Valley Conservation, 2009

ELC polygons containing species at risk are considered to be "Special Features" as part of the Terrestrial Analysis. Where we could confidently assign an ELC polygon to the species at risk, they were included in the analysis. Four species could not be included in the analysis: The accuracy of the record for Carey's sedge (*Carex careyana*) was very poor (within 10 km) and it was omitted from the analysis. The western chorus frog (*Pseudacris triseriata*) records were obtained through roadcall counts, and because the specific ponds from which they were calling was not determined during that study, they could not reliably be assigned to a specific ELC polygon. The identification of woodland muhly (*Muhlenbergia sylvatica*) required verification by the botanist at the Royal Botanical Gardens, and it was not confirmed until after the terrestrial analysis was completed. The record for St. John's Wort (*Hypericum ascyron*) was not entered into our database until after the terrestrial analysis was completed.

Table 2.3.5 List of Species at Risk and Provincially Rare Species within the Erin SSMP Study Area

Species	**Species at Risk Status**				**Notes**
	National		**Provincial**		
	COSEWIC[1]	**SARA[2]**	**SARO[3]**	**S-Rank[4]**	
Butternut *(Juglans cinerea)*	**END**	**END**	**END**	**S3?**	Located in two distinct areas north and south of Erin Village. The main threat to Butternut is a serious fungal disease called Butternut Canker. The fungus can kill a tree within a few years of infection. High rates of infection and mortality have been observed throughout Ontario.
Canada warbler *(Wilsonia canadensis)*	**THR**	Pending THR status	**SC**	S4B	Several individuals have been encountered in 2 distinct habitat patches. This species has experienced a significant long-term decline. The reasons for the decline are unclear, but loss of primary forest on the wintering grounds in South America is a potential cause, as well as a reduction in forests with a well-developed shrub-layer within their breeding range in Canada.
Hooded warbler *(Wilsonia citrina)*	**THR**	**THR**	**SC**	S3B, SZN	One singing male was encountered in the largest forest patch in the study area. The Hooded Warbler has been designated as threatened in Canada because of its small population size, specific habitat requirements, and the fact that there are few remaining large areas of mature deciduous or mixed forest in south-western Ontario.
Western chorus frog *(Pseudacris triseriata)* Great Lakes / St. Lawrence - Canadian Shield Population	**THR**	Pending THR status			Recorded at 4 sites by Rob Milne and Lorne Bennett in 2000 during amphibian roadcall surveys. Despite there being some areas where chorus frogs remain evident, surveys of populations in Ontario indicate a significant decline in abundance of 30% over the past decade. Ongoing losses of habitat and breeding sites for this small frog due to suburban expansion and alteration in farming practices have resulted in losses of populations and isolation of remaining habitat patches.
Eastern snapping turtle *(Chelydra serpentina)*	**SC**		**SC**	**S3**	Recorded at 2 sites. Under-recorded for this area because it has only recently been listed. Suitable habitat is abundant within the study area. While still widespread and somewhat abundant, life history traits (late maturity, low recruitment), egg predation by urban predators (raccoons and skunks), and road mortality are all contributing factors to the decline of this species.

Monarch butterfly *(Danaus plexippus)*	**SC**	**SC**	**SC**	**S2N, S4B**	Recorded at 2 sites. Declines in the Ontario populations are due to logging and disturbance of the Mexican wintering grounds and from widespread use of pesticide and herbicides in Ontario.
Species	**Species at Risk Status**				**Notes**
	National		**Provincial**		
	COSEWIC[1]	**SARA[2]**	**SARO[3]**	**S-Rank[4]**	
The following are not Species At Risk, but are considered provincially rare:					
Carey's sedge (*Carex careyana)*				**S2**	One record exists from 1977 (NHIC). Accuracy of the record's location is very poor. Sedge of dry or moist rich hardwood forests, often with a limestone or calcareous substrate. This species is rare throughout its entire range, and has been given THR or END status in several US states.
Great St. John's Wort (*Hypericum ascyron)*				**S3?**	Recorded at one site in 2008. Designated THR and END in seven US states. * not entered into CVC database until after the terrestrial analysis was completed
Woodland muhly *(Muhlenbergia sylvatica)*				**S2?**	Found in one location in 2008. Requires verification by botanist at the Royal Botanical Garden. Rare throughout its range.

Note:

[1] *COSEWIC = Committee on the Status of Wildlife in Canada*

[2] *SARA = Species at Risk Act (federal species at risk)*

[3] *SARO = Species at Risk in Ontario (provincial species at risk)*

[4] *S-Rank = Provincial (or Subnational) ranks are used by the Natural Heritage Information Centre to set protection priorities for rare species and natural communities. These ranks are not legal designations. Provincial ranks are assigned in a manner similar to that described for global ranks, but consider only those factors within the political boundaries of Ontario. S-Ranks S1-S3 are considered provincially rare.*

[5] *END = Endangered*

[6] *THR = Threatened*

[7] *SC = Special concern*

2.3.4 Significant Species in the Study Area

2.3.4.1 Flora

The majority of the data on the flora within the Erin SSMP study area was accumulated through ELC field work conducted by CVC staff from 1997 to 2009 and from the detailed botanical inventories conducted by Charles Cecile for CVC's Natural Areas Inventory in 2009. Several incidental observations noted by Bob Curry, Bill McIllveen, and Jim Proudfoot were also included.

Over 450 plant species were recorded for the study area. Of these, 185 are considered significant or rare species. A large proportion of the significant species were documented during the intensive botanical surveys that occurred within the fen and bog communities, so the list appears skewed to fen and bog specialists. Charles Cecile's botanical surveys were only conducted in two distinct natural area patches within the study area, therefore it is anticipated that the number of significant flora would be much higher if other natural areas were as intensely examined. Of particular note, hooded lady's tresses (*Spiranthes* *romanzoffiana*), handsome sedge (*Carex formosa*), and small bur-reed (*Sparganium natans*), previously not known to occur within the Credit River watershed, were discovered within the study area.

Table 2.0 of the Natural Heritage Appendix provides a list of the significant plant species documented in the Erin SSMP study area. There is no one comprehensive source for significant flora within the Erin SSMP study area, so several sources were used to assess rarity (see references following the table).

2.3.4.2 Fauna

Mammals
Mammal records were obtained from incidental observations noted during ELC field work (1997-2009), Bob Curry's breeding bird surveys (2008, 2009), and from the surveys conducted by Rob Milne and Lorne Bennett for the 2003 Marsh Surveys for Anura in the Credit River watershed. Mammals can be difficult to accurately survey for many reasons such as their mobility, size, fear of humans, nocturnal or crepuscular activity, and others. Occasionally an animal may be seen, or a carcass may be found, but many species records come from in-direct observations: tracks, scat, feeding evidence, vocalizations, distinctive parts (e.g., feathers, quills), and even dens.

In total 13 mammals were found within the Erin SSMP study area (including a 2 km buffer outside the study area boundary) as noted in Table 2.1 of the Natural Heritage Appendix. As expected, some species were much more commonly recorded than others. For example, American mink (*Mustela vison*) were only found once, woodchucks (*Marmota monax*) were found twice, while Northern Raccoons (*Procyon lotor*) were found thirty-seven times and white-tailed deer one hundred and forty-one times. The much greater incidence of white-tailed deer is likely related to the population size across the study area, as well as the ease in finding and identifying signs of their presence. It is certain that there are many other individuals of these species, and other species, in the study area that were not identified by the incidental field observations. Indeed, there are known to be 41 species of mammals in the Credit River watershed. Therefore specific mammal studies would need to be carried out to get a better understanding of the presence and abundance of species in the study area.

Birds
Bird observations were collected during ELC field work (1997 – 2008) and through breeding bird surveys conducted by Bob Curry for CVC's Natural Areas Inventory project (Curry 2008, 2009). Bob Curry's survey protocol can be found in Appendix C – Natural Heritage. A total of 115 bird species were documented in the Erin SSMP study area (Table 2.2 of the Natural Heritage Appendix).

Three species at risk were recorded: Canada warbler (*Wilsonia canadensis*), hooded warbler (*Wilsonia citrina*), and red-shouldered hawk (*Buteo lineatus*). A family of provincially rare trumpeter swans (*Cygnus buccinator*) was observed on the Unknown (Olesovsky) Pond, south of Hillsburgh. Chimney swift (*Chaetura pelagica*) was not recorded within the study area, but a sighting in close proximity (within 2 km) indicates that there is potential for this species to occur within the study area should suitable habitat be available.

Reptiles and Amphibians

Reptile and amphibian records were obtained from incidental observations noted during ELC field work, Bob Curry's breeding bird surveys, and from the amphibian roadcall survey conducted by Rob Milne and Lorne Bennett for the West Credit Subwatershed Study. (Bennett and Milne 2001). The Amphibian Road Call Count protocol used by Bennett and Milne (2001) generally followed the procedures of the Wildlife Assessment Program outlined by the Ministry of Natural Resources (Konze and McLaren 1997), however see Bennett and Milne's report for specific details. A complete list of reptiles and amphibians is difficult to obtain without a specialized inventory because they are often cryptic in nature and many species tend to aggregate for only brief periods of time in the spring. Table 2.3 of the Natural Heritage Appendix provides a list of the species documented within the study area.

Insects (Odonates and Lepidoptera)

Incidental observations of Odonates (dragonflies and damselflies) and Lepidopterans (butterflies and moths) were recorded by Bob Curry (consultant) while he was conducting breeding bird surveys for CVC's Natural Areas Inventory project. His results should be viewed as an incomplete list, because breeding bird surveys are not often conducted at appropriate times during which Odonates and Lepidopterans are active. Should specific inventories for Odonates and Lepidopterans have been completed, a much more robust list would certainly have been obtained. The list of Odonate and Lepidopteran species encountered within the Erin SSMP study boundary can be found in Table 2.4 and Table 2.5, respectively, of the Natural Heritage Appendix.

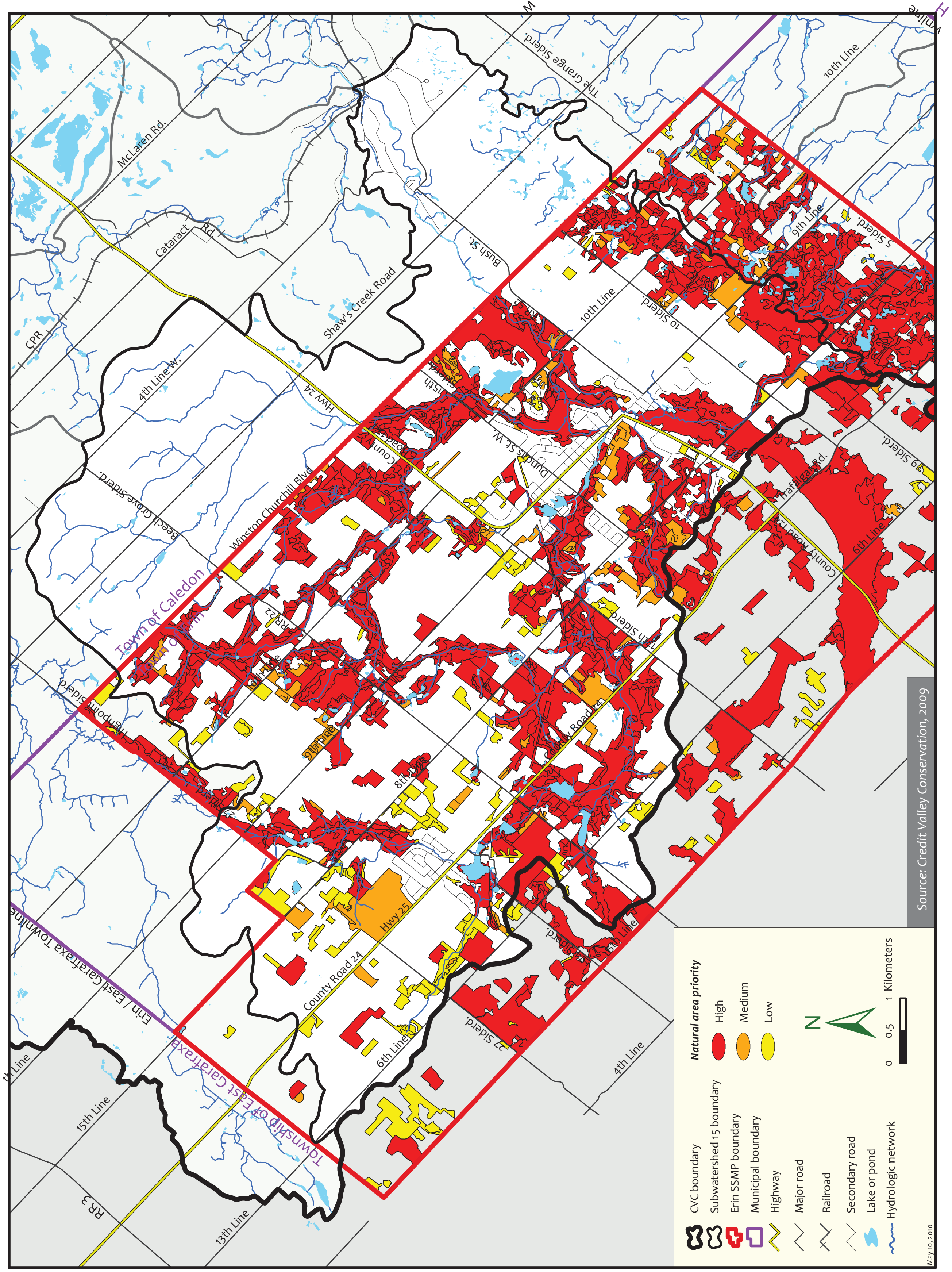
Compared with other groups of wildlife such as birds, amphibians and reptiles, our understanding of the status, distribution and ecology of Odonates and Lepidopterans in Ontario is much less known. Only recently has the popularity of studying odonates gained attention, much of it in response to the creation of new identification guides. The City of Guelph Natural Heritage Strategy (Dougan and Associates 2009) provides the best assessment and estimation of significance (or rarity ranks) for Odonates relevant to the Erin SSMP study area. These ranks can also be found in Table 2.4 of the Natural Heritage Appendix. The NHIC database does not have sufficient data on Lepidopterans to assess regional or local significance or rarity (Dougan and Associates 2009) and therefore Table 2.5 presents only those species currently designated as Species at Risk and provincial status (S-Ranks).

