West Credit Subwatershed Study

Characterization Report

Coordinated by
Conservation for:

Township of Erin
Town of Caledon
Village of Erin
Region of Peel

Credit Valley

County of Wellington

January 1998

Cover Credit: Mary N. Traversy

September, 1996

Erin Public School

Age seven

IMPORTANT

NOTE TO THE READER:

This digital version of the West Credit Subwatershed Study includes a simplified recommended plan (figure 6.2.1). The original version of the recommended plan is available for viewing at Credit Valley Conservation, or the offices of the local municipalities who sponsored the plan:

Town of Erin
Town of Caledon
Region of Peel
County of Wellington

The original could not be included in the report due to difficulties associated with replicating the map at a small scale.

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INTRODUCTION

This report ends Phase I (subwatershed characterization) of the West Credit Subwatershed Study and presents the Study's findings. The West Credit Subwatershed Study is being co-ordinated by Credit Valley Conservation (CVC) for the Village of Erin, the Township of Erin, the Town of Caledon and the Region of Peel. It was initiated to address concerns about the health of the subwatershed's water and related environmental resources. Subsequent phases of the subwatershed planning process need not be carried out at this point in time, although components of Phases III (Implementation) and IV (Monitoring) are addressed in this report.

Subwatershed plans are based on natural drainage boundaries as opposed to political boundaries. The West Credit Subwatershed (also known as Subwatershed 15) is the land drained by the West Credit River. The subwatershed is 105 kilometres square in area and runs from north-west of Hillsburgh to the Forks of the Credit. It includes many wetlands and dozens of little feeder streams that contribute water to the West Credit River. When we consider the water and related environmental resources of the West Credit Subwatershed, we look at the whole natural system including the soils, climate, rivers and streams, groundwater, surface waters, terrestrial and aquatic habitats and wildlife.

The West Credit Subwatershed Plan is an Environmental Resource Management Plan. The natural systems in the subwatershed are in a relatively healthy state and no large major land use changes are expected, so the thrust of the subwatershed plan is to preserve the high quality systems and features that exist. It was initially felt that only a Phase I level of analysis was needed for the West Credit. As the study progressed, however, it became clear that elements of Phases III and IV would be appropriate. The purpose of the West Credit Subwatershed Study is to:

- establish locations, extent, significance and sensitivities of existing natural systems;
- prepare a natural systems plan noting important linkages and processes;
- set subwatershed resource management objectives; and
- identify opportunities for protection, enhancement, rehabilitation and development.

Conclusions

Since this study was only meant to cover Phase I of the subwatershed planning process, additional conclusions should be made once Phase II is completed. As there are no expected major land use changes in the subwatershed, there are no plans to complete Phase II at this time.

1) The Vision and Goals

> **VISION**
>
> The terrestrial and aquatic systems in the West Credit Subwatershed will be protected, restored and enhanced through the conservation and management of important features.
>
> The goals are to provide a framework to achieve:
>
> - a clean healthy environment with a balance of areas where people can work, live and play;
> - areas of natural systems or process including viable habitat of wildlife and fish;
> - opportunities for rural, urban and resource use that are compatible within a clean healthy environment;
> - areas where recreation will be available including access to public natural areas for passive uses and nature interpretation;
> - active areas for swimming and fishing; and
> - a ground water resource that is managed to ensure that it is clean and available for use.

2) The overall health of the West Credit Subwatershed has been defined as good, despite human activities. The broad-scale processes of surface hydrology, groundwater infiltration and discharge are still functional although in some cases impaired or modified by loss of upland forest cover. There are problems in some reaches with water quality impairment due to high coliform counts although the evidence suggests that this problem can be addressed through improved cattle fencing and spot checks of urban septic bed or septic tank leaks.

In Southern Ontario, the West Credit Subwatershed is somewhat unusual in having an almost contiguous stable riparian zone along its banks from mouth to headwaters. However, some headwater sections have been impacted upon significantly by agriculture resulting in degradation to aquatic habitat. These riparian zones are made up of two major vegetative forms: forests and wetland/beaver meadows. Other riparian forms include manicured lawns, residential properties and farm fields. Fortunately for the health of the stream and its valley, the forest and wetland zones are extensive with only small breaks in continuity. These breaks, caused by the three urban areas and several dams, have altered the movement and distribution of wildlife species and of fish communities. Wildlife species have been affected by the reduction of critical forest patch sizes, loss of volume and fragmentation, fish communities have been affected by changes in water temperatures, modifications in channel structure, impacts on water quality and in construction of dams.

3) Not all the recharge to the subwatershed discharges to the West Credit River. The average annual precipitation within the subwatershed is 850 mm per year, and average infiltration within the subwatershed is estimated to be 338 mm per year. The average infiltration contributing to baseflow is estimated to be 294 mm per year. The difference is approximately 13%, meaning that this water would discharge outside the West Credit Subwatershed to the main Credit River, within Subwatershed 18. Based on permitted water taking (actual water taking may be less than the permitted water taking) approximately 79 mm per year could be utilized for water consumption. Much of this water is discharged back to the shallow groundwater or to the surface water and is therefore not “lost” from the system.

4) Based on analysis of data from the stream gauge upstream of the Village of Erin, the peak flow rate associated with the two year storm is 3.9 m^3/s and for the 100 year storm is 9.2 m^3/s. Increased urbanization in the West Credit Subwatershed would increase the level of flooding particularly in the identified flood damage centres of Hillsburgh, Village of Erin and Belfountain.

5) The main branch of the West Credit River is perennial, which means it flows all year. Many of the smaller first order streams that feed into the main branch only convey water for a few weeks of the year. The main branch can be characterized as having little erosion and stable banks.

6) Two dams located on the West Credit at Church Street and Charles Street in the Village of Erin have been found to be structurally inadequate by current standards.

7) Approximately 15 % of the West Credit Subwatershed is currently covered with natural forests or tree plantations. It is important to protect those forested areas in the subwatershed that are of high value. Approximately 92% of the forested land in the subwatershed is either a high or medium priority for protection based on value (location, size, connectivity and condition, enhancing recharge to groundwater).

8) Wetlands currently make up about 14% of the subwatershed. They play an important role in controlling floods, removing contaminants and nutrients from overland and stream flows, and prevent erosion and facilitate recharge to groundwater in certain geologic settings.

9) The West Credit's riparian zone is unusual for Southern Ontario because of its contiguous length and width. The dominance of forests or wetlands along the banks ensures that bank erosion is held in check. In addition these wide riparian zones act as natural sponges, retaining nutrients that come from adjacent table lands. These zones also moderate flood flows by retaining water and releasing it gradually into the stream. This moderates the severity of floods including reducing impacts on aquatic habitats.

10) Notably, the West Credit contains wild self sustaining populations of brook trout. While many rivers in Southern Ontario have undergone drastic changes, much of the West Credit system and the coldwater fishery it supports have remained relatively unchanged. The presence of self sustaining populations of brook trout is an indicator of a healthy complex ecosystem with high quality ground and surface waters.