2.3.5 Significance of Natural Areas

For a detailed explanation of the criteria used in determining natural area significance, as well as a brief summary of the methodology used to determine priority areas, please see Section 3.0 in the Natural Heritage Appendix.

Based on the analysis of the terrestrial system within the Erin SSMP study area, virtually all of the medium and large natural areas of the subwatershed have been designated as "high priority" (**Table 2.3.6**). **Figure 2.3.9** identifies the overall significance of the natural areas. The majority of the medium priority areas are cultural meadows and smaller woodlands and plantations that are situated next to high priority areas, thereby acting to buffer and enhance the quality of the high priority areas. Low priority areas include some small and/or isolated fragments of coniferous and deciduous forests and plantations, and several cultural communities that have limited connections to large natural areas.

Figure 2.3.9 Overall Significance of the Natural Areas



Source: Credit Valley Conservation, 2009

Table 2.3.6 Summary of Priority Areas for the Erin SSMP Study Area

Natural Area Priority	Area (ha)	Percentage of Subwatershed	Percentage of Natural Area
High	4334.54	34.4	84.5
Medium	372.72	3.0	7.3
Low	420.34	3.3	8.2
Total	**5127.60**	**40.7**	**100.00**

A summary of the criteria and the findings for the Erin SSMP study area can be found in **Table 2.3.7**.

2.3.6 Corridors and Linkages

The *West Credit Subwatershed Study, Draft Phase 1 Addendum* report (CVC 2001[a]) provides an assessment of Corridor Priority; therefore corridor analyses were not completed for this study.

2.3.7 Natural Heritage Characterization

The natural areas within the Erin SSMP study boundary support significant natural heritage resources, which contribute heavily to the overall health of the Credit River watershed. They include the following:

- Six Environmentally Significant Areas, one Provincially Significant Life Science Area of Natural and Scientific Interest (ANSI), and two Regionally Significant Life Science ANSIs. These areas are considered significant for providing substantial hydrological function to the West Credit River, such as headwater protection, groundwater recharge/discharge areas, and supporting large wetland complexes. In addition, they are also considered significant for the presence of rare flora and vegetation communities, and for the diversity and size of the natural habitat.
- Five Provincially Significant Wetland Complexes. These wetland complexes contribute significant hydrological function to the subwatershed such as flood attenuation, water quality improvement, groundwater recharge and discharge, and contributions to baseflow. The wetlands also support a wide variety of wildlife species and provide habitat for a large number of rare plant species.
- Habitat for six known Species at Risk and three provincially rare species. These species include butternut (*Juglans cinerea*), hooded warbler (*Wilsonia canadensis*), Canada warbler (*Wilsonia citrina)*, western chorus frog (*Pseudacris triseriata*), snapping turtle (*Chelydra serpentina*), monarch butterfly (*Danaus plexippus*), Carey’s sedge (*Carex careyana*), great St. John's wort (*Hypericum ascyron)*, and woodland muhly (*Muhlenbergia sylvatica*).

Table 2.3.7 Summary of the Terrestrial Analysis for the Erin SSMP Study Area

Criterion	Description	Results
Community Diversity or Complexity (Figure 3.0.1 in Natural Heritage Appendix)	Number of different communities compared to the number of polygons within a given natural area (i.e., patch).	Most diverse natural areas are located in the vicinity of the Paris Moraine, the West Credit-Hillsburgh ESA (Roman Lake/Olesovsky Pond area), the Binkham Swamp ESA, and the Alton Swamp Complex ESA. The least diverse natural areas are found in headwater areas of the West Credit River, intensive agriculture has resulted in the loss, isolation, and fragmentation of natural area on the landscape.
Relative Community Size (Figure 3.0.2 in Natural Heritage Appendix)	Significant communities based on the relationship between their size and frequency of occurrence.	The largest concentration of vegetation communities considered to be significant based on their size related to their representation in the study area are associated with the Eramosa River-Blue Springs Creek Wetland Complex, the Credit River West –Hillsburgh ESA (Roman Lake/Olesovsky Pond area), and along the Paris Moraine.
Interior Habitat or Core Area (**Figure 2.3.8**)	Area surrounded by a buffer of 100 metres (core) and 200 metres (deep core).	There are 125 patches of core habitat (100 m). The total area of 100 m core is 583.97 ha. There are 24 patches of deep core habitat (200 m). The total area is 95.96 ha. The largest patches of core habitat occur within the Eramosa River-Blue Springs Creek Wetland Complex and along the Paris Moraine south of Erin Village.
Special Feature: *Provincially Significant Wetlands* (**Figure 2.3.3**)	Wetlands evaluated under the Ontario Wetland Evaluation System and determined to be "Provincially Significant."	5 Provincially Significant Wetland Complexes: ▪ Alton-Hillsburgh Wetland Complex ▪ Ballinafad Ridge Wetland Complex ▪ Eramosa River-Blue Springs Creek Wetland Complex ▪ Speed-Lutteral-Swan Creek Wetland Complex ▪ West Credit Wetland Complex
Special Feature: *Species at Risk*	Areas that may provide habitat for a "Species at Risk" listed by the Ontario Ministry of Natural Resources, COSEWIC or under the schedules of the Species at Risk Act.	Areas have been identified for butternut, hooded warbler, Canada warbler, snapping turtle, and monarch butterfly. Western chorus frog was also found at several sites within the study area, but its habitat could not be reliably mapped for this analysis.

Criterion	**Description**	**Results**
Special Feature: *Escarpment Natural Area*	Land identified under the Niagara Escarpment Plan as Escarpment Natural Area.	There are no Escarpment Natural Areas identified in the Erin SSMP study area.
Special Feature: *Areas of Natural and Scientific Interest* (provincial life science only)	Ontario Ministry of Natural Resources identified areas having provincially significant representative ecological features.	There is one provincially significant Life Science ANSI in the study area: ▪ Eramosa River Valley LS-ANSI
Special Feature: *Environmentally Significant Areas* (**Figure 2.3.6**)	Areas identified by CVC having significant ecological, hydrological, geological, or aesthetic features.	There are 6 ESAs: ▪ Brisbane Swamp ▪ Brisbane Woods I ▪ Brisbane Woods II ▪ Alton Swamp Complex ▪ Credit River at Hillsburgh ▪ Binkham Swamp
Special Feature: *Communities with 4 or more Rare Species* (**Figure 2.3.7**)	Based on CVC fieldwork, communities with 4 or more Rare Species.	There are 23 vegetation communities in the study area with 4 or more CVC/Peel rare species.
Special Feature: *Rare Communities* (**Figure 2.3.7**)	Rare Communities (5% or less in area of the natural communities identified).	Rare Communities: Aquatic (2.8%), Fen (0.3%), Marsh (3.8%), Thicket Swamp (4.8%), and Treed Bog (0.1%).
Special Feature: *Forests Older than 100 years* (**Figure 2.3.7**)	Forests that may contain trees older than 100 years based on Forest Resource Inventory Mapping and field work.	According to Forest Resource Inventory mapping and field work by CVC staff, 25 communities have trees over 100 years old.

- At least three fen communities, which are a regionally rare wetland habitat type, are known to exist within the subwatershed. A large number of rare plant species are associated with these communities.
- Many rare, unusual and significant flora and fauna can be found in the study area. This may be explained, in part, by the large undisturbed natural areas found here and the rare fen communities that were discovered. Many of the plant species that are especially rare within the watershed are important contributors to the overall biodiversity of the Credit River watershed.
- Largely intact vegetated riparian zone (84%), resulting in an almost contiguous riparian zone along the banks of the West Credit within the study area. This is not only important for stream health, but also allows facilitates wildlife movement and seed dispersal.
- 125 large natural areas provide habitat for forest interior species.

2.3.8 Next Steps

The assessment of the terrestrial system, as described above, must be combined with the other components to determine the overall sensitivities of the features, functions, and linkages with the Erin SSMP study area. This analysis will form the basis for the assessment of potential impacts from future land use changes and servicing.

Further studies that will be conducted by the terrestrial monitoring team include:

- Mapping and field verifying locations of rare fen and bog wetland communities in the West Credit River subwatershed;
- Review of new OMNR wetland mapping against CVC ELC wetland mapping to identify updates required to CVC's Regulation mapping;
- Inventory of aquatic communities, particularly open water ponds. CVC recognizes the importance of these features to wildlife such as waterfowl, amphibians, and odonates, in addition to specialized aquatic vegetation.
- With respect to provincially rare vegetation communities, in order to confidently deem Leatherleaf Shrub Kettle Peatland (BOT2-1) provincially rare, it needs to be determined if this community is indeed a kettle depression.

2.4 STREAM GEOMORPHOLOGY

Fluvial geomorphology is the science that studies the form and function of watercourses and their interaction with the surrounding landscape. Gaining understanding of the characteristics of watercourses within a study area and identifying those factors that control (e.g., geology, hydrology) and modify (land use, land cover, animal and human activity in and around the channels) its functions requires analyses to be completed at a range of spatial and temporal scales. This places observations and analyses both within drainage network and site-specific contexts.

The geomorphic study of watercourses situated within the Erin Servicing and Settlement Master Plan (SSMP) study area is similar to that undertaken for an entire subwatershed. Analyses were intended to characterize the form and function of channels within the Erin SSMP study area and included both desktop and field components. Analyses were completed at a range of spatial scales progressing from study area → catchment area → watercourse → reach → site scales. This spatial progression enables insight to be gained into the macro (planform), meso- (channel cross-section level), and micro- (bed material level) scales of channel form within the study area and into the factors that influence them. Specific tasks that were undertaken for this study, and which are documented in proceeding chapters, included:

- a review of background material relevant to understanding existing and future channel form, function, and process;
- drainage network and drainage basin analyses;
- documentation of existing channel conditions both at local (e.g., site) and study area scales through synoptic (catchment and reach scales) and detailed level field investigations (5 field sites). Sufficient data to enable assessment of channel impacts due to various future development scenarios and to develop an appropriate management plan that benefits the study area, and the overall Credit River drainage network;
- detailed analysis of geomorphic field data;
- trend analysis with reference to previous studies undertaken in the study area (e.g., CVC 1998[a], CVC 2001[a], and CVC 2001[b]);
- an assessment of inter-relations between physical channel form, benthic habitat, and species abundance/diversity;
- the effect of hydromodification (i.e., change in flow regime within watercourses due to urbanization); and
- a synthesis of findings.

2.4.1 Introduction

The Erin SSMP study area is primarily within CVC's West Credit River subwatershed (Subwatershed 15) but it also extends into the headwaters of Subwatersheds 10 (Black Creek), 11 (Silver Creek) and 12 (Cheltenham to Glen Williams – Credit River main branch and tributaries). Review of watercourse mapping and background reports suggests that the study area contains many low order, or headwater channels. Although the West Credit River subwatershed is not considered to be a headwater subwatershed for the Credit River, the study area certainly does contain headwater streams for the West Credit River, and also for Subwatersheds 10, 11 and 12. Headwater streams, defined as 2nd or 3rd order or smaller channels, typically make up between 70 – 80% of the drainage network in terms of both flow and channel length (Meyer et al. 2003; Vought et al. 1995). In addition to the length that headwater streams contribute to the drainage network, watercourses and drainage systems in headwater regions exert an important influence on ecological health, stability, and sustainability of the downstream receiving watercourses. Specific roles attributed to headwater streams include (Dunne and Leopold 1978; Schollen et al. 2006):

- flow attenuation and storage, thereby affecting hydrograph shape;
- sediment production and trapping of excess sediment;
- contribution of organic energy inputs that sustain aquatic biota and contribute to the productivity of the downstream watercourse (Wallace et al. 1997);
- nutrient retention and uptake (Alexander et al. 2000; Peterson et al. 2001);
- moderation of temperatures;
- habitat for terrestrial and aquatic species and biota (Morse et al. 1993); and
- groundwater recharge.

A loss of headwater streams typically occurs in conjunction with land development, resulting in deleterious effects on flood frequency and intensity, aquatic habitat, and water quality. Given that hydromodification impacts from urban development have thus far been somewhat limited, an opportunity is provided during an SSMP study, such as this, to identify goals and objectives for protection, restoration and/or enhancement of the watercourses. These serve not only to protect or enhance existing watercourse conditions within the study area, but also provide benefits to downstream receiving channels and adjacent lands.

2.4.2 Morphometric Analysis

Morphometric analyses refer to quantitative measures or indicators of physical properties of the drainage basin and drainage network. These provide insight into how well an area is drained and how efficiently water is conveyed out of the study area. While typically completed on a subwatershed basis, they can be applied to specific study areas such as that corresponding to the Erin SSMP. Morphometric basin relations are highly influenced by the geology and climate of an area (see Sections 2.1.2 and 2.2.2 respectively within this report).

2.4.2.1 Drainage Density

The efficiency of a drainage network in draining an area (i.e., how water is removed from the area, rather than through infiltration or storage) is represented by the drainage density. The density of channels within a landscape is a result of the two primary factors: those that determine the amount of water received at the surface (e.g., precipitation) and those that control the distribution of water (e.g., geology, soils, vegetation, topography) (Knighton 1998).

Drainage density is simply a ratio of length of channel per km^2 of drainage area. The ratio was calculated for the study area and included all watercourse features (i.e., agricultural drains, roadside ditches, all watercourses, wetland channels and ponds) but not swales (i.e., zero-order channels). Within the 144.42 km^2 of the study area, the drainage density for the study area was calculated to be 1.05 km/km^2.

The drainage density ratio of the study area were calculated by watershed, and within the Credit River watershed, the 1.11 km/km^2 ratio was considered to be low in comparison to the other Credit River subwatersheds for which drainage densities were readily available (**Table 2.4.1**). The drainage density is also lower than that reported for other Southern Ontario watersheds [e.g., drainage densities of 2.08 and 1.5 respectively reported for Carruthers Creek and Duffins Creek (TRCA 2002[a], 2002[b])].

Lower drainage densities are typical of permeable watersheds as there will be more infiltration than overland flow (see Section 2.2.2 for further discussion). Low drainage densities are also associated with heavy use of tile drains in agricultural fields.

Information regarding stream classification (e.g., swale, intermittent etc.) was not available for the Grand River watershed. Hence, the drainage density reflects the drainage network as shown on mapping and thus does not distinguish between stream classifications. As such, the values may not be directly comparable to those calculated for the CVC portion of the study area.

Table 2.4.1 Drainage Density for Erin SSMP Study Area and Other Watersheds (CVC 1998[a]; CVC 2006) based only on Channel Length (including agricultural drains, roadside ditches, all watercourses, wetland channels and ponds but excluding swales)

Study Area	**Area (km^2)**	**Channel Length (km)**	**Drainage Density (km/km^2)**
Erin SSMP Study Area	144.42	152.03	1.05
CVC area	110.41	122.87	1.11
GRCA area	34.01	29.16	0.86
Credit River Subwatersheds			
East Credit (13)	*n/a*	*n/a*	1.92
West Credit (15)	105.56	128.13	1.21
Caledon Creek (16)	*n/a*	*n/a*	1.33
Shaw's Creek- numerous headwater (17)	*n/a*	*n/a*	1.84
Credit River Headwaters (19)	130.41	80.20	1.34

The active drainage network (i.e., that which conveys flows) will expand and contract through time, in response to fluctuations and magnitude in precipitation patterns and antecedent soil moisture conditions (Gregory and Walling 1968). Thus, during precipitation events, ephemeral zero-order channels (i.e., swales etc.), become an active part of the drainage network. For this reason, the drainage density analyses were repeated by including all swales (**Table 2.4.2**). Review of the results shows that the drainage density increases substantially when the role of swales is considered in the calculation. That is, drainage density increases from 1.11 to 1.41 within the CVC portion of the Erin SSMP study area. This drainage density is smaller than that of Subwatershed 19 when zero-order streams were included in the calculation. The drainage density is comparable to drainage densities reported for other CVC watersheds in which it is unknown if zero-order streams were included in the calculation. Thus, surface features appear to play an important role in removing surface water from the study area. The swales are expected to exert a moderating control on the hydrograph of the main channel in their catchments which, in turn, benefits the Credit River. The significance of this finding will be explored further in Phase 2 of this study to determine whether there are any management implications

Given the similarity in geology and the geographic similarity in location, it is presumed that swales within the GRCA portion of the Erin SSMP study area serve an equally important moderating effect on the hydrograph of the Grand River and its tributaries as described in the preceding paragraph.

Table 2.4.2 Drainage Density for Erin SSMP Study Area and other Credit River Subwatersheds during Precipitation Events by Including Zero-order Channels (swales) in the Calculation

Catchment	Area (km^2)	Channel + Swale Length (km)	Drainage Density (km/km^2)	Increase in Drainage Density when incl. swales (km/km^2)	Factor of Increase
Erin SSMP Study Area	144.42	184.5	1.28	0.22	1.21
CVC area	110.14	155.35	1.41	0.29	1.26
Credit River Subwatersheds					
West Credit River subwatershed (15)	105.56	145.83	1.38	0.28	1.14
Credit River Headwaters (19)	58.42	97.32	1.63	0.29	1.21

2.4.2.2 Stream Order

Stream order was determined for the entire drainage network within the study area. This revealed that the highest stream order was 4. A break down of channel length per stream order is provided in **Table 2.4.3.** Results are typical in that the lowest order streams typically contribute the highest length of channel within a drainage network. Interestingly, the total length of zero and first order streams (93.43 km) is markedly more than the length of all other stream orders combined (i.e., 61.92 km).

Table 2.4.3 Tabulation of Channel Length by Stream Order for Watercourses within CVC's Portion of the Erin SSMP Study Area

Stream Order	Total Channel Length (km)
0	32.48
1	60.95
2	38.51
3	18.00
4	5.41

2.4.2.3 Bifurcation Ratio

Bifurcation ratio is the total number of streams of one stream order divided by the total number of streams of the next highest stream order. In other words, bifurcation ratio is the proportion of small order streams to large order streams. The magnitude of this measurement indicates the pattern of water and sediment delivery throughout the watershed as well as the shape of the hydrograph. The average bifurcation ratio for the Erin SSMP study area is 5.14; the ratio for the CVC area is 4.88; and 4.10 for the GRCA area (**Table 2.4.4**). The value exceeds the upper range reported by Horton (1945) and Strahler (1957), that is a ratio range of 2 – 4, but values between 3 and 5 are typical for areas in Southern and Eastern Ontario where glacial deposits (e.g., till) comprise the overburden materials (Chorley 1969). The ratio indicates that water is routed more quickly from low order stream segments to higher order receiving channels leading to a relatively rapid response to a precipitation event, and peakiness in the event based hydrograph.

The bifurcation ratio for the Credit and Grand River portions of their respective drainage networks within the Erin SSMP study area was compared to values reported for other CVC watersheds (**Table 2.4.4**). Both ratios are higher than that recorded in other subwatersheds, suggesting that the hydrograph of the receiving streams respond more quickly and are 'flashy'. This response, however, is moderated by the presence of numerous online ponds and wetlands that occur along the drainage network within the Erin SSMP study area.

Table 2.4.4 Bifurcation Ratios for the Erin SSMP Study Area and other Credit River Subwatersheds

Area	Bifurcation Ratio	Bifurcation Ratio (incl. swales)
Erin SSMP Study Area	5.14	4.03
CVC area	4.88	3.86
GRCA area	4.1	*n/a*

Credit River Subwatersheds		
East Credit (13)	3.30	*n/a*
Shaw's Creek (17)	1.89	*n/a*
Credit River Headwaters (19)	3.8	4.9

When swales are included as part of the drainage network, the bifurcation ratio decreases. This may simply be a function of stream classification within the CVC database. Nevertheless, the bifurcation ratios remain high, supporting the notion that swales are important elements of the drainage network, especially during precipitation events. Thus, a comprehensive management plan should give appropriate consideration to maintaining form or at least the function of this important part of the channel network.

2.4.2.4 Stream Order Gradients

Gradients of many channel reaches within the CVC area were readily available from the database developed by Aquafor Beech (2005). The data were used to examine how stream gradients changed by stream order for the reaches. In general, the low order streams exhibited steeper gradients than high order streams and a wider range of gradients (**Figure 2.4.1**). This observation may be somewhat biased by the fact that there were fewer higher (3rd and 4th) order reaches within the study area.

The large range in low order stream gradients is likely due to the more prevalent impacts to these streams resulting from historic agricultural land uses in addition to long-term lowering of the channel bed within the floodplain (e.g., lowering of base level). Further, the natural erosional histories and geologic settings would tend to be more variable for the larger population of low order streams. The conventional pattern of increasing gradient with decreasing stream order may also be complicated by the overall physiography of the study area. The presence of numerous online wetlands and ponds, especially along the higher order streams attests to physiographic controls and accounts for lower gradients along those streams. Channel gradients have also been modified by artificial grade controls (i.e., dams) on both low order and higher order streams within the study area.

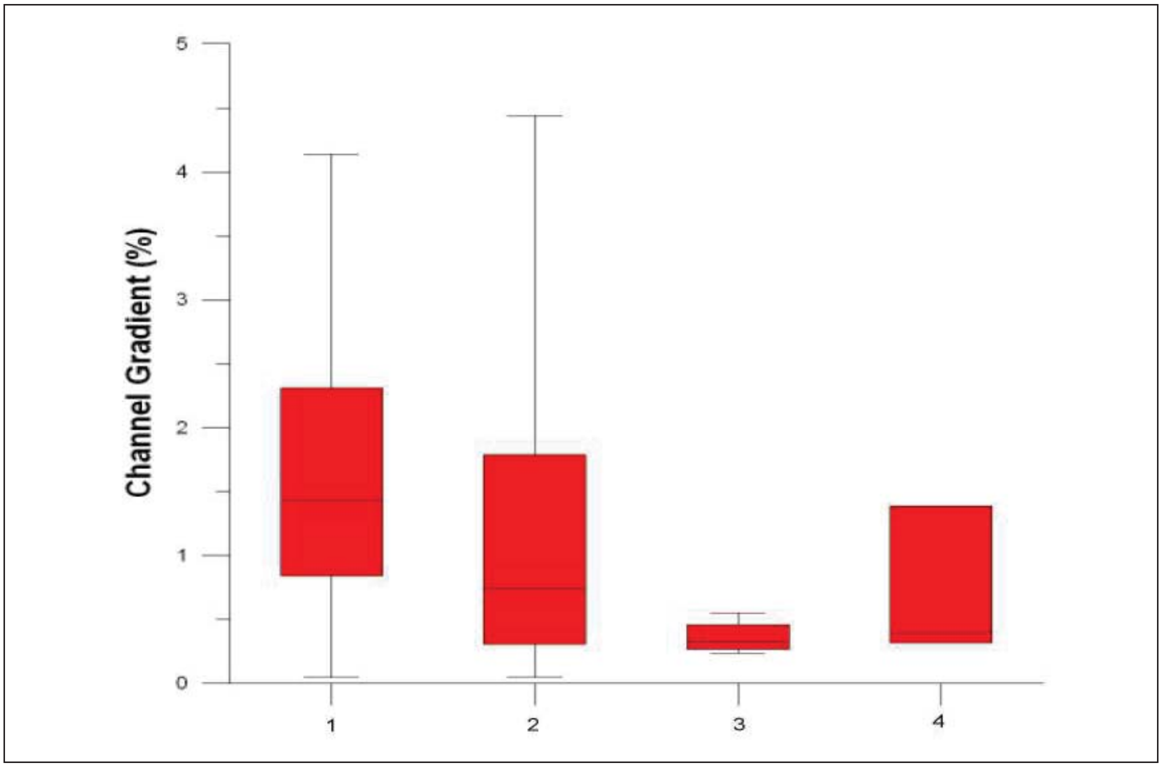


Figure 2.4.1 Box plot of channel gradients (%) by stream order in the CVC portion of the Erin SSMP study area showing maximum, 1st quartile, median, 3rd quartile, and minimum values

2.4.2.5 Summary of Basin Morphometry

Morphometric measures of the drainage area and drainage network provide insight into how well water that enters the area is removed from the subwatershed which, in turn affects sediment transport/removal from the subwatershed. The drainage density of the Erin SSMP study area is relatively low and reflects the importance of surficial geology in reducing overland flow through infiltration.

A well-drained area (represented by bifurcation ratio) will bring water from the catchment more directly to the main channel, leading to a more rapid response time to a precipitation event and a relatively flashier hydrograph. While the bifurcation ratio is appropriately high, the presence of online wetlands and ponds, however, exert a modifying influence. That is, these features enable temporary storage during a high flow event and interfere with the sediment transport process (see further discussion in Section 2.4.7). While low-order streams are often sources of sediment for a drainage network, the low gradients of these streams, in addition to the presence of wetlands and ponds, suggest local reductions in sediment transport potential and accumulation of sediment along the drainage network.

Modification of drainage networks (through straightening/shortening channel section and/or removing channels from the drainage network) will change the hydrograph shape, which can induce a channel response (e.g., erosion). Results of analyses have shown that swales exert an important influence on the routing of water through the drainage network. Indeed headwater channels and swales not only drain water from lands, but delay the time of delivery to the main branch and provide some storage. The delay is reduced when there is a reduction in channel length due to straightening and/or replacement of low order (e.g., zero or first order) streams with stormwater management pond outlet. Online wetlands and ponds can modify the rate of water and sediment delivery to receiving watercourses. Thus, a comprehensive management plan should give appropriate consideration to maintaining form or at least the function of this important part of the channel network.

2.4.3 Reach Delineation and Characterization

Geomorphic studies that are intended to gain insight into watercourse characteristics and into the functions and processes operative within different components of the drainage network, typically conduct studies at varying scales of spatial resolution. After completing investigations for the study area that examine properties of the drainage network (refer to Section 2.4.2), analyses typically begin to focus on individual tributaries and variation within them before proceeding to site specific investigations. The spatial sequence of analyses undertaken in this study extended from catchments → reaches → field sites → features. Findings from each of these spatial levels of analyses are presented in this chapter and are supported by materials within the Stream Geomorphology Appendix.

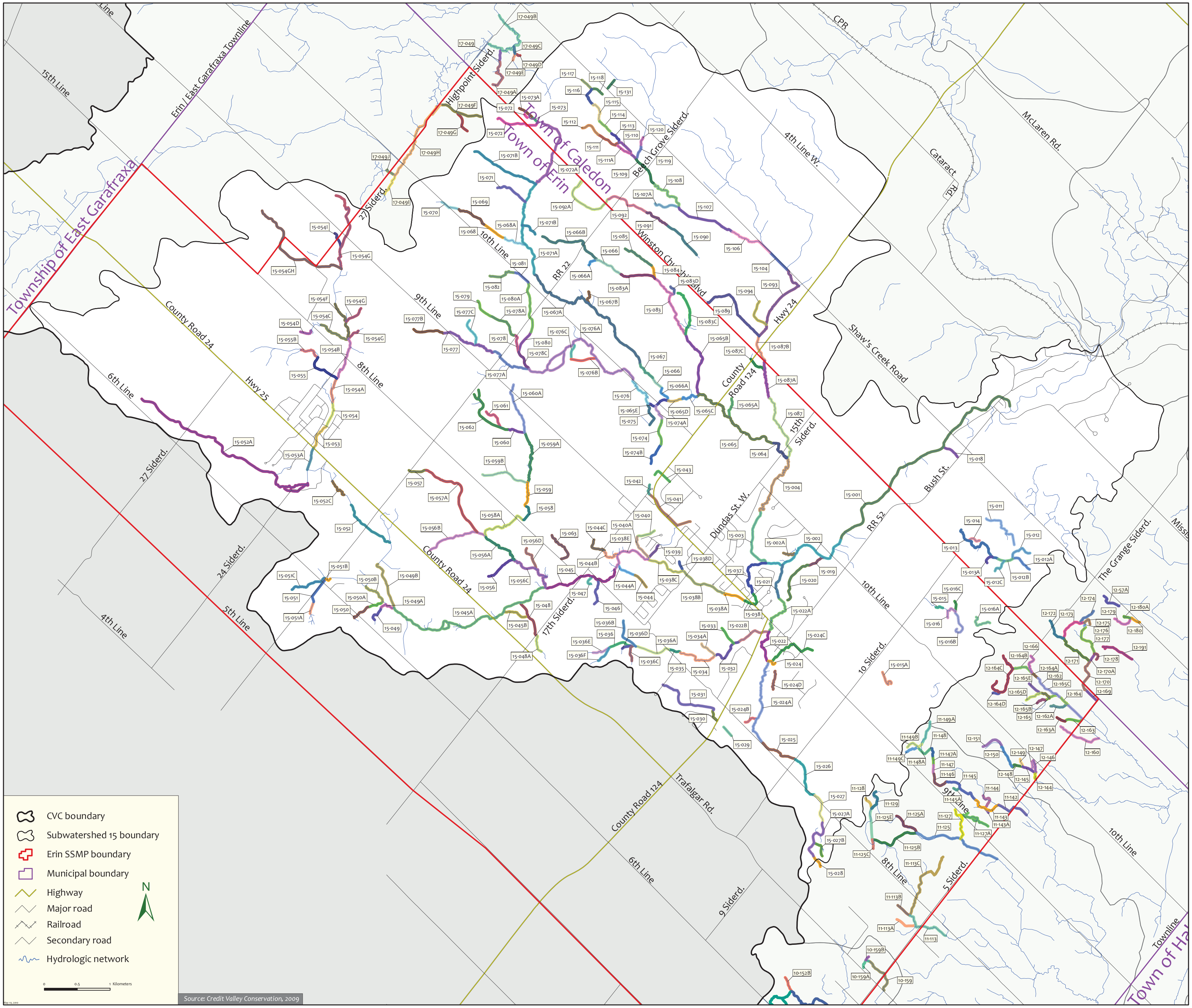
Reaches were defined along all watercourses within the Erin SSMP study area to facilitate the recording of information, and assessment of channel conditions along the watercourses (**Figure 2.4.2**). Please note in figure 2.4.2 colours were used to differentiate the many reaches. The reaches represent morphological channel units with similar forms and controls. Three general steps were used to delineate the reaches:

- Initial delineation based on previous work completed by Aquafor Beech (2005) for CVC;
- Further delineation using secondary sources (slope, surficial geology, planform, land use, and hydrological consistency, air-photo analyses); and
- Synoptic-level field reconnaissance to refine reach boundaries and characteristics – for this study, this was limited to reaches in proximity to watercourse crossings.

A total of 552 reaches were defined along CVC watercourses of which there were 246 zero-order reaches and 306 reaches having stream orders 1 to 4. A total of 26 reaches were defined along GRCA watercourses.

Reach delineation within the Erin SSMP area was complicated by many low order streams, agricultural drains, discontinuous drainage areas, ‘not visible’ watercourses (as defined by CVC) and wetland features. Low order features within the subwatershed, such as clusters of swales and ditches, were recognized as groups of zero order drainage features and were not included in the actual reach inventory; these features have not been

Figure 2.4.2 Watercourses Reach Mapping in Erin SSMP Study Area



Source: Credit Valley Conservation, 2009

described in detail within this study since groups of zero order streams are better documented using basin parameters. Wetland features and zero order streams are less significant as individual geomorphic elements, but may have important functions collectively within the subwatershed (i.e., sediment and flow contributions downstream to higher order channels).

Discontinuous channels, wetlands, and other channel sections not labelled in the initial desktop reach delineation (i.e., Aquafor Beech 2005) were added as new reaches, sub-reaches, or secondary reaches relative to the adjacent channel reaches. This was accomplished by adding in reach numbers between existing reaches (e.g., between reaches 15-039 and 15-038, reach number 15–038a was added) rather than renumbering reaches, to avoid multiple reach numbering schemes for the same area within CVC databases.

As part of the existing conditions documentation, reach attributes have been tabulated based on GIS analysis and findings during the synoptic level field investigation. Reach attributes include reach length, geology, drainage area, sinuosity, and valley setting, in addition to rapid measures of channel dimensions, substrate type, bed morphology, vegetation cover (see Tables in Section 1.0 of the Stream Geomorphology Appendix). The appendix tables also provide channel gradient and stream order for each reach as these are important indicators of stream energy and thus morphology and are important for understanding subwatershed processes at the basin scale. Unless readily determined through GIS analyses, attributes of zero-order reaches were not tabulated in the appendix tables.

A summary of general reach characteristics is provided as follows:

- The average reach gradient of watercourses is 1.47%. The main branch of the West Credit River within the study area was approximately 0.5%, indicating higher slopes along the lower order tributaries.
- There are four groups which best describe the riparian setting, listed from most to least common: i) cedar forests ii) agricultural pastures iii) wetlands with cedars, shrubs, and grasses, iv) urban areas with manicured floodplains and some bank hardening.
- Two controlling influences within the watercourse include the low-gradient wetlands and the bankside vegetation throughout the higher order streams.
- The Rosgen classification applied to the majority of reaches along the main branch of the West Credit River and higher order tributaries was a “C” type. Lower order tributaries within agricultural pastures and wetland areas were deemed “DA”, “D”, and “E” type streams. Refer to **Figure 2.4.4** for Rosgen stream classifications.

2.4.4 Catchment Areas/Tributary Characteristics

A synoptic level field investigation was completed for watercourses along which landowner access was permitted. The purpose of this level of field investigation was to gain insight into characteristics of the watercourses, to enable measurement of key channel parameters, and to enable identification of controlling and modifying influences. Observations made during the synoptic level field investigation were limited to reaches that were in proximity to, but outside the direct influence of, watercourse crossings and are summarized in the following paragraphs. Photographs illustrating the variation in channel morphology observed throughout the study area for each of the following sections are provided in Section 2.0 of the Stream Geomorphology Appendix.

For the purpose of description, characteristics of each of the watercourses within the Erin SSMP study area, as determined through the synoptic level field investigation are grouped by the main branch, or tributary of, the West Credit River. Watercourses situated within Subwatersheds 10, 11, 12, 17, or 18 or within the Grand River watershed are described separately.

2.4.4.1 Main Branch West Credit River

The Main Branch of the West Credit River was predominately stable, with few localized areas of erosion observed. This branch is described from the upstream extent at the Highway 25 crossing in the Village of Hillsburgh, through the Village of Erin to where it exits the study area at Shaw's Creek Road north of Bush Street. The average gradient of the Main Branch of the West Credit River was approximately 4.5 m/km.

Between the Town of Hillsburgh and Dundas Street West, the Main Branch flows through predominantly wetland areas with a defined channel. These wetlands were composed of dense cedar and poplar forests. Throughout these sections, bed materials were observed to consist of finer materials than found downstream, and aggradation was identified as the dominant process. Three dams were observed in this length of channel, each approximately 3 metres in height [from upstream to downstream – Hillsburgh Dam, Fish Club Dam, and an unnamed (Olesovsky) dam]. Refer to **Figure 2.6.6** for the locations of dams.

Throughout the Village of Erin, some areas of encroachment onto the floodplain as well as hardening of the banks to prevent erosion and river migration along private and public properties were observed. At Charles Street, approximately 120 metres upstream of the Main Street (Hwy 24) crossing in the Village of Erin, the watercourse encounters the first (heading upstream) of two manmade dams which created backwater conditions beyond Dundas Street West. The first dam (heading upstream), which is privately owned and referred to as Hall's dam, is approximately 3.5 m in height. The second dam is located at Church Hill Lane, and is approximately 2.5 m in height.

Downstream of the Main Street crossing bed materials were composed of larger alluvial material than upstream, indicating sediment discontinuity caused by the interruption of flow regime.

From the 10th Line crossing to the downstream extent of the study area, the Main Branch of the West Credit River flowed through a wide riparian zone composed primarily of conifer forests and wetlands. Throughout this length the vegetation was found to cover the majority of the floodplain and bordered the banks, and the channel generally appeared well-connected to the floodplain.

Bed materials along the Main Branch were alluvial dominated by cobble and boulders with a sandy matrix. Lastly, effects due to Beaver activity were found upstream of the Winston Churchill crossing where an accumulation of toppled trees slightly redirected flow, causing some deposition behind the accumulation and minor bank erosion on the opposing bank.

2.4.4.2 Hillsburgh Main Branch and Tributaries

These watercourses are described from the upstream extent of the study area defined by 27 Sideroad to where the Main Branch of the West Credit River crosses Highway 25 in Hillsburgh. In this area, the Main Branch was found to be primarily aggradational, influenced by a combination of culverts and large woody debris jams. Widening of the Main Branch was observed as a secondary process, which has contributed to exposure of a building foundation at the corner of Mill Street and Spruce Street. Upstream of the Town of Hillsburgh, the Main Branch showed signs of stress presumably from the effects of local urbanization, which impinges upon the floodplain, thereby creating inconsistencies in the flow regime. The tributaries were observed to be vegetation dominated through agricultural fields, or composed of wetland flows and found to be stable.

2.4.4.3 Winston Churchill Boulevard West Credit Tributaries

Some of the tributaries upstream of Winston Churchill Boulevard were significantly modified by privately owned dams that created online ponds. Other sections displayed natural channel characteristics with riffle-pool and vegetation controlled channel morphology. Geomorphic indicators identified using the Rapid Geomorphic Assesment (RGA) method found these tributaries to generally maintain stable to moderately stable levels of channel form and only localized areas of erosion were observed.

The reaches which were associated with online ponding were impacted primarily by backwater effects and sediment deposition behind the dam structures. Significant erosion downstream of the dams was not identified. Beyond the upstream extent of the ponds, backwater effects presumably contributed to the observed aggradation within the channel. This was exacerbated in some areas by the swamp and wetland conditions.

Initiation of planform development was observed in several of the formerly straightened channel sections (roadside ditches and agricultural channels), following the sequence identified by Rhoads and Herrick (1996). That is, watercourses are rarely straight in nature and, when straightened, given time and opportunity, they will redevelop a meandering planform configuration. These channels were situated within a vegetated (grasses, shrubs) 'ditch' which appeared to exert an influence on channel form. Some erosion was found at the downstream end of the straightened sections in the form of degradation and widening.

2.4.4.4 Binkham Tributaries

The Binkham Tributaries are situated between 9th Line and Winston Churchill Boulevard. The confluence of two tributaries occurs upstream of 17th Sideroad and the third tributary joins this channel immediately downstream of 15th Sideroad. These tributaries were identified as stable headwater streams controlled primarily by vegetation and wetlands with minimal observed erosion. These low-order watercourses flowed though low-gradient wetland corridors and were mainly aggradational. Near the downstream extent of the Binkham Tributaries (i.e., 17th Sideroad), thick accumulations of sand and silt were observed; the channel was poorly defined though a cedar wetland. These conditions were attributed to the low gradient (0.0024 m/m) south of 15th Sideroad, as well as effects from a private dam approximately 500 m downstream. Recent culvert work was observed at the 15th Sideroad crossing; the channel was in good condition upstream of the crossing and was situated within a grassed floodplain.

2.4.4.5 Black Creek (Subwatershed 10), Silver Creek (Subwatershed 11) and Cheltenham to Glen Williams (Subwatershed 12) Tributaries

These tributaries were characterized as headwater streams in each of the three subwatersheds. Together, these 3 subwatersheds drain approximately 8% of the study area.

The tributaries within Subwatershed 12 were observed to be primarily vegetation dominated channels and were classified as stable with minimal areas of erosion. Along a straightened section modified to run alongside 5th Sideroad, the channel was well vegetated and beginning to form a meandering pattern, with minor degradation at the intersection of Winston Churchill Boulevard and 5th Sideroad. Topographic mapping identified 16 ponds within this small portion of the subwatershed which is contained within the study area.

The tributaries within Subwatershed 11 were found to be stable, with recent culvert and gabion work identified upstream of the 5th Sideroad crossing along reach 11-125 (refer to **Figure 2.4.2** for the location of this reach). Backwater conditions were observed at Reach 11-113 attributable to a private dam found along the Southwest corner of 8th Line and 5th Sideroad. These backwater conditions were observed both upstream and downstream of the 5th Sideroad culvert.

The tributaries within Subwatershed 10 were observed to be mainly wetlands with no defined channels. No erosion was observed within the wetlands or swales of Subwatershed 10.

2.4.4.6 Shaw's Creek (Subwatershed 17)

These tributaries lie predominantly within a permanent wetland area. The zero, 1st and 2nd order tributaries are situated within wetlands with no defined channels observed. Indeed, it was not until the 3rd order channel was there a defined channel within the study area. This was located near the intersection of 27 Sideroad and Shaw's Creek Road, where the channel was predominately aggradational and minimal observed flow. These processes are explained by a combined effect of low gradient and large woody debris build-up.

2.4.4.7 General Overview of Channel Characteristics in the Study Area

The study area, which contains a portion of the West Credit River and associated tributaries, is drained primarily by CVC's West Credit River subwatershed along with small portions of CVC Subwatersheds 10, 11, 12, and 17. The general land use is dominated by agricultural activities and also contains two urban centres (the Villages of Erin and Hillsburgh). Although the watercourses do flow through agricultural fields (primarily low order (zero and 1st order streams), the majority of the watercourses are surrounded by natural areas. The main branch of the West Credit River was characterized as stable with few areas of local erosion. A combination of low channel gradients through wetlands, beaver and man-made dams, and woody debris obstructions were the cause of aggradation throughout much of the drainage network investigated.

Throughout the synoptic level field investigations no instances were observed where livestock access was granted to a 3rd order stream or higher. In some of the headwater streams however, livestock access was granted. Typically, livestock trample channel banks and bed configurations, leading to a loss of channel form and instability. The majority of the banks were vegetated with grasses, shrubs, and woodlands that were dominated by coniferous trees.

Online ponding was common along the drainage network within the study area. Notably, five large dams were observed along the Main Branch of the West Credit River, between the Villages of Erin and Hillsburgh. In addition, privately owned dams were commonly observed along Winston Churchill tributaries

Only a few locations where bank hard lining was implemented were observed during the field investigation. When present, then these occurred primarily at road crossings and along private properties through the Village of Erin.

Within the agricultural areas, many online and offline ponds were observed which can have adverse affects on stream morphology, water quality, and fisheries. A number of 1st and 2nd order streams observed were realigned alongside roadsides through well vegetated, grass ditches. In many of these ditches planimetric adjustment was the dominant process in the process of initiating meander development.

Some headwater streams which had been previously straightened were noted to be undergoing active planform development as the watercourses seek to regain sinuosity.