11) Limited sampling of aquatic invertebrates (water bugs) on the main branch of the West Credit and analysis of the types, varieties and numbers collected suggest that water quality is generally quite good.

12) There is evidence that the West Credit is polluted during the swimming season with *E. coli* which indicate high levels of fecal source pollution.

13) Recent data shows average stream temperatures of 19.5^{o}C in the main branch of the West Credit, which is above the target of 18^{o}C for healthy coldwater communities. Temperature impacts are attributed to ponds, groundwater impacts, land use impacts and loss of riparian cover.

14) The chloride concentrations in the subwatershed are 15-40 mg/L which is well below the provincial water quality objectives. However chloride concentrations have doubled over the past two decades.

15) Based on concentrations of total phosphorus and invertebrate species present, the West Credit Subwatershed can be classified as having good water quality. However some ponds in the lower West Credit appear to be well nourished based upon the presence of algae in the summer months.

16) Overall good water quality is maintained because of the extensive riparian vegetation and large amount of baseflow contributed by groundwater.

Recommendations

The following recommendations are made to support the vision and goal statements established for the West Credit Subwatershed.

1) Establish an Implementation Committee to follow up on the implementation in the following areas:

- Land use Planning and Policy
- Stewardship and Education
- Rehabilitation and Retrofitting
- Monitoring
- Research and Development

The composition of the committee should include representation from the municipalities, CVC, government agencies, special interest groups and members of the public.

2) The additional work and measures outlined in Chapters 3 and 5 should be implemented. A working group or subcommittee of the Implementation Committee with the necessary expertise, should be initiated in order to assess financial as well as technical needs and priorities over the long and short term. The following classification system of features, based on significant function, offers protection, enhancement and restoration opportunities for the West Credit Subwatershed:

TERRESTRIAL AND RIPARIAN SYSTEMS

PROTECTION AREA 1 lands provide core natural areas and contribute to biodiversity and environmental integrity within the subwatershed. They also have a significant hydrologic and hydrogeologic function. Protection Area 1 lands are important to maintain surface water and groundwater quality and quantities within the subwatershed. These areas also perform important ecological processes and protect biological diversity and life supporting systems that would be lost or degraded if such areas were permanently disturbed in any way. These areas must be protected from land use impacts. Protection Area 1 lands include all wetlands, forested areas in or adjacent to wetlands, connecting corridors, areas with interior habitat, woodlots in Areas of Natural or Scientific Interest and in Environmentally Sensitive Areas, and forested land on recharge areas.

PROTECTION AREA 2 lands provide important secondary benefits in terms of wildlife habitat linkages to the Protection Area 1 lands, and act as seed sources or nuclei from which revegetation efforts can be built upon. Protection Area 2 lands should be protected through stewardship programs, particularly where they are adjacent to streamland and valley corridor Level 1 Areas. However if land use change is proposed, these areas should be protected or replaced with equivalent features depending on the results of more detailed evaluation. These areas provide important ecological functions to the subwatershed and allow for the creation of new ecological features such as vegetative buffers, wetlands and linkages between vegetated areas and watercourses. If land use changes are proposed, subject to detailed studies in the form of an Environmental Impact Statement, some level of development may be permitted to alter the size and physical form of Protection Area 2 lands, provided that ecological functions including hydrologic and hydrogeologic functions are protected and maintained. Protection Area 2 lands include wooded areas with very little interior habitat and no corridor connectivity, and all unforested land with a high potential for recharge.

PROTECTION AREA 3 lands represent priorities for revegetation in a stewardship or rehabilitation context. Protection Area 3 lands that are targeted for revegetation should be replanted with native species appropriate for the area and conditions. Degraded streams should be enhanced to buffer the effects of potential land use change. Protection Area 3 lands include small unconnected pockets of woodlot with no interior habitat.

AQUATIC SYSTEM

Upon considering the information provided by the other technical components in the study, and for the purposes of implementation, the riparian and aquatic system was prioritized into three categories based on the following criteria where information was available:

LEVEL 1 includes areas of coldwater fish habitat, probable coldwater fish habitat and wetlands adjacent to watercourses. Level 1 Areas provide critical life support functions, such as spawning areas, discharge areas, special status habitat, nursery habitat, and the areas just upstream or downstream of such habitats. Flood plains adjacent to watercourses supporting coldwater fisheries are also assigned Level 1 protection. Furthermore areas with solid riparian cover that provide shade to the river, and also provide corridors for terrestrial animals will be assigned Level 1 protection. These areas must be protected from land use impacts.

LEVEL 2 includes all potential coldwater fish habitat and on line ponds. Level 2 Areas provide habitat for various life stages and functions. Some of these areas could be upgraded to Level 1 with rehabilitation and restoration. Maintaining the stability of these reaches is important in maintaining critical habitats in the long term.

LEVEL 3 Areas include areas that provide fish passage, water passage and runoff conveyance. Intermittent streams are included in this classification. Level 3 Areas help maintain water quality and have limited food production and provide little to no critical habitat for life supporting functions.

UNCLASSIFIED These areas have not yet been studied. If there are proposed land use changes adjacent or in these areas, further research would have to be conducted on fisheries and terrestrial habitat unless they are assumed or treated as Level 1.

All areas listed above have been shown on Figure 6.2.1. Various ways of protecting, enhancing and rehabilitating these areas have been discussed in Chapter 5.

An environmental monitoring program should be carried out that recognizes the principles of Adaptive Environmental Assessment Management. The major elements of this concept recognize the uncertainty when dealing with the natural environment and include the need to explicitly recognize uncertainty, be explicit in prediction techniques and most importantly learn from the management approach utilized. This concept supports the need to monitor appropriately, carry out evaluations and make changes accordingly. Monitoring techniques must recognize the importance of indicator and surrogates of environmental health as well as the need to utilize simple, repeatable procedures that can be carried out by a variety of persons (students, interest groups, residents, etc.) when appropriate.

The need to initiate Phase II (impact analysis) of the subwatershed planning process should be assessed if significant land use or land management changes that are proposed that interfere with subwatershed functions. Depending on the magnitude of the change, assessment could occur on a subcatchment basis. It should also be noted that not all tributaries have been assessed within this document due to lack of existing information. As a result, information must first be collected to characterize these tributaries before any impact analysis is carried out. In the event that development is proposed a review procedure should be jointly developed by the reviewer agencies.

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Appreciation is extended to members of the steering committee (*) and municipal councils for their support of the study. We also thank those residents of the subwatershed who provided input during public meetings and throughout the study.

1.0 INTRODUCTION

This report ends Phase I of the West Credit Subwatershed Study and presents the Study's findings. The West Credit Subwatershed Study was co-ordinated by Credit Valley Conservation (CVC) in concert with the Village of Erin, the Township of Erin, the Town of Caledon, County of Wellington and the Region of Peel. It was initiated to address concerns about the health of the subwatershed's water and related environmental resources.