2.4.5 Detailed Site Characteristics

In addition to completing synoptic/reconnaissance level field site investigations along each of the watercourses, detailed morphological data were collected at five sites within the study area and restricted to occur within the CVC regulated area. The purpose of the data collection was twofold. First, the data were intended to gain insight into site specific channel characteristics and processes and to gather baseline data that will be particularly useful in Phase 2 of this study (i.e., to enable the impact of various management alternatives to be identified and assessed). The second purpose of data collection was to enable integration of the data with benthic macro-invertebrate data (see Section 2.5) for the purpose of examining biogeomorphic interrelations (see Section 2.4.8 of this report and Section 3.0 of the Stream Geomorphology Appendix). The field site locations were identical to those at which benthic macro-invertebrate data were collected and were in proximity to those used by other study disciplines.

At each field site, data were collected of the cross-sectional configuration and dimensions (width, depth, etc.), banks (height, angles, materials, stratigraphic units), substrate materials (size gradations, sorting, and shape), bed configuration (spacing of features), and planform characteristics. A photographic inventory of each field site was compiled and observations of channel conditions were made (e.g., occurrence of large woody debris, riparian zone characteristics, active channel processes). A summary of the field data is provided in **Table 2.4.5**. Further details are provided in the Stream Geomorphology Appendix. **Figure 2.4.3** illustrates the locations of each field site.

Undertaking detailed field assessments provided an opportunity to look more closely at channel form, revealing the following:

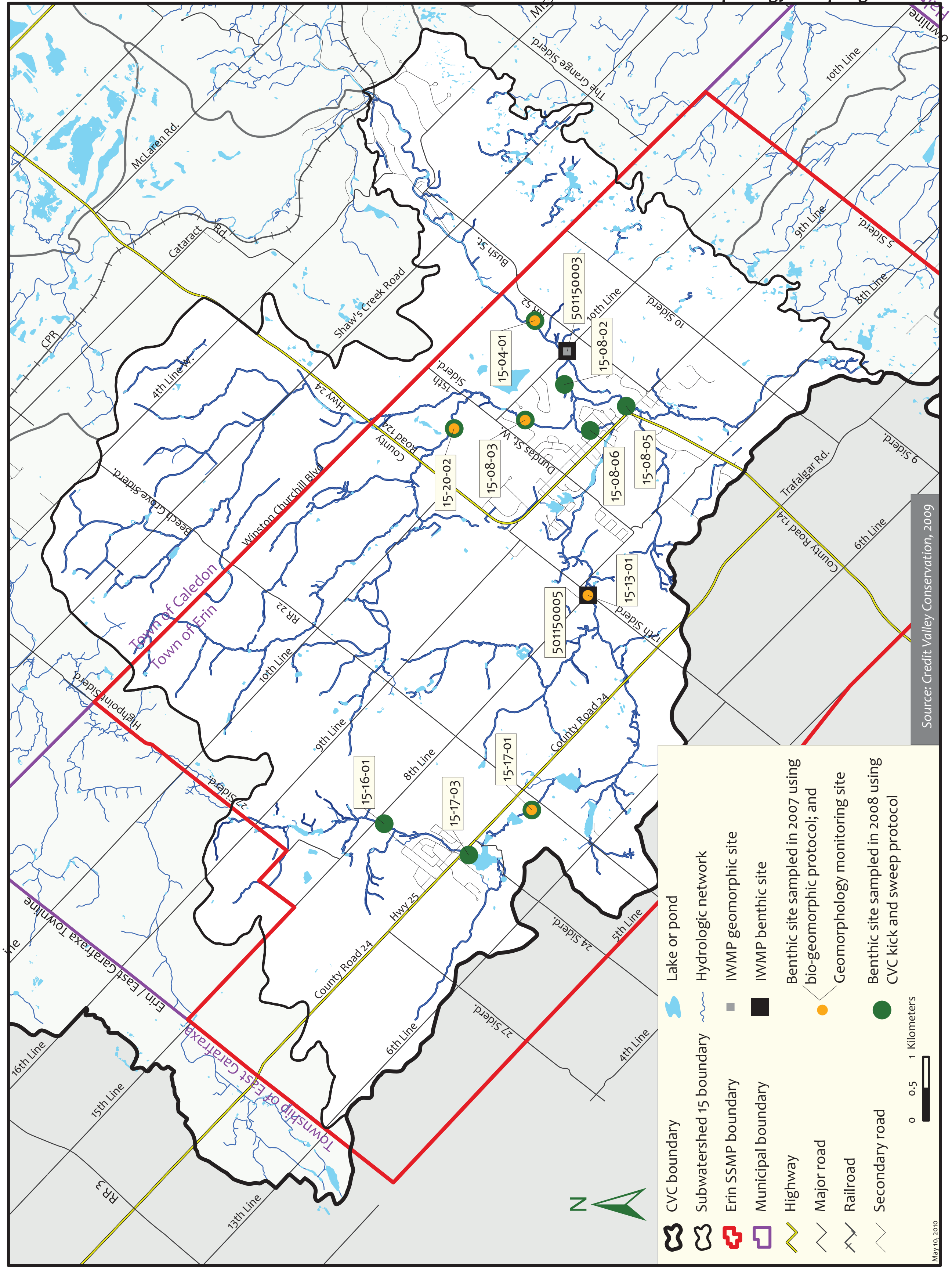
- Watercourses are typically well connected to the floodplain;
- Substrate materials tend to consist of a fine sediment matrix, underlying cobbles;
- Woody debris is prevalent when channel is situated in wooded riparian zone;
- In-channel vegetation (i.e., macrophytes) occurs where banks are vegetated with herbaceous plants; and

Table 2.4.5 Overview of Morphological Site Conditions at Detailed Field Data Collection Sites

Station ID	**15-04-01**	**15-08-03**	**15-13-01**	**15-17-01**	**15-20-02**
Location	**Upstream Winston Churchill**	**Downstream 10th Line**	**Upstream 8th Line**	**Upstream Country Rd 22**	**Upstream 15th Side Rd**
Watercourse Branch	**W.Credit (main branch)**	**W. Credit (east branch)**	**W. Credit (main branch)**	**W. Credit (main branch)**	**Binkham Tributary**
Drainage Area (km^2)	92.55	39.26	33.05	16.41	18.64
Site length (m)	139	121.5	104.5	150.0	107.3
Slope (%) (avg bankfull)	0.16	0.16	0.56	0.65	0.57
Estimated Bankfull Flow (cms)	3.44	0.87	4.92	2.48	0.98
Bankfull velocity (m/s)	0.88	0.47	1.06	1.04	0.73
Bankfull (BF)					
Max BF depth (m)	0.60	0.40	0.73	0.49	0.38
BF area (m^2)	5.06	1.83	4.64	2.39	1.34
BF Width (m)	11.30	6.61	9.59	6.78	5.47
Avg. BF depth (m)	0.45	0.28	0.50	0.35	0.25
Width:Depth ratio (m/m)	25.53	24.45	20.50	19.39	22.74
BF perimeter (m)	12.16	8.15	9.79	7.19	5.88
BF hydraulic radius (m)	0.42	0.23	0.48	0.33	0.23
Banks					
Height					
left (m)	0.60	0.40	0.64	0.52	0.36
right (m)	0.51	0.42	0.69	0.42	0.38
Angles					
left (o) lower	23.50	30.44	38.61	42.13	23.85
left (o) upper	25.81	10.02	46.01	22.39	46.08
right (o) lower	19.96	20.92	37.79	34.54	19.62
right (o) upper	32.63	26.43	31.65	40.01	12.77
Active Water					
Water Width (m)	9.64	4.26	8.61	5.73	3.89
Avg water depth (m)	0.25	0.12	0.27	0.32	0.14
Max. water depth (m)	0.35	0.17	0.42	1.21	0.20
Width:depth ratio (m/m)	40.09	40.35	39.18	29.29	31.68

Station ID	**15-04-01**	**15-08-03**	**15-13-01**	**15-17-01**	**15-20-02**
Location	**Upstream Winston Churchill**	**Downstream 10th Line**	**Upstream 8th Line**	**Upstream Country Rd 22**	**Upstream 15th Side Rd**
Watercourse Branch	**W.Credit (main branch)**	**W. Credit (east branch)**	**W. Credit (main branch)**	**W. Credit (main branch)**	**Binkham Tributary**
Wetted perimeter (m)	9.97	4.54	8.25	5.01	4.57
Substrate					
Substrate (mm)					
5	12	27	20	15	40
10	15	53	30	17	45
16	20	60	35	24	50
25	32	75	45	30	60
35	60	85	60	40	70
50	80	105	90	50	85
65	105	120	125	65	105
75	120	140	160	90	130
84	140	155	210	110	140
90	160	170	260	140	190
95	210	210	330	160	280
Particle Shape Sphericity	discoid	discoid	spheroid / discoid	discoid / spheroid	discoid / spheroid / roller
Sediment Sorting	poorly sorted	moderately sorted	poorly - v poorly	poorly sorted	moderately sorted
Site Observations	Fine sediment matrix on bed, vegetation to water's edge, well-connected to floodplain, emergent macrophytes in channel locally, fewer defined riffles	Dense herbaceous banks, vegetation in channel, cobble riffles, fine sediment on bed, woody debris jam, somewhat entrenched	Woody debris accumulations, wooded riparian setting, fine sediment matrix on bed, leaning tree trunks, some herbaceous bank vegetation, well connected to floodplain	Wooded riparian setting, cedars at toe of bank, leaning trunks, woody debris in channel, lenses of fine sediment, well-connected to floodplain	Coarse substrate, extensive riffle/run, vegetation to water's edge, herbaceous and woody vegetation on banks, accumulation of fine sediment in pools, some emergent vegetation locally

Figure 2.4.3 Benthic Macroinvertebrate and Geomorphology Sampling Stations



Source: Credit Valley Conservation, 2009

May 10, 2010

- Vegetation seemed to exert important control on channel form.

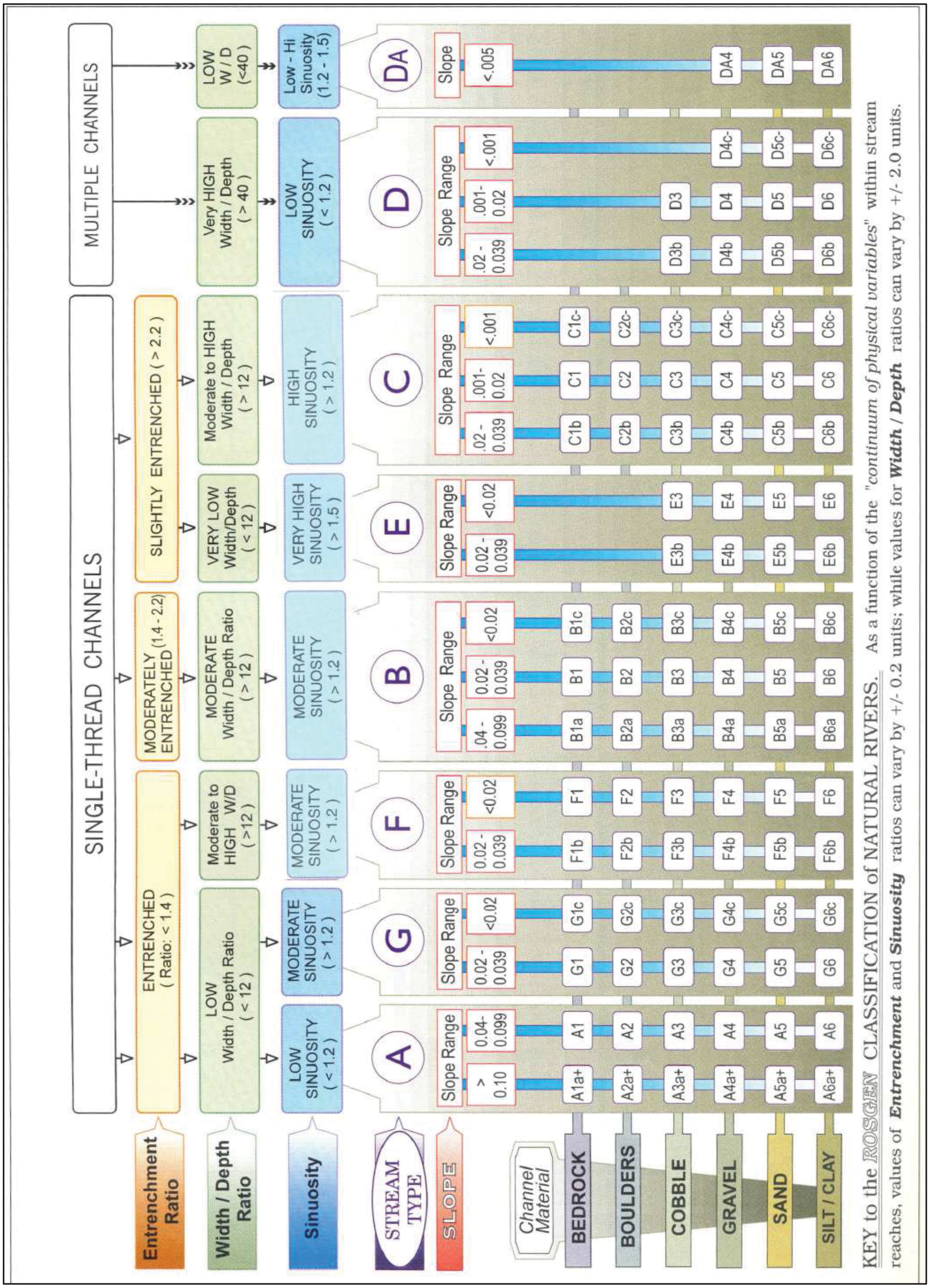
2.4.6 Stream Classification

Channel form is a product of the channel flow regime, as well as the availability and type of sediments within the stream corridor. The dynamic equilibrium between these inputs and boundary conditions controls the channel morphology and processes occurring within the channel. Although channel properties are best understood in terms of a multi-dimensional continuum of channel forms (Leopold and Wolman 1957; Schumm 1985; Knighton 1998), distinct channel classifications are a useful communication and management tool. They are important for documenting existing conditions, setting management priorities, and defining end state restoration objectives (Kondolf 1995).