Subwatershed plans are being carried out in many of the Credit River's twenty subwatersheds (see Figure 1.0.1). The development of the 1990 Credit River Water Management Strategy by CVC in partnership with member municipalities set the stage for the initiation of these subwatershed studies. The Water Management Strategy looked at existing environmental conditions across the entire Credit River Watershed and made predictions for the future based on existing management approaches. The study found that continued "conventional" land use practices and resource use would dramatically change the environment within the Credit River Watershed: peak flows of rivers would rise by up to 200%, baseflow to rivers and groundwater would be significantly reduced, and water quality would be degraded. These outcomes, in turn, would have damaging effects on wildlife habitats, plants and animals, would cause increased erosion and sedimentation, and would impair human uses of water resources. Because of these impacts, in order to preserve a healthy watershed, the Credit River Water Management Strategy recommended the following:

- improved land use planning and stormwater management practices;
- an emphasis on approaches that prevent pollution from occurring; and
- enhancing and/or restoring environmental features.

Subwatershed studies are the logical next step after the development of the Water Management Strategy for the Credit.

1.1 What is a Subwatershed Plan?

Subwatershed plans are based on natural drainage boundaries as opposed to political boundaries. The West Credit Subwatershed (also known as Subwatershed 15) is the land drained by the West Credit River. The subwatershed is 105 square kilometres in area and runs from north-west of Hillsburgh to the Forks of the Credit. It includes many wetlands and dozens of little feeder streams that contribute water to the West Credit River. When we consider the water and related environmental resources of the West Credit Subwatershed, we look at the whole natural system including the soils, climate, rivers and streams, groundwater, surface waters, terrestrial and aquatic habitats and wildlife. The subwatershed study area is shown in Figure 1.0.2.

Figure 1.0.1: Status of Subwatershed Studies in the Credit River Watershed

Sources: Credit Valley Conservation, 1997; Ontario Ministry of Natural Resources, 1982. Material prepared by Credit Valley Conservation.

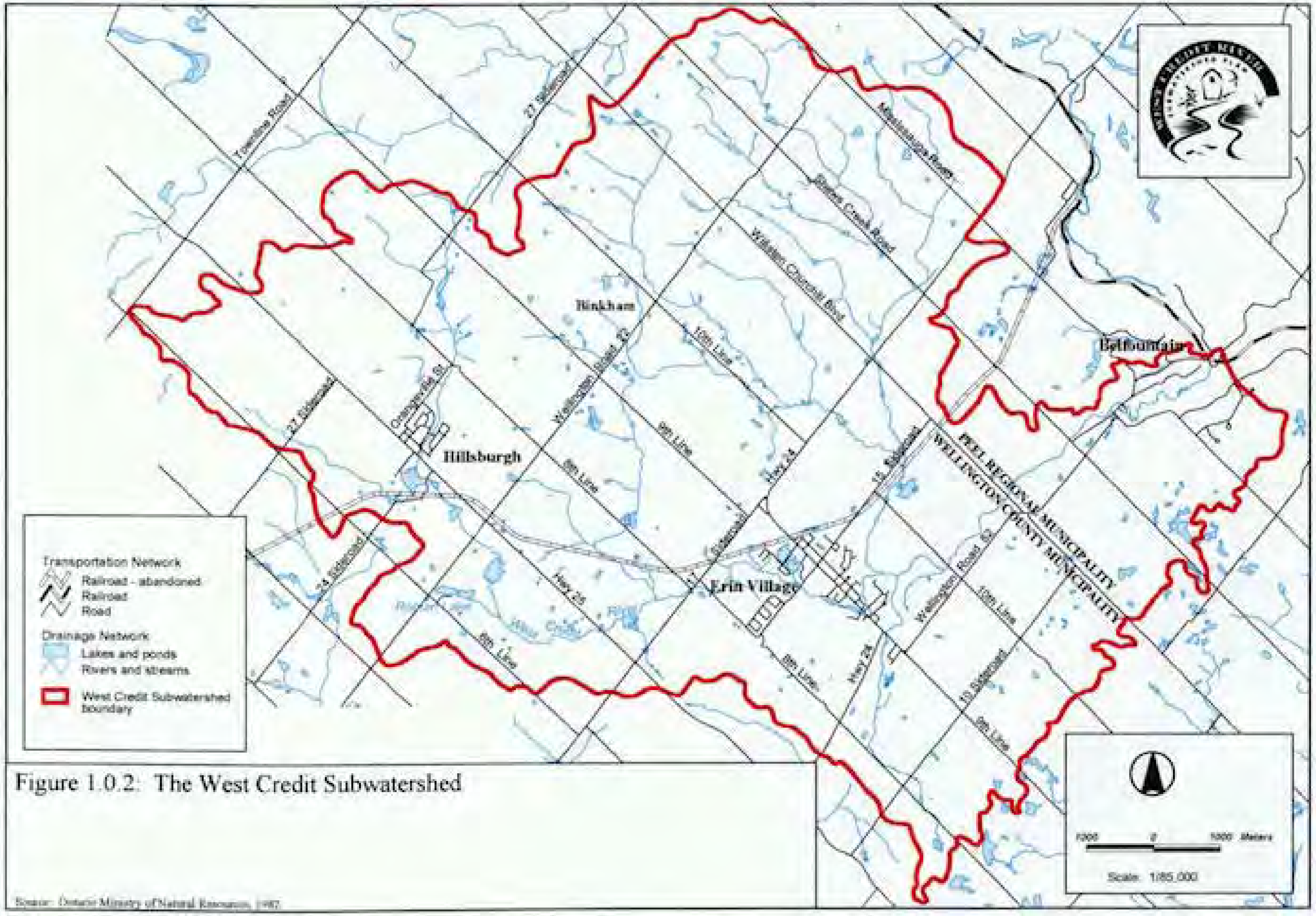

Figure 1.0.2: The West Credit Subwatershed

Source: Ontario Ministry of Natural Resources, 1987

A subwatershed plan is a management strategy for the protection, enhancement and rehabilitation of natural features such as woodlots, wetlands, streams and wildlife. As outlined in Figure 1.0.3, there are four major phases in a subwatershed plan. Phase I, the phase which is now complete, is focused on collecting information and data so that the subwatershed can be characterized accurately. Phase I typically involves establishing the form, function and linkages of the water and related environmental resources. This is done by examining environmental features and functions — soils, climate, groundwater, surface waters, river systems, habitats and wildlife — and how they interrelate.

In Phase II of a subwatershed study, referred to as the prediction component, impacts on natural features and functions are assessed based on future land use changes. In Phase III of the subwatershed plan, an implementation strategy is developed that includes priorities and roles. In Phase IV, a monitoring program is developed so that changes in the natural environment can be measured over time so that those responsible for implementation can make changes in a timely fashion.