Channel classification requires that lengths of channel be identified as discrete units or morphological reaches. To understand the interactions among the controlling factors, the existing channels in the Erin SSMP study area have been separated into reaches of relatively homogeneous character (see Section 2.4.3 for further detail). Delineation of reaches typically considers planform, gradient, hydrology, surficial geology, and vegetative/land cover controls (Montgomery and Buffington 1997; Richards et al. 1997).

In addition to documentation of existing conditions through the synoptic level field investigation (see Section 2.4.4) and delineation of reaches, two classification systems have been used: Rosgen Classification and Downs Evolution Model (**Figure 2.4.4 and 2.4.5,** respectively). Under the Rosgen (1996) classification system, stream characteristics are organized into relatively homogeneous stream types based on the degree of entrenchment, gradient, width-to-depth ratio, and sinuosity (**Figure 2.4.4**). Each type is then subdivided into six categories depending on the dominant bed and bank materials. Additional reference to the Rosgen approach can be found in Annable (1999). The Rosgen Classification approach provides a common language for defining channel form and inferring channel process, and provides a continuity between this and previous studies. Nevertheless, the Rosgen system is limited in its ability to classify channels that are undergoing adjustment and does not always adequately represent Southern Ontario stream characteristics.

Downs (1995) developed a classification scheme to account for trends and patterns of adjustment to the fluvial and sedimentation processes responsible for driving channel change (**Figure 2.4.5**). Unlike classifications based on morphology, the Downs Evolution Model assesses the current nature of the channel adjustment processes. Unfortunately, pertinent channel information (e.g., historical records of change) may not always be available, and historic patterns of change may not be representative of current or future adjustments. The geomorphologists' Downs classification system therefore requires training to reliably assess the stage of evolution based on channel morphology.



KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the *"continuum of physical variables"* within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

Figure 2.4.4 Rosgen Classification System (Rosgen 1996)

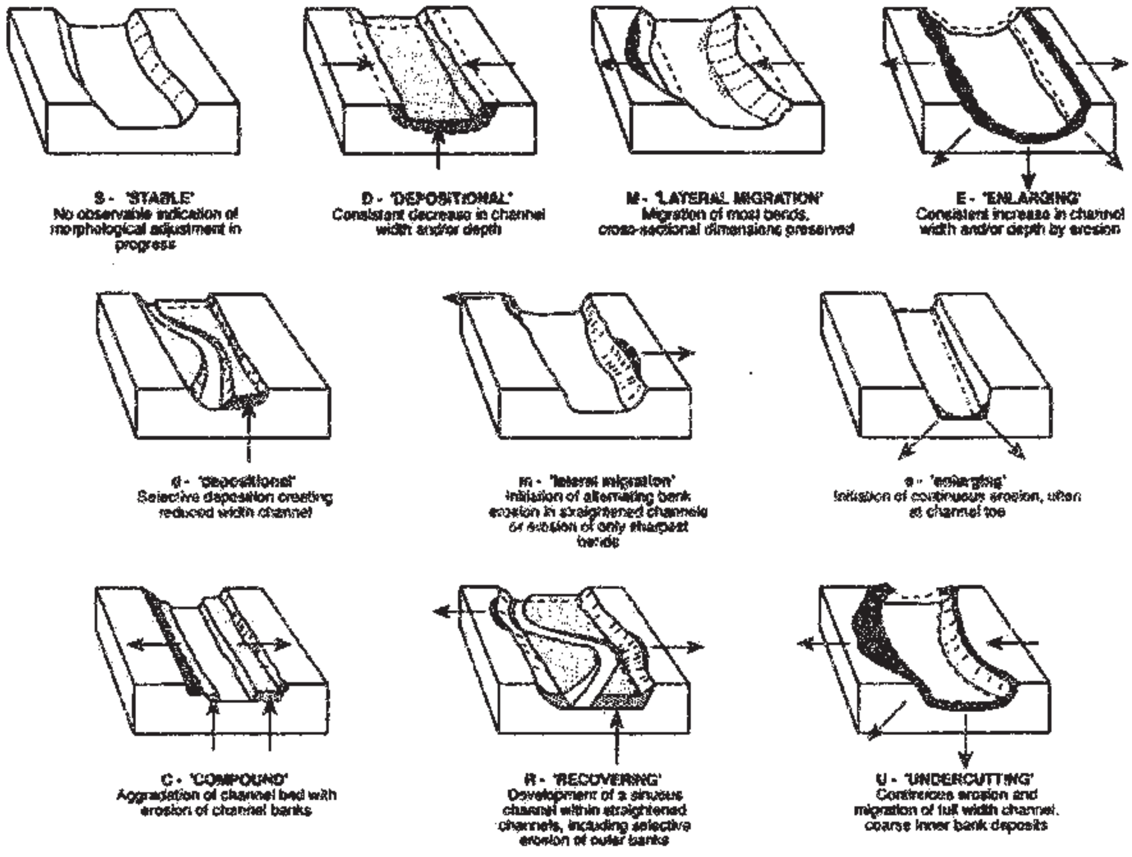


Figure 2.4.5 Down's Evolution Model (Downs 1995)

From the Downs Evolution Model, channel adjustment types are based on the mode of adjustment and include the following: stable, depositional, lateral migration, enlarging, compound, recovering, and undercutting. Application of this classification system requires the researcher to examine the field evidence and determine the predominant mode of adjustment. For example, depositional channels can be indicated by various factors including excessive bar development, sediment deposition on floodplain surfaces, or burying of infrastructure. Enlarging channels can be indicated by various factors including leaning trees and outflanked or undermined structures.

In order to identify reaches impacted by and sensitive to land use change within the study area, channel stability was assessed on the reaches included in the synoptic level field assessment (see Section 2.4.4) by using a Rapid Geomorphic Assessment (RGA) (MOE 1999^b). The RGA documents indicators of channel instability, providing a relative measure of channel stability and identification of the dominant mode of adjustment occurring in the system. Although the RGA method is primarily for urbanized watercourses, it has been adapted for other reaches in the Erin SSMP study area in order help characterize dominant processes occurring as possible responses to agricultural modifications to the channels and drainage network. Based on the RGA scores, channel stability was rated as either Stable (0.0 – 0.2), Moderately Stable (0.2 – 0.4), or Unstable

(0.4 – 1.0). Reaches scoring close to the threshold between these ratings have been indicated as such. The RGA stability ratings and dominant adjustment processes are provided in **Table 2.4.6**.

Table 2.4.6 Stream Classifications for Selected Reaches in the Erin SSMP Study Area

Reach ID	Branch	RGA #		*Downs Evolution Model	*Rosgen Classification
		Dominant Process	Stability		
REACH_10-159	SUB 10	N/A	S	N/A	N/A
REACH_11-113	SUB 11	N/A	S	N/A	N/A
REACH_11-125	SUB 11	PI/W	MS	m	Intermittent
REACH_11-142	SUB 11	PI	S	M	Intermittent
REACH_12-145	SUB 12	N/A	S	N/A	N/A
REACH_12-162	SUB 12	PI	S	M	C4
REACH_12-169	SUB 12	D	MS	R	C6b
REACH_12-191	SUB 12	W	S	S	Intermittent
REACH_12-257	SUB 12	A	S	D	C4
REACH_15-002WC	Main	W/PI	S	S	C3
REACH_15-004WC	Main	PI	MS	M	C3
REACH_15-022	Erin Village Trib	A	MS	D	C6b
REACH_15-035	Erin Village Trib	A/PI	U - MS	D	Intermittent
REACH_15-037	Main	W	MS	M	C3
REACH_15-038	Main	W	MS	M	A3
REACH_15-039	Erin Village Trib	A	MS	N/A	N/A
REACH_15-041	Erin Village Trib	PI	S	R	B6c
REACH_15-043	Erin Village Trib	A	S	Intermittent	Intermittent
REACH_15-045	Main	PI/W	MS	M	C5b
REACH_15-050	Hillsburgh Trib	D	S	S	C5b
REACH_15-052	Main	A / PI	S	D	B3c
REACH_15-053	Hillsburgh Main	A / W	MS	C	C6b
REACH_15-054	Hillsburgh Main	A / W	MS	C	C6b
REACH_15-055	Hillsburgh Trib	A	S	D	C5
REACH_15-055A	Hillsburgh Main	A	S	D	C4
REACH_15-064	Binkham Trib	A/PI	MS	D/M	E3
REACH_15-070	Binkham Trib	A	S	Intermittent	Intermittent
REACH_15-087	Winston Churchill Trib	PI/A	MS	D	E3
REACH_15-093	Winston Churchill Trib	PI	S	S	E6b
REACH_15-108	Winston Churchill Trib	PI	S-MS	M	B
REACH_15-	Winston	PI/A	S	N/A	Intermittent

Reach ID	**Branch**	**RGA #**		***Downs Evolution Model**	***Rosgen Classification**
		Dominant Process	**Stability**		
089A	Churchill Trib				
REACH_15-104	Winston Churchill Trib	PI	MS	R	B
REACH_15-040	Erin Trib	A	S	D	Intermittent
REACH_15-066A	Binkham Trib	W/PI	MS	M	Intermittent
REACH_15-068A	Binkham Trib	PI	MS	M	B3
REACH_15-077A	Binkham Trib	PI/D	MS	D	C5
REACH_15-058	Hillsburgh Trib	D	MS	E	B3
REACH_15-058B	Hillsburgh Trib	PI/W	S	m	C4
REACH_15-045A	MAIN	A	MS	D	C5
REACH_15-038A	MAIN	A	S	D	C3
REACH_15-H	Hillsburgh Trib	D	S	Intermittent	Intermittent
REACH_17-049A	SUB 17	A/W	S	C	E4

Note:
Forward slash (/) = Combination; Hyphen (-) = Threshold in Stability Score
RGA#: N/A = Not Assessed; W = widening; Pl = Planametric variation; D = deepening;
A = Anastomosing; S = stable; U = unstable; MS = moderately stable
Downs: Refer to ***Figure 2.4.5*** *for definitions*
Rosgen: Refer to ***Figure 2.4.4*** *for definitions*

2.4.6.1 Results from Rapid Geomorphic Assessment

Based on the RGA results, most reaches are considered stable to moderately stable with only minor signs of channel adjustment locally (**Table 2.4.6**). The most significant exception occurred along the Erin tributary where the channel showed evidence of instability (Reach 15-035). Refer to **Figure 2.4.2** for the reach locations.

Aggradation and planform adjustment were considered to be the most dominant channel processes at work within the observed reaches. Factors influencing aggradation include low stream gradients, and the moderating effect of online ponds and wetlands on sediment transport. The aggradation was commonly observed as fine sediment accumulations either as sediment lenses or as a fine sediment matrix supporting larger gravels and cobbles.

Planform adjustments were observed to occur along channel sections that had been previously straightened.

Evidence of channel widening was most often observed along channel sections situated in wooded areas. Degradation of the channel bed was observed occasionally to be the dominant channel adjustment process.

2.4.6.2 Rosgen Classification

Few reaches in the Erin SSMP study area are significantly entrenched according to Rosgen's (1996) definition, resulting in the dominance of E and C class channels within the basin. Refer to **Figure 2.4.4** for definitions of stream classifications E and C. Substrate within the study area reaches is predominately sand, with gravel and cobble due to local sediment sources; sandy substrates often coincided with areas influenced by backwater in addition to low channel grades (e.g., as a result of physiography). Channels termed "intermittent" were not classified using the Rosgen methodology, and primarily vegetation dominated and illustrated minimal and / or discontinuous flows.

The most significant limitation of the Rosgen approach within the Erin SSMP study area is associated with channel sinuosity. Classification of reaches as E and C type channels suggests that the channel sinuosities are relatively high which is not generally the case in the study area. Problems with strict adherence to the Rosgen Classifications definitions, especially with respect to the sinuosity criterion may be due to historic straightening and the dominance of low order streams with low power-resistance ratios. Therefore, many channels within the Erin SSMP study area do not exhibit well developed meandering planforms, despite low entrenchment ratios and channel gradients. Further, the alternation between C and E type channels is dominantly due to the spatial variability in riparian vegetation.

2.4.6.3 Downs Classification

Downs classifications reflect observations made during the field investigation and are supported by results from the RGA assessment (**Table 2.4.6**). The Downs Evolution Model provides more detail with regard to the relative significance of the inferred processes and the potential role of lateral migration processes within the collection of processes occurring in each geomorphic reach. Review of **Table 2.4.6** reveals that deposition and meandering are dominant processes occurring along study area reaches.

2.4.7 Erosion and Sedimentation

Channel stability is a relative term where there is a balance between sediment supply and transportability. Eroding channels can have a deficiency of sediment and progressively degrade the stream bed and/or banks. Stable channels have no progressive change in channel cross sectional form although short-term variations may occur during floods. The material eroded in stable channels is replaced by material supplied from upstream. Therefore a stable channel can still migrate across its floodplain while maintaining similar cross sectional dimensions. Depositing channels have an excess sediment load delivered to the stream which results in progressive aggradation and/or bank deposition.

The processes of erosion and deposition occur along all natural watercourses and are necessary for the dissipation of energy and for enabling morphological adjustments in response to changes in flow and sediment regimes within the channel. Natural rates of erosion and deposition can be exacerbated along any watercourse due to local perturbations (e.g., bank failure, backwater effects from ponds or dams) and episodic events (e.g., large flood flow) or through gradual change in watershed characteristics (e.g., hydrologic regime due to climate, change in land cover, and urbanization).

Within the Erin SSMP study area, deposition and aggradation of fine sediment is the dominant process found along the main branch of the West Credit River and many of its associated tributaries. This accumulation is attributed to the combination of low stream energy through wetland areas and backwater conditions created from flow regime interruptions (e.g., human-made and beaver dams).

Headwater reaches which flow through agricultural areas were often found to be vegetation controlled channels with some accumulations of fine sediment, potentially derived from adjacent and upstream agricultural fields.

Few areas of significant erosion were identified during the synoptic level field investigation. Downstream of Hall's Dam in Erin Village, some areas of erosion and bank hard lining were observed (e.g., a manicured bank along the inside of a > 90^0 bend; the outside of the bend was a private property with areas of active erosion and intermittent hardening).