There are at least four types of subwatershed plans. These vary with respect to emphasis, scope and issues addressed and include the following types:

<u>Environmental Resource Management</u> These subwatershed plans emphasize environmental protection and management.

<u>Land Use Changes and Environmental Management</u> These subwatershed plans are developed in urbanizing areas and are carried out to determine *where* land use changes will occur or *how* land use changes will occur in areas that have already been designated for change but not yet developed.

<u>Land Use Management</u> These subwatershed plans are developed in areas where there is no expected major change in land use, but where changes in land use management are expected.

<u>Redevelopment/Restoration</u> These are developed in areas which are already largely developed. The emphasis is on improving ecosystem health including habitat restoration.

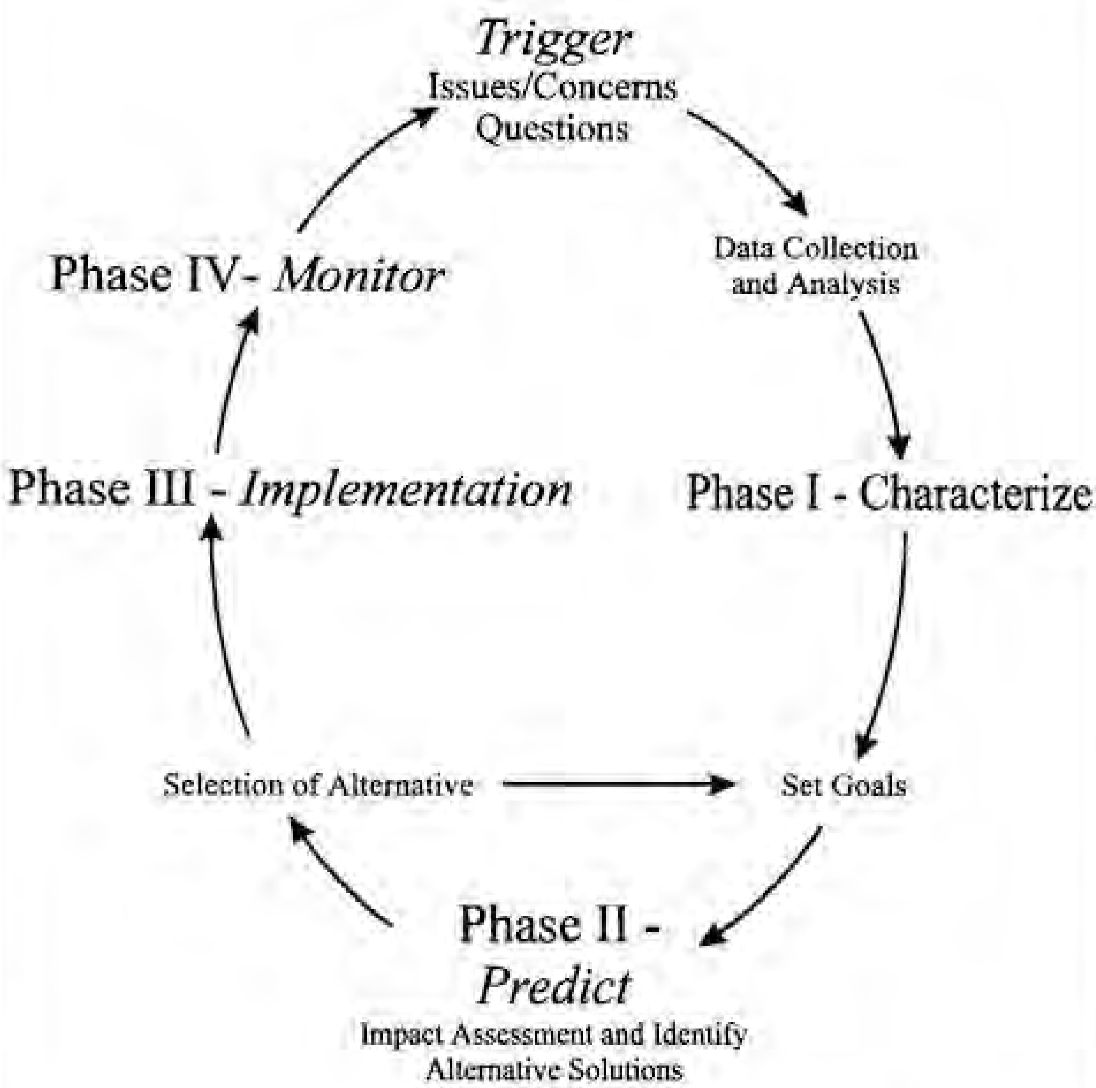

Figure 1.0.3: The Subwatershed Planning Process

The West Credit Subwatershed Plan is an Environmental Resource Management Plan. The natural systems in the subwatershed are in a relatively healthy state and no large major land use changes are expected, so the thrust of the subwatershed plan is to preserve the high quality systems and features that exist. It was initially felt that only a Phase I level of analysis was needed for the West Credit. As the study progressed, however, it became clear that elements of Phases III and IV would be appropriate. The purpose of the West Credit Subwatershed Study is to:

- establish locations, extent, significance and sensitivities of existing natural systems;
- prepare a natural systems plan noting important linkages and processes;
- set subwatershed resource management objectives; and
- identify opportunities for protection, enhancement, rehabilitation and development.

Please see Appendix K for photographs of the West Credit Subwatershed.

2.0 BACKGROUND

2.1 History of the Area

Settlement of the West Credit Subwatershed by Europeans began in the early 1800s. Early settlers, many of them United Empire Loyalists bought or were granted land by the British government. The land was heavily-forested then, with towering pines having trunks more than a metre in diameter. The Crown retained the rights to white pines in the area for use as masts in sailing ships. In the early days, the Credit River was recognized as a salmon river "par excellence" with Atlantic salmon journeying upstream from Lake Ontario likely as far as the Cataract, and perhaps up to Belfountain, although records do not confirm this. Due to over fishing, the Atlantic salmon subsequently disappeared and have been recently re-introduced in the lower Credit River. Much of the upper river also supported populations of brook trout. Although populations of wild, self-sustaining brook trout are still found in the West Credit Subwatershed, the construction of dams and on-line ponds and other factors have led to a reduction in range over the last 200 years.

Erin Township's early days focused on the clearing of land for farming and the construction of houses and barns. Water-powered mills were necessary for sawing timber, milling grain and weaving wool, and the first local sawmill was reportedly built in 1826 by the Trout family. Emigrants from Scotland, the McMillan family, arrived in 1832 at the site of what is now the Village of Erin and began to clear land. The following year they built the first mill and dam (where the Charles Street dam is today) and in 1834 they erected the first house.

In the Village of Erin, as elsewhere, mills anchored growth and the settlement soon expanded to include more houses and two more mills that were built in 1838 and 1840. The first store was opened in 1836 by a Miss Caldwell, and William Cornock soon followed with the village's first dry goods store, a distillery and a post office. Churches, schools, inns, hardware stores and other amenities soon followed. Originally called McMillan's Mill after its founding family, in 1851 the village, population 300, was re-named Erin. The village was legally incorporated in 1879 and the first meeting of council took place in 1881.

Stanley Park was named to commemorate the death by drowning of young Stanley Long, son of the park's second owner. In the 1890s, Peavoy's Boathouse and Wharf were built in the park and it became a popular destination for visitors from Toronto, Brampton and Fergus who arrived on the Credit Valley Railway. Use dwindled until the 1950s when a trailer park development was set up.

2.2 Physical Description

The West Credit Subwatershed drains significant portions of the Township of Erin and the Town of Caledon and flows through Hillsburgh, the Village of Erin and Belfountain. In terms of land use, the subwatershed is dominated by agriculture and natural areas. About 68% of the subwatershed is used for agriculture, about 15% is woodlands, and 14% of the area is made up of wetlands. Only 3% of the subwatershed is classified as urban.

The West Credit 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 (provide baseflow) wetlands and streams. The flow from the West Credit 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 fish such as brook trout. Observations show brook trout populations are greater in the West Credit compared to the Credit River downstream of the forks, which may indicate cooler water and more favourable habitat.

The West Credit has been identified as having some of the best quality fish habitat in the Credit River system. Brook trout, brown trout, sunfish, bass, perch and catfish can be found in the subwatershed's 270 ponds and dozens of streams. Because so much of the land is in a natural state, the subwatershed sustains a large variety of plant and animal communities and a number of sensitive species.

There are many important wetlands in the West Credit. These sustain terrestrial and aquatic communities containing invertebrates, fish, reptiles, amphibians, birds and mammals. 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 flood plain of the West Credit 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.

The West Credit Subwatershed has a number of important outdoor recreational areas including a portion of the Elora Cataract Trail and the Belfountain Conservation Area which receives about 17 500 visitors a year, many of them from outside the Credit River Watershed.

2.3 Vision and Key Issues

With the assistance of West Credit Subwatershed residents, the study team was able to establish a vision for the subwatershed.

2.3.1 Vision and Goals

VISION

The terrestrial and aquatic systems in the West Credit Subwatershed will be protected, restored and enhanced through the conservation and management of important features.

The goals are to provide a framework to achieve:

- a clean healthy environment with a balance of areas where people can work, live and play;
- areas of natural systems or process including viable habitat of wildlife and fish;
- opportunities for rural, urban and resource use that are compatible within a clean healthy environment;
- areas where recreation will be available including access to public natural areas for passive uses and nature interpretation;
- active areas for swimming and fishing; and
- a ground water resource that is managed to ensure that it is clean and available for use.

2.3.2 Key Issues

During Phase I of the West Credit Subwatershed Study, a number of meetings were held with municipal councillors, stakeholders and members of the public. In these meetings and through a questionnaire that was distributed, residents and professionals identified issues relating to the environmental resources of the subwatershed. These concerns helped guide the Study process. In terms of frequency of response, the key environmental issues identified were:

Groundwater

- The need for secure groundwater supplies from a water quantity and quality standpoint, particularly in urban centres.

Surface Waters

- The impacts of ponds on the stream system.
- The impact of rural and urban land uses on water quality particularly bacteria, nutrients and chlorides.
- The preservation of base flows for various uses such as recreation, human use and fisheries.
- Erosion of soil including streambank erosion.
- Development of appropriate alternatives for removal/repair of the ageing dams located along the main branch within the Village of Erin.

Aquatic Habitats and Wildlife

- The protection and enhancement of coldwater fishery resources.
- The impacts of accidental releases from fish farms in the subwatershed.

Terrestrial Habitats and Wildlife

- The protection and enhancement of terrestrial resources including woodlands, wetlands and stream corridors.

Protection of Features

- The identification of terrestrial features and development of a protection strategy.
- Protection of the visual amenities (viewscapes) provided by the unique rolling topography.
- Protection of the Niagara Escarpment.

Environmental Education

- The need to provide environmental education to ensure areas are protected for future use.

Other

- The preservation and enhancement of recreation, particularly swimming in the Belfountain Conservation Area and fishing along the West Credit.
- The continued use of aggregate resources, its impact on the environment and the preferred management approach needed.
- Impacts and implications of a municipally run sewage disposal system.
- The concern that was most frequently cited was the need to protect groundwater supplies in terms of both quality and quantity.

2.4 Questions Raised By the Public

The issues raised by the public and professionals lead to important questions that needed to be answered in the subwatershed plan study. These include:

1. *What is the overall groundwater/surface water process and how do activities such as aggregate extraction or water taking affect water balance?*

2. *How susceptible are groundwater supplies to water quality impacts and what protection is required?*

3. *What are the important environmental features and how can we protect them? (e.g. discharge and recharge areas, terrestrial habitats, aquatic habitats)*

4. *How is subwatershed health (particularly flows, erosion and habitats) linked to terrestrial resources (woodlands, wetlands and riparian vegetation) and what protection is needed?*

5. *How healthy is the fishery and how can we maintain or improve it?*

6. *What impact do existing ponds have on water quality processes in the streams?*

7. *What is the most effective approach to control coliform counts to an acceptable level and is it feasible?*

8. *What is the long term potential impact of aggregate extraction on flow regimes and water quality?*

See section 6.3 for responses to these questions.

3.0 STUDY COMPONENTS

Water is a vitally important resource that ties us to the natural world. Every plant and animal on earth requires water to sustain its life. The movement of water (past and present) creates the features we observe in our subwatersheds. Where water comes from and where and how it moves over and through the land dictate the form and function of local terrestrial systems, especially in valley bottoms and in streams. This movement of water creates the streams, wetlands, forests, water tables and environmental features that sustain us ecologically and spiritually. The movement of water dictates whether a stream is cold or warm, how much water it carries, and its productivity. It also provides the groundwater that individuals, communities and businesses draw upon for home, farm and industrial use.

The character, form and nature of rivers and streams are a function of the geology and climate of any particular subwatershed. Geology describes the overburden of sand, gravel, rock, clay and silt and the resulting topography left by the glaciers and the parent bedrock. Climate provides the water and the erosive forces which not only shape the weathered rock into soil but also provide the streams with water flows of varying volumes over the course of the year. The topography of an area in conjunction with its soils modify the local climate and encourages the growth of particular vegetation and plant communities. These forces and processes operating on streams within the subwatershed dictate how, when and where water volumes (i.e. discharge) enter the streams. The characteristics of a subwatershed, its topography, valley slopes, geology and physiography ultimately shape the form of river channels found at any specific location within the subwatershed. All these characteristics in turn interactively dictate what types of substrates are found on stream bottoms and the amounts of habitat and cover for fish.