Downstream of Hall's Dam the bed material along the main branch of the West Credit River was composed of larger alluvial material and deposition and aggradation was not as apparent. There were no areas of systemic erosion observed which is often associated downstream of such a large discontinuity in flow regime (i.e., notion of hungry water or sediment-starved water having a higher carrying capacity and higher erosion potential). Dams disrupt a river's natural course, disrupting continuity of flow and associated sediment. Numerous dam structures were observed throughout the study area, creating backwater conditions which are sinks for sediment. Immediately downstream of these structures there was often a noticeable lack of fine sediments and the bed material was much coarser, however, this was only noticed for short lengths downstream of the inspected sites. Along these short lengths the channels were slightly enlarged or degraded, however, the channel degradation was not found to proceed beyond the extent of the reach. This could potentially be explained by the low gradients and wetland conditions often found downstream of the degrading channels and common to the study area, where substantial energy to further the process is not conveyed. A total of nine dams are identified within the study area on the GIS mapping (**Figure 2.6.6**). These dams are located along the higher order segments. Numerous other dams were found during the study area reconnaissance which appeared to be privately owned. Small, private dams are generally used for agricultural or recreational purposes.

2.4.8 Biogeomorphic Assessment

The term biogeomorphology refers to the science relating biota with geomorphic forms and processes (Osterkamp and Friedman 1997). Hydraulic conditions, in combination with bank composition and land uses can influence the degree of habitat stability and sediment deposition, both of which have been shown to influence benthic communities (Jowett 2003; Mazeika et al. 2004). To date there have been many field-based empirical studies of biogeomorphological interactions, and many species-habitat interactions have been widely accepted and supported (Hancock and Skinner 2000). Inter-related factors of width, depth, velocity, and substrate are the most common morphological elements used to predict the distribution and abundance of benthic invertebrates, each of which can be particularly sensitive to land use practices and hydromodification.

For many benthic organisms, the substrate and substratum of the channel bed is the foothold in which they reside. It is used as a site to deposit eggs, as a means to grind food, and as a refuge from conditions beyond tolerance levels (Gordon et al. 2004). Species vary in preference of substrate and substratum, dependant upon factors such as particle size, gradation of material, size of pores, and degree of packing. One of the most consistent results in bio-geomorphic studies is the positive correlation between benthic invertebrates and particle size (Jowett and Richardson 1990; Jowett et al. 1991). In general, the greatest magnitude and diversity of benthic invertebrates occur in riffle materials composed of medium gravel and cobbles (Gore 1985). Further, habitats with an abundance of shifting sands and fine gravels, or boulders and bedrock have been shown to negatively affect most benthic communities (Minshall 1984; Jowett and Richardson 1990). The composition and movement of sediments has different effects on species as habitat preferences and suitability varies. For example, Trichoptera require unstable, fine grain sands, Diptera require mud into which they can burrow, and Salmanoids require a mix of gravels with some fine sediments (Beschta and Platts 1986; Gordon et al. 2004). Milhous (1982) suggests gravel streams which fill with silt may display shifts in invertebrate compositions from Ephemeroptera and Trichoptera towards Diptera.

A stream’s depth, width, and velocity are primarily related to the quantity of flow conveyed through the channel, and the roughness of the bed and banks. Depth affects the distribution of benthic invertebrates, with most preferring relatively shallow waters (Wesche 1985). Moreover, species density has been found to be most abundant at depths of 0.4 m and decreases at greater depths, with Diptera being the exception with increased abundances beyond 0.4 m (Jowett and Richardson 1990). Jowett et al. (1991) suggest benthic invertebrates heavily rely on current to assist with respiration and feeding, which explains the general findings that maximum densities have been found in velocity areas in the range of 0.6 m/s. With regards to depth and velocity, Jowett (2003) found that habitat preferences in small streams differed from those in large streams. In small streams, benthic invertebrates were generally most abundant at depths of 0.05 - 0.20 m and velocities of 0.05 - 0.40 m/s; however, in large streams depths of 0.3 - 0.5 m and mean velocities of 0.5 - 1.0 m/s were preferred.

The West Credit Subwatershed Study (CVC 2001[a]) investigated linkages between aquatic habitat health and many interrelated factors such as channel stability, primary mode of adjustment, opportunities for refuge, characteristics of bed materials, and depths of flow during dry periods and bankfull stage. Additionally, relationships between aquatic habitat health deterioration with positive changes in total basin imperviousness (TIMP) were discussed. Three of the strongest correlations found within the West Credit River subwatershed data identified a decrease in benthic invertebrate diversity and number of taxa with an increasing stability index value (indicating increasing levels in channel instability), and a decrease in number of taxa with an increasing channel widening factor.

An opportunity was provided in this study to examine in detail the linkage between physical channel conditions and various parameters of benthic abundance and diversity. Within the scientific literature, it is well known that both water depth and flow velocity are two critical habitat parameters. In addition, previous analyses undertaken as part of the 2001 West Credit Subwatershed Study by CVC suggested that physical characteristics of sites, typically measured during geomorphic field investigations, such as substrate characteristics, might account for the abundance and diversity of benthic species. Of particular interest is the fact that the micro-form elements of channel form that comprise the habitat of benthic invertebrates are the same elements that are most sensitive to changes in urban hydromodification.

The analyses undertaken for this study progressed systematically to examine characteristics of species abundance and diversity within the study area to within the field sites and then locally within individual cross-sections. Highlights of the results are provided within Section 2.4.8. Details of the biogeomorphic analyses are provided in the Section 3.0 of the Stream Geomorphology Appendix.

Intra-site comparisons

The benthic data were examined to determine what, if any, variation in species diversity and abundance existed within sites. Review of the results typically revealed the following:

- Number of taxa is greater in riffles than pools;
- Number of EPT is greater in riffles than pools;
- More individuals in riffles than pools; and
- Shannon diversity slightly higher in riffles than pools, except for site 15-04-01 where the H1 value in riffles are markedly lower than the pool.

Inter-Site Comparison

The benthic data were examined to determine if variation in species diversity and abundance occurred between sites. Review of **Table 2.4.7** revealed that some sites were more ‘rich’ than others with respect to the abundance (number of individuals) and

Table 2.4.7 Summary of Benthic Data Collected on a Site by Site Basis

Field Site	Location	Drainage Area (km^2)	Slope (%)	Riffle/Pool/ Site Total	Number of Individuals	Number of Taxa	Ephem- eroptera	Plecop- optera	Trichop- optera	EPT Richness	% EPT	% Chiron- omids	Shannon Diversity (H1)
15 - 17 - 01	Country Rd 22	18.41	0.65	Riffles total	4838	82	10	3	12	25	0.36	0.31	4.63
15 - 17 - 01	Country Rd 22	18.41	0.65	Pools total	476	55	7	2	9	18	0.28	0.40	4.81
15 - 17 - 01	Country Rd 22	18.41	0.65	Site total	5314	88	10	3	12	25	0.35	0.31	4.72
Average					**3543**	**75**	**9**	**2.7**	**11**	**23**	**0.33**	**0.34**	**4.72**
15 - 20 - 02	15th Sideroad	14.51	0.57	Riffles total	2548	93	7	1	13	21	0.17	0.44	4.93
15 - 20 - 02	15th Sideroad	14.51	0.57	Pools total	750	64	5	0	5	10	0.15	0.62	4.69
15 - 20 - 02	15th Sideroad	14.51	0.57	Site total	3298	109	9	1	14	24	0.16	0.48	5.15
Average					**2199**	**89**	**7**	**0.7**	**11**	**18**	**0.16**	**0.51**	**4.92**
15 - 04 - 01	U/S WCB	13.22	0.16	Riffles total	46115	90	9	3	14	26	0.87	0.11	1.19
15 - 04 - 01	U/S WCB	13.22	0.16	Pools total	3053	72	7	0	9	16	0.10	0.82	3.27
15 - 04 - 01	U/S WCB	13.22	0.16	Site total	52221	101	10	3	16	29	0.78	0.20	1.68
Average					**33796**	**88**	**9**	**2**	**13**	**24**	**0.58**	**0.38**	**2.05**
15 - 08 - 03	10th Line	33.67	0.16	Riffles total	4525	106	10	1	21	32	0.29	0.37	4.99
15 - 08 - 03	10th Line	33.67	0.16	Pools total	2395	82	11	0	9	20	0.16	0.40	4.50
15 - 08 - 03	10th Line	33.67	0.16	Site total	9315	132	14	1	24	39	0.23	0.39	5.17
Average					**5412**	**107**	**12**	**0.7**	**18**	**30**	**0.23**	**0.39**	**4.89**
15 - 13 - 01	8th Line	35.83	0.56	Riffles total	1256	46	2	0	7	9	0.39	0.41	3.72
15 - 13 - 01	8th Line	35.83	0.56	Pools total	226	33	1	0	5	6	0.20	0.35	3.58
15 - 13 - 01	8th Line	35.83	0.56	Site total	1482	55	2	0	7	9	0.36	0.40	3.79
Average					**988**	**45**	**2**	**0**	**6**	**8**	**0.32**	**0.39**	**3.70**

diversity (number of taxa) observed at the field sites. Most notably, Site 15-08-03 appeared to be 'richest' and Site 15-13-01 was the 'poorest' (**Table 2.4.8**).

While many factors can influence the occurrence and abundance of benthic macroinvertebrates (e.g., water quality etc.), a review of field observations was completed to determine if any physical site characteristics (i.e., at the site or along the watercourse) might account for the observations of **Table 2.4.8**. Review of **Table 2.4.5** and field notes suggests the following:

- Richer sites convey a lower bankfull discharge than the 'poorer' sites;
- Bankfull channel dimensions (e.g., width, cross-section area, hydraulic radius) tend to be lower for 'richer' than 'poorer' sites;
- Low flow channel dimensions tend to be smaller for 'richer' than 'poorer' sites (e.g., wetted perimeter, width:depth ratio, avg. and max. water depth). The low flow width:depth ratio did not appear to be linked to richness or poorness of site
- Substrate was somewhat coarser for the 'richer' than 'poorer' sites, especially for the smaller grain size fraction (e.g., D25 or less);
- The 'richer' sites are situated along the Binkham tributary. The poorer sites are situated along the main branch of the West Credit River; and
- 'Richer' sites had moderately sorted bed materials, 'poorer' sites had poorly sorted bed materials.

Table 2.4.8 Inter-site Comparison of Benthic Abundance and Diversity

	Most	Least
Number of Individuals	15-04-01	15-13-01 and 15-20-02
Number of Taxa	15-08-03	15-13-01
EPT Richness	15 - 08 - 03	15 - 13 - 01
% Chironomids	15 - 20 - 02	15-17-01
Shannon Diversity	15-08-03 and 15-20-02	15-04-01

2.4.9 Geomorphic Characterization

Review of the existing geomorphologic conditions within the Erin SSMP study area has revealed the following:

- Aggradational channel conditions are common, resulting from the presence of numerous online ponds. This affects continuity of sediment transport to downstream channel sections;
- Planform adjustment is common especially as previously straightened channels seek to regain a meandering form; and
- Many of the observed channel reaches were considered to be stable or moderately stable.

Biogeomorphic Characterization

The Stream Geomorphology Appendix presents results of the detailed biogeomorphic data analysis that has been undertaken, including summaries of key findings and presentation of graphics illustrating the relations examined. The analyses suggested the following:

- Relations between measurable channel parameters were typically stronger for low-flow parameters and benthic diversity or abundance, than for bankfull channel parameters;
- When data were separated into Riffle data only, the statistical strength of relations between channel parameters and benthic diversity or abundance did not consistently improve relations for the low-flow parameters nor for the bankfull channel parameters;
- In general, both benthic invertebrate abundance and diversity decrease as mean particle mobility increases; and
- While the statistical strength of the relations were typically poor, the data revealed an overall positive correlation with increasing size of substratum and benthic indicators.

2.4.10 Next Steps

Based on the analyses completed as part of this study, and in reviewing results from previous work completed in the West Credit River subwatershed, the following have been identified as possible next steps to proceed forward with the West Credit Subwatershed Plan and maintain the high quality systems:

- Assess potential impacts of urbanization and changes in land use on channel stability and flow regimes;
- Consider implication of dam removal (e.g., as part of any rehabilitation plan - two dams in Erin Village were noted to be structurally inadequate in the *West Credit Subwatershed Study Phase 1 Characterization* report) on overall channel functions (e.g., sediment transport);
- Consider implication of potential stormwater or water treatment outfall locations in proximity of dam structures and channel stability;
- Minimize alteration to drainage density when considering redevelopment of lands within the Erin SSMP study area; and
- Assess potential impacts on benthic macro-invertebrate habitats through furthering biogeomorphic relationship studies**.**

Next Steps with the Biogeomorphic Assessment

Based on the analyses completed as part of this study, and in reviewing results from previous work completed in the West Credit River subwatershed, the following have been identified as possible next steps in examining linkage between channel form and benthic invertebrate abundance and/or diversity:

- Identify, if possible, what other site factors contribute to, or can explain, why some sites demonstrate particularly poor statistical relations between measurable channel parameters and benthic diversity/abundance, and some have particularly good statistical relations. This could include multi-variate analyses of physical channel data and consideration of upstream influences. Consideration should also be given to other site data such as water quality.
- Continue analyses of data set to examine relation between other measurable parameters collected in the field and benthic diversity/abundance data.
- Undertake further analyses by segregating taxa and EPT into groupings that are more likely to be affected by specific channel parameters.
- Repeat analyses for data collected along other sections of the Credit River drainage network. This study has demonstrated that the co-ordination of site specific data collection locations provides a unique opportunity to explore linkages between different study disciplines. Collection of similar data as was completed in this study, along many more data collection stations with the Credit River watershed, would provide more statistical reliability of analytical results. Once the sample size is sufficiently large to promote confidence in trends, findings could be invaluable in guiding stream restoration efforts that will enhance benthic invertebrate abundance/diversity. This would ultimately assist in improving aquatic habitat.

2.5 BENTHIC MACROINVERTEBRATES

2.5.1 Introduction

Benthic macroinvertebrates are larger-than-microscopic organisms that live on a stream bottom. Examples include aquatic insects, worms, and crayfish. Benthic macroinvertebrates are a commonly used indicator group for aquatic environmental conditions for several reasons. First, they integrate biologically relevant variations in water and habitat quality. Second, they are limited in their mobility and therefore reflect local conditions and can thus be used to identify point sources of inputs or disturbance. Their short life spans (about 1 year) also allow them to integrate the physical and chemical aspects of water quality over annual time periods and provide early warning of impending effects on fish communities (Kilgour and Barton 1999). Finally, based on known tolerances of benthic taxa, it is possible to re-create the environmental conditions determining the animals present (Rooke and Mackie 1982^{a}, 1982^{b}).