At any site within a stream system, the stream's form and its biological life are intrinsically and directly dependent upon the stability, productivity and health of the lands draining into them from the subwatershed. An eminent river ecologist, Dr. H.B.N. Hynes eloquently stated in 1975 that, "A stream is only as healthy as the valley through which it flows." Put another way, rivers and streams and the life supported by them are the ultimate integrators of the physical, chemical, and biological processes that occur throughout the subwatershed and within any particular segment of valley within the subwatershed.

In order to understand the subwatershed and answer the questions posed by residents and experts, studies were carried out in the following technical areas: physiography and hydrogeology, climate and hydrology, stream morphology, terrestrial systems, riparian and aquatic systems, fisheries and water quality. Information is also included on recreation and conservation lands, mapping and data management, and public consultation. The following sections of this chapter contain summaries of this work including major findings; more detail can be found in the Appendices to this report.

3.1 Physiography and Hydrogeology

3.1.1 Physiography

As illustrated in Figure 3. 1.1 the West Credit Subwatershed contains six physiographic regions: spillway, till moraine, kame moraine, till plain, drumlin field and escarpment.

The Hillsburgh Sandhills are located along the western boundary of the subwatershed. They are part of the Orangeville Moraine, a hummocky, hilly area consisting primarily of fine sand. The area west and northwest of Hillsburgh is the highest area in the subwatershed: local relief of up to 30 metres is common. The surficial soils in the Hillsburgh Moraine are composed of ice-contact sand and gravel with some till present. This unit provides significant opportunity for groundwater recharge due to the highly permeable nature of its soils, the high relief, and the hummocky terrain that minimizes runoff. The West Credit River cuts through the area creating a relatively steep-walled valley which provides considerable opportunity for groundwater to discharge to this portion of the river. The surficial sands and gravels in the Hillsburgh Sandhills are relatively thick (up to 45 metres thick except in valley areas) but do not appear to extend to bedrock. A lower-permeability till unit appears to be present above bedrock throughout this area.

The Guelph Drumlin Field, located in the central and eastern portion of the subwatershed, is composed of several geologic units. The area is characterised by the presence of drumlins which are small, oblong-shaped glacial hills formed by the glaciers of the last ice age. This area is also characterized by a gently sloping topography in a southeasterly direction towards the West Credit and Main Credit Rivers. The soils in the Guelph Drumlin Field are mostly composed of a sandy silt till (Port Stanley till). This typically has a moderately low infiltration rate. The sandy tills appear to extend to depth throughout the area, are generally greater than 30 metres in depth, and do not appear to have any extensive sand and gravel units at depth. The valley areas within the Guelph Drumlin Field contain glacio-fluvial outwash sands and gravels that appear to extend to bedrock at many locations. The overburden thins considerably in some areas to 5 to 15 metres; this is where baseflow is lost within a number of tributaries.

A small portion of the Horseshoe Moraine (mapped as the Paris Moraine) is found in the southeast portion of the West Credit Subwatershed. It is characterized by very hummocky terrain containing mostly till soils; its numerous depressions are often filled with water. The soils in the Paris Moraine are mostly composed of a sandy silt till (Wentworth till). This typically has a moderately low infiltration rate but because of the hummocky nature of the ground surface, may result in greater recharge as water is trapped in its depressions and continually infiltrates into the water table.

Extensive glacio-fluvial outwash sands are present between the Port Stanley till unit of the Guelph Drumlin Field and the Wentworth till unit of the Paris Moraine. The lower portion of the West Credit flows through this unit. Numerous gravel pits are also located here. The physiographic composition of the area makes it ideal for aggregate extraction (see figure 3.1.1).

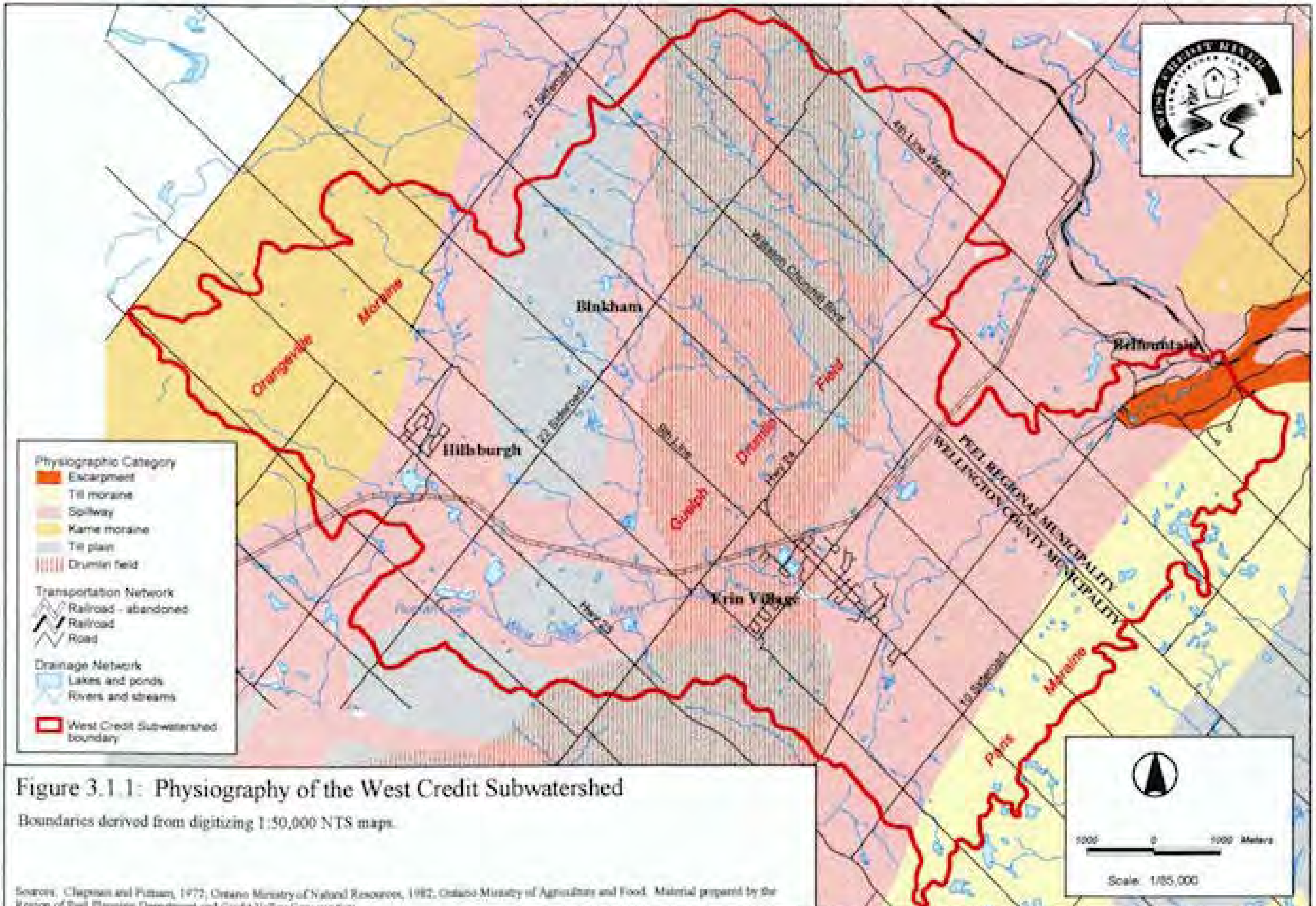

Figure 3.1.1: Physiography of the West Credit Subwatershed

Boundaries derived from digitizing 1:50,000 NTS maps.