2.5.2 Methodology and Data Analyses

As part of the Phase 1 component of the Erin SSMP study, surveys of benthic macroinvertebrates were undertaken at eleven locations (**Table 2.5.1** and **Figure 2.4.3**).

These data are used to characterize the existing condition of the benthic community, and will be used during Phase 2 (Impact Assessment) of the study for identifying reaches and subcatchments that are potentially sensitive to proposed servicing (i.e., outfalls).

Two of the stations (501150003 and 501150005) have been sampled annually since 1999 through CVC's Integrated Watershed Monitoring Program (IWMP). The remaining stations were sampled specifically for the Erin SSMP study for one or two years between 2007 and 2008. Stations sampled in 2007 followed a bio-geomorphic protocol to better understand relationships between benthic communities and geomorphological features. The Biogeomorphic Assessment is discussed in Section 2.4.8 within this report, and Section 3.0 within the Stream Geomorphology Appendix.

Table 2.5.1 Benthic Macroinvertebrate Sampling Stations and Length of Data Record in the Erin SSMP Study Area

Station ID	Site name	Purpose of Site	Years sampled
15-04-01*	West Credit River downstream 10th Line (upstream of Winston Churchill Blvd)	Downstream end of study area	2007-2008
501150003	West Credit River at 10th Line	Long-term monitoring station	1999-2006
15-08-02	West Credit upstream 10th Line	Surrogate for station 501150003	2008
15-08-03*	East Branch downstream 10th Line	Original sampling location (benthos and geomorphology) through West Credit SW study Characterization of east branch	2007-2008
15-08-05	South Trib downstream Main St., Erin Village	Characterization of south tributary	2008
15-08-06	West Credit at Woollen Mills, Erin Village	Downstream end of urban area; Upstream of proposed outfall location	2008
501150005*	West Credit River at 8th Line Gauge Station	Long-term monitoring station	1999-2008
15-16-01	West Credit upstream 8th Line/Orangeville St., upstream Hillsburgh	Upstream of Hillsburgh Village; Upstream of proposed outfall location; Characterization of headwaters; Original sampling location (benthos) through West Credit SW study	2008
15-17-01*	West Credit upstream County Rd 22 (downstream Hillsburgh)	Downstream of impoundment	2007-2008

Station ID	**Site name**	**Purpose of Site**	**Years sampled**
15-17-03	West Credit downstream Hwy 25, Hillsburgh	Downstream of proposed outfall location	2008
15-20-02*	Binkham Tributary upstream 15th Sideroad	Characterization of east branch	2007-2008
Note: ** Indicates site sampled using bio-geomorphic protocol in 2007, see Section 3.1 of the Stream Geomorphology Appendix for details.*			

2.5.2.1 Field Procedure

Samples were collected in July or August to correspond with the period during which benthic sampling has traditionally been conducted by CVC. Due to the life history patterns of some benthic macroinvertebrates (i.e., emergence period of many aquatic insects), there is typically a shift in the benthic community composition at certain times of the year (Reid et al. 1995). There is good evidence that samples from mid-summer are indicative of limiting conditions. That is, when sites are impaired, samples collected in mid-summer will show impairment to a greater degree than will samples collected in either spring or fall (Barton 1996).

With the exception of samples collected in 2007, a single composite travelling kick sample was collected at each station from all microhabitats in the sampled stream reach (e.g., riffle, run, pool) following the methodology proposed by Reynoldson et al. (1999). Samples were collected and washed in a D-framed net with 500-µm mesh. Each sample was preserved on site using 70% undenatured Ethanol.

Samples collected in 2007 followed a bio-geomorphic protocol. The collection protocol was similar to the kick sample described above, however each kicked sample was placed into a separate container for identification. Kicks were conducted at three sampling points across each of two pools and three riffles at each site. Geomorphological surveys were conducted at the same locations where benthos were collected. See Section 3.1 of the Stream Geomorphology Appendix for details regarding the Biogeomorphological methodology.

2.5.2.2 Laboratory Procedure

Samples were delivered to an independent taxonomist for identification. In the laboratory, samples were rinsed and filtered to remove excess preservative and silt. A minimum of 300 animals were randomly removed and identified in the Erin SSMP study area. Sorted individuals were identified to lowest practical levels using current taxonomic literature.

For the bio-geomorphic samples, all individuals were counted and identified in order to more accurately quantify the benthic community and to relate it to geomorphological features

2.5.2.3 Data Analyses

A number of summary metrics of benthic community composition were calculated including:

- Taxa Richness;
- Ephemeroptera, Plecoptera, Trichoptera (EPT) Richness;
- % EPT;
- Shannon index (H');
- Hilsenhoff's Biotic Index (HBI);
- % Oligochaeta;
- % Chironomidae; and
- % Isopoda

These indices are commonly used as general descriptors of benthic communities. CVC regularly uses these metrics in the benthic community analysis for its IWMP and other studies.

Diversity (Shannon's H') was calculated as follows:

$$H' = -\sum p_i \log_2 p_i$$

where p_i is the fraction of animals in a sample belonging to taxon i. Shannon H' values tend to decrease with increasing impairment.

The Hilsenhoff (1987) biotic index was calculated as follows:

$$HBI = \frac{\sum t_i n_i}{\sum n_i}$$

where t_i is the tolerance of taxon i to organic enrichment and n_i is the number of taxon i in the sample. Hilsenhoff's index was originally designed to reflect nutrient status with values ranging between 1 (pollution-sensitive taxa dominant) and 10 (pollution-tolerant taxa predominate). It is also used as a general screening-level index of impairment with low values indicating an unimpaired system and higher numbers indicating impairment. Taxa tolerance values used in this assessment were taken from Bode et al. (2002).

The number of taxa is normally high in waters with good water quality, as is the percentage of the community dominated by EPT taxa. Percent Oligochaeta, Chironomidae, and Isopoda (all relatively tolerant groups) tend to be higher in watercourses with degraded water quality. Definitions of each of the indices as well as the direction of the index response to disturbance are presented in **Table 2.5.2**.

Table 2.5.2 Definitions of Indices Used and Respective Directional Response to Disturbance

Index	Definition	Direction of Response to Disturbance
Taxa Richness	Number of taxa represented in the sample	Decrease
Number of EPT Taxa	Number of Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) taxa. These taxa are generally considered to be sensitive to pollution	Decrease
% EPT	Proportion of the sample represented by EPT taxa	Decrease
Diversity (H’)	A measure of diversity that takes into account number of taxa and evenness	Decrease
HBI	A measure of organic enrichment based on species tolerance values	Increase
% Oligochaeta	Proportion of the sample represented by oligochaete worms	Increase
% Chironomidae	Proportion of the sample represented by chironomid taxa (midge flies)	Increase
% Isopoda	Proportion of the sample represented by isopod taxa (sow bugs)	Increase

Table 2.5.3 lists the typical range expected for each index for an impaired, possibly impaired, and unimpaired site. An impaired site typically has low richness, few or no EPT taxa, low percent EPT and diversity, and a high HBI. Impaired sites tend to be dominated by oligochaete worms, chironomids, and isopods.

Index values were calculated for each station by year and then compared to the expected ranges in **Table 2.5.3**. For stations with multiple years of data, calculated indices were averaged across the years to yield an overall value. For stations sampled using the bio-geomorphic protocol, the counts from each individual kick sample were summed to provide the total counts for the site.

Because all individuals, rather than a subset, were counted and identified from the bio-geomorphic samples, richness indices (i.e., Taxa Richness and EPT Taxa) for these sites tended to be higher than samples where only a subset were counted and identified. Because of this phenomenon and for the potential to skew the average results for measures of richness, the bio-geomorphic sites were omitted from the calculated averages (for multiple years of data) for both Taxa and EPT Richness.

Table 2.5.3 Biological Criteria used to Establish Impact

Index	Impaired	Possibly Impaired	Unimpaired	Source
Taxa Richness	<15	15 to 20	>20	Barton (1996), Griffiths (1998)
Number of EPT Taxa	0	1 to 3	>3	Barton (1996)
% EPT	<5	5 to 10	>10	David et al. (1998)
Diversity (H')	<1	1 to 3	>3	Wilm and Dorris (1968)
HBI	>8	6 to 8	<6	Barton (1996)
% Oligochaeta	>30	10 to 30	<10	Griffiths (1998), David et al. (1998)
% Chironomidae	>40	10 to 40	<10	Griffiths (1998)
% Isopoda	>5	1 to 5	<1	Griffiths (1998)

2.5.3 Results and Discussion

Since 1999, close to 300 distinct taxa have been identified in the Erin SSMP study area through CVC's benthic sampling, with 18 major groups represented. The highest number of individuals came from the following taxonomic groups (in order of dominance): Ephemeroptera, Chironomidae, Coleoptera, and Trichoptera.

Metrics results by year and averaged results for stations with multiple years of data are presented in **Table 2.5.4**.

As indicated by the metrics presented in **Table 2.5.4**, stations within the Erin SSMP study area generally have a healthy benthic macroinvertebrate community. With only a few exceptions, the sampled stations showed high taxa and EPT taxa richness, high percent EPT, and low percent Oligochaeta and Isopoda. Shannon Diversity was mainly above 3 and HBI was usually below 6, both indications of a relatively unimpaired site. One metric that was almost consistently high was percent Chironomids (generally a tolerant group).

Annual sampling at the long-term station 501150003 (West Credit at 10th Line) has shown high Shannon Diversity and with one exception HBI has been below 6. Samples also had a high proportion of EPT taxa, including some particularly sensitive taxa such as the mayfly *Isonychia* and the caddisfly *Rhyacophila*. Stonefly taxa were present in most years of sampling, although numbers of stoneflies have been lower in recent years. The proportion of the sample comprised of chironomids was quite high in some years.

Table 2.5.4 Benthic Macroinvertebrate Index Values at Stations in the Erin SSMP Study Area, 1999-2008.

Station ID	Year	Methodology	Taxa Richness	EPT Taxa Richness	% EPT	% Oligochaeta	% Chironomidae	% Isopoda	Diversity (H^1)	HBI
501150003	1999	Standard	51	20	40%	3%	29%	0%	3.50	5.43
	2000	Standard	47	15	36%	2%	47%	0%	4.95	5.06
	2001	Standard	53	23	51%	10%	25%	0%	4.83	4.40
	2001	Standard	52	18	29%	8%	41%	0%	5.15	5.45
	2002	Standard	53	17	22%	5%	54%	0%	3.99	6.02
	2003	Standard	47	14	46%	5%	24%	0%	4.63	5.54
	2004	Standard	32	13	46%	10%	22%	0%	3.80	5.25
	2005	Standard	57	18	43%	6%	22%	0%	4.71	4.55
	2006	Standard	61	22	38%	5%	21%	0%	4.59	5.15
	Average (99-06)		**50**	**18**	**39%**	**6%**	**32%**	**0%**	**4.46**	**5.20**
501150005 and 15-13-01	1999	Standard	27	7	16%	2%	47%	0%	3.18	5.53
	2000	Standard	32	9	14%	8%	65%	0%	3.90	6.09
	2001	Standard	34	9	28%	3%	33%	0%	4.73	4.93
	2002	Standard	57	9	7%	13%	58%	0%	4.17	6.34
	2003	Standard	40	7	20%	13%	45%	0%	4.29	6.35
	2004	Standard	32	8	23%	6%	10%	0%	4.35	5.27
	2005	Standard	37	6	20%	3%	19%	0%	4.75	5.45
	2005	Standard	17	2	9%	7%	11%	0%	3.63	5.57
	2006	Standard	15	2	11%	11%	15%	0%	3.53	5.26
	2007	Biogeomorphic	55	9	36%	0%	40%	0%	3.79	4.78
	2008	Standard	29	8	21%	0%	49%	0%	4.01	3.88
	Average (99-08)		**32***	**7***	**18%**	**6%**	**36%**	**0%**	**4.03**	**5.40**
15-04-01	2007	Biogeomorphic	101	29	82%	0%	16%	0%	1.46	4.23
	2008	Standard	53	12	38%	3%	40%	0%	4.27	3.84
	Average (07-08)		**53***	**12***	**60%**	**1%**	**28%**	**0%**	**2.87**	**4.03**
15-08-02	**2008**	Standard	**49**	**20**	**42%**	**0%**	**14%**	**0%**	**3.98**	**4.28**
15-08-03	2007	Biogeomorphic	132	39	25%	0%	38%	0%	5.21	5.62
	2008	Standard	63	14	36%	0%	17%	0%	4.66	4.69
	Average (07-08)		**63***	**14***	**30%**	**0%**	**27%**	**0%**	**4.94**	**5.15**
15-08-05	**2008**	Standard	**44**	**11**	**31%**	**0%**	**19%**	**17%**	**3.69**	**4.38**
15-08-06	**2008**	Standard	**39**	**8**	**16%**	**3%**	**37%**	**0%**	**4.10**	**4.90**
15-16-01	**2008**	Standard	**46**	**10**	**14%**	**0%**	**15%**	**0%**	**2.58**	**6.98**
15-17-01	2007	Biogeomorphic	88	25	35%	0%	31%	0%	4.72	4.62
	2008	Standard	55	19	28%	0%	36%	0%	4.03	4.68
	Average (07-08)		**55***	**19***	**32%**	**0%**	**34%**	**0%**	**4.38**	**4.65**
15-17-03	**2008**	Standard	**48**	**18**	**63%**	**0%**	**14%**	**0%**	**3.11**	**5.36**
15-20-02	2007	Biogeomorphic	109	24	16%	2%	48%	0%	5.15	5.27
	2008	Standard	54	12	42%	5%	28%	0%	4.53	4.69
	Average (07-08)		**54***	**12***	**29%**	**3%**	**38%**	**0%**	**4.84**	**4.98**

Note:
Bio-geomorphic site data were omitted from the calculated averages (for multiple years of data) for Taxa Richness and EPT Richness.
Red cells indicate impaired; Yellow cells indicate possibly impaired; Green cells indicate unimpaired.