Sources: Chapman and Putnam, 1973; Ontario Ministry of Natural Resources, 1982; Ontario Ministry of Agriculture and Food. Material prepared by the Region of Peel Planning Department and Credit Valley Conservation.

3.1.2 Hydrogeology

Hydrogeology is the study of the movement of water below the ground and the interaction of this groundwater with surface water. Groundwater often plays an important role in the functioning of an ecosystem as the movement of groundwater links areas of the subwatershed through the hydrologic cycle. To determine the role of groundwater in a subwatershed, it is necessary to understand the relationship between areas where precipitation infiltrates into the ground — "recharging" the groundwater — and where it "discharges" back to surface water. This is important also in determining the impact that land use changes will have on groundwater function.

Figure 3.1.2 shows a generalized hydrologic cycle. Rainwater and melting snow infiltrate into the ground and move through it until the water table is reached. Areas where groundwater flows away downwards from the water table are known as recharge areas. These are generally found in areas of high relief with more permeable sand and gravel soils. Areas where groundwater moves upwards toward the water table are known as discharge areas. These are typically found in areas of low relief such as valley bottoms. The groundwater that discharges into a stream is said to maintain its "baseflow".

Depending on the geographic setting, wetlands can be part of discharge or recharge areas. In areas of higher relief, wetlands will typically recharge groundwater; in areas of lower relief such as the bottom of a stream valley, they are typically discharge zones.

Understanding where groundwater moves is key to understanding ecosystem function. Groundwater recharge may be local or regional in nature. Understanding the system requires knowing where groundwater moves and at what rate. Groundwater movement is typically much slower than surface water movement and is measured in terms of centimetres to tens of metres a year, depending on the permeability of the material through which it moves.
In Phase I of the West Credit Subwatershed Study, a number of sources of information were used to characterize the hydrogeology of the subwatershed. These included reviewing existing data and reports, collecting and analysing baseflow data to determine major discharge areas, and analysing water well records to determine major aquifers and aquitards. A conceptual hydrogeologic model was developed to assess the sensitivity of groundwater to impacts from land use changes. Major discharge and recharge areas in the West Credit Subwatershed are shown on Figure 3.1.3.

Some areas within the West Credit Subwatershed show significant gains in flow, while some areas show a reduction in flow. Contribution to baseflow is highly variable throughout the subwatershed as a result of variable recharge rates (due to variable surficial geologic conditions), location in the groundwater flow system, and topographic relief. Low flow data collected and used as part of a general water budget for this study indicted that the West Credit River maintains a high volume of baseflow relative to most other watercourses in the

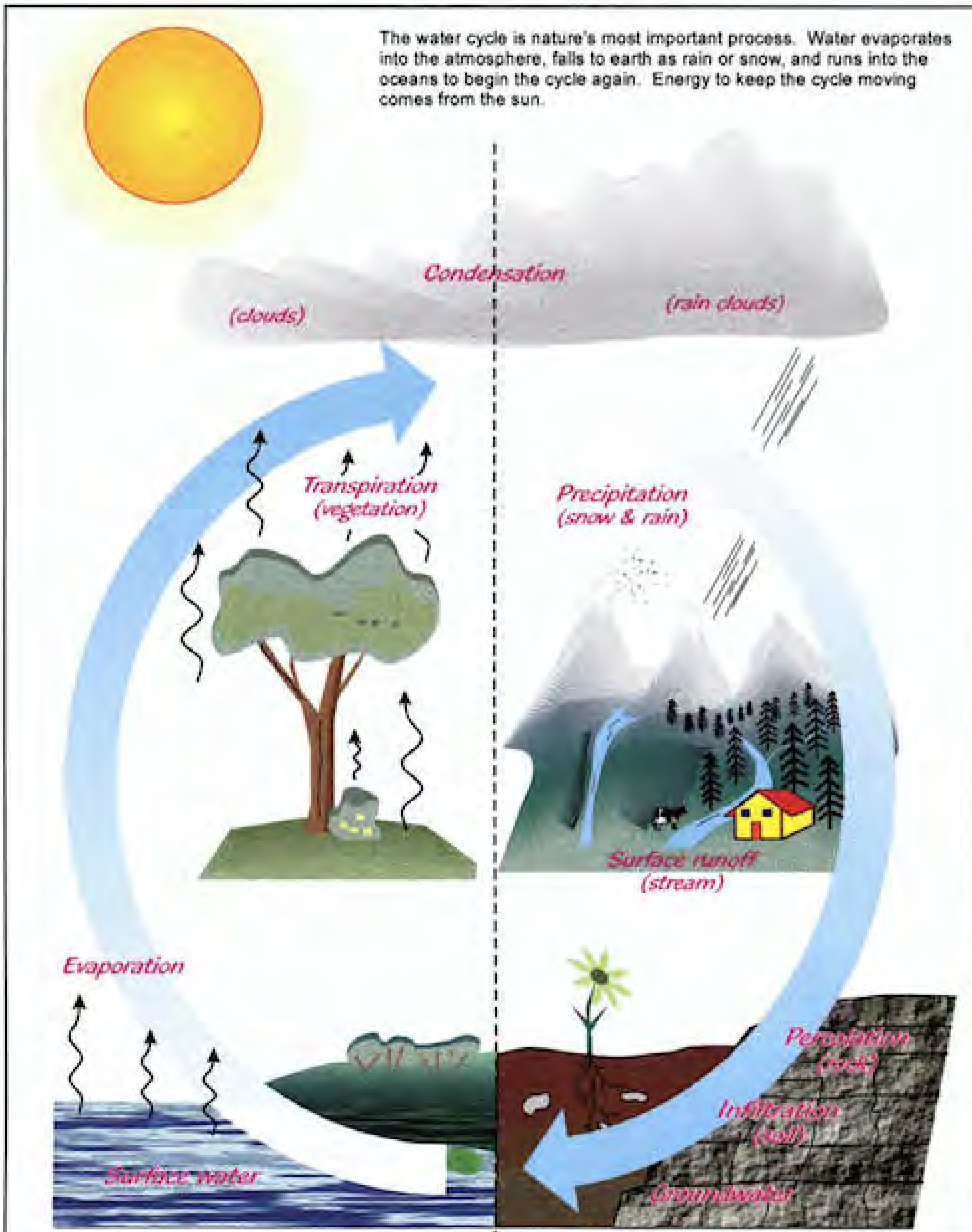

Figure 3.1.2. The Hydrologic Cycle

Modified from Region of Peel "Together for Health" diagram.

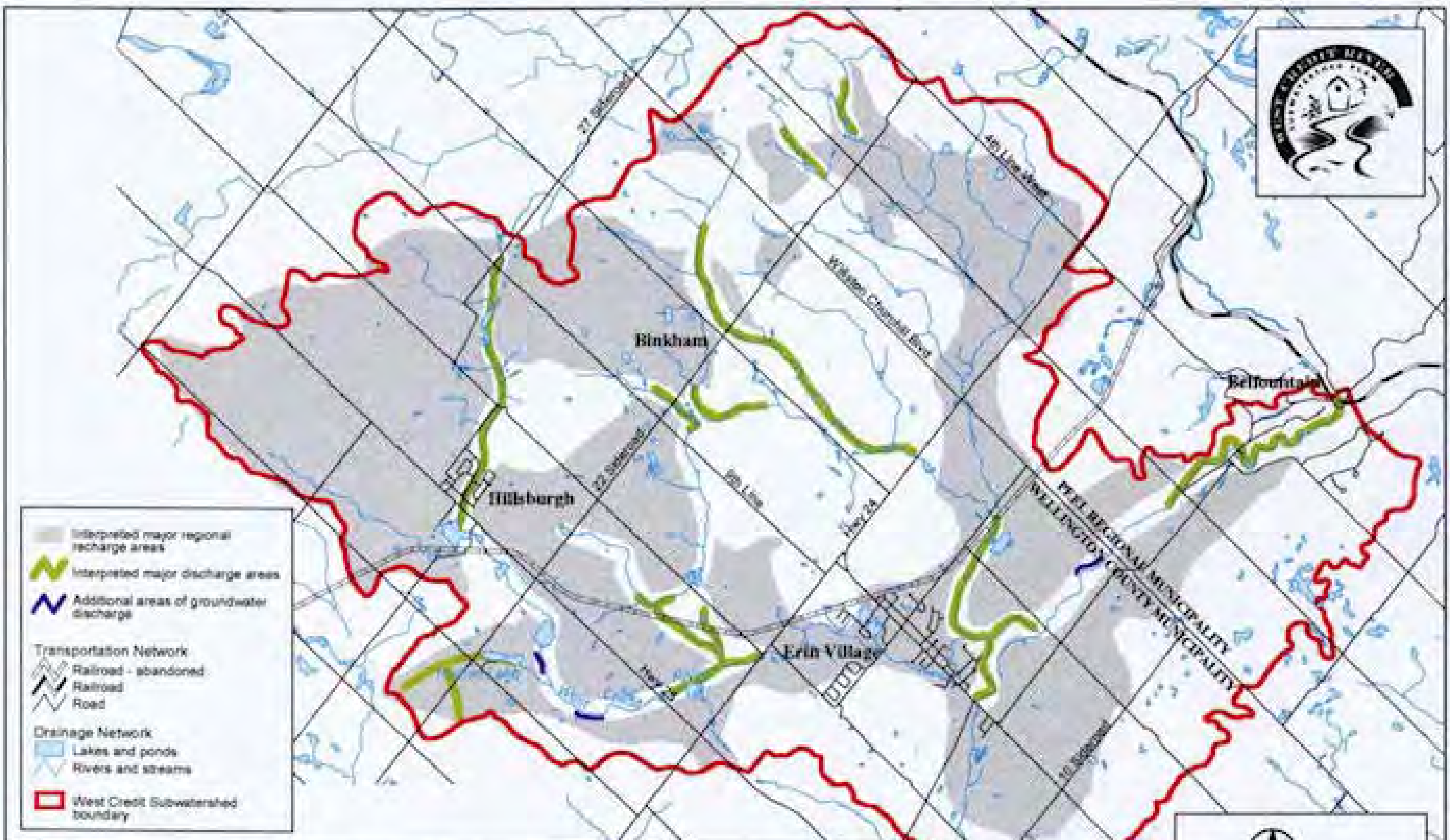

Figure 3.1.3: Major Recharge / Discharge Areas in the West Credit Subwatershed

Regional recharge areas may also contribute to local groundwater systems.

Sources: Terraqua Investigations Ltd., 1997; Ontario Ministry of Natural Resources, 1993. Material prepared by the Region of Peel Planning Department.

Credit River Watershed. Much of the baseflow lost in the lower reaches of the northern tributaries of the West Credit appears to be related to the change in surficial geology from till to sands and gravel. Contrary to this, the area downstream of the Village of Erin and the area near Belfountain show significant increases in baseflow. This is the result of a significant decrease in topographic relief and the presence of a buried bedrock valley influencing regional groundwater flow. As such, much of the baseflow gained near Belfountain likely originates from the area of the northern tributaries. Figure 3.1.4 shows where low flow measurements were taken in the West Credit Subwatershed.

The overall groundwater/surface water process is characterized by the hydrologic cycle (see figure 3.1.2). Not all the recharge to the subwatershed discharges to the West Credit River. The average annual precipitation within the subwatershed is 850 mm per year, and average infiltration within the subwatershed is estimated to be 338 mm per year. The average infiltration contributing to baseflow is estimated to be 294 mm per year. The difference is approximately 13%, meaning that this water would discharge outside the West Credit Subwatershed to the main Credit River, within Subwatershed 18. Based on permitted water taking (actual water taking may be less than the permitted water taking) approximately 79 mm per year could be utilized for water consumption. Much of this water is discharged back to the shallow groundwater or to the surface water and is therefore not “lost” from the system.

3.1.3 Groundwater Usage

Groundwater usage in the subwatershed is not great as most of the area is rural in nature. Most water taking is done via individual domestic wells and the municipal well systems in Hillsburgh, the Village of Erin and Belfountain. There are also several aquaculture operations and farm operations that take water for irrigation. Total water taking for the subwatershed is estimated to be on the order of 15,000 litres per minute or about 4.75 million gallons a day.

Water well records show that most well users obtain water from bedrock, primarily the Guelph-Amabel formation which extends from Hamilton to north of Orangeville and is one of the main aquifers in southern Ontario. Some wells are capable of producing several million gallons a day from this aquifer. Although the geologic information shows that there are a number of extensive sand and gravel units in the subwatershed, few wells are located in these units. Most of the overburden (shallow) wells in the subwatershed are either located in the sand and gravel immediately above bedrock, or in the sand and gravel of the Hillsburgh Sandhills.

For more information on physiography and groundwater resources of the West Credit Subwatershed, see Appendix A.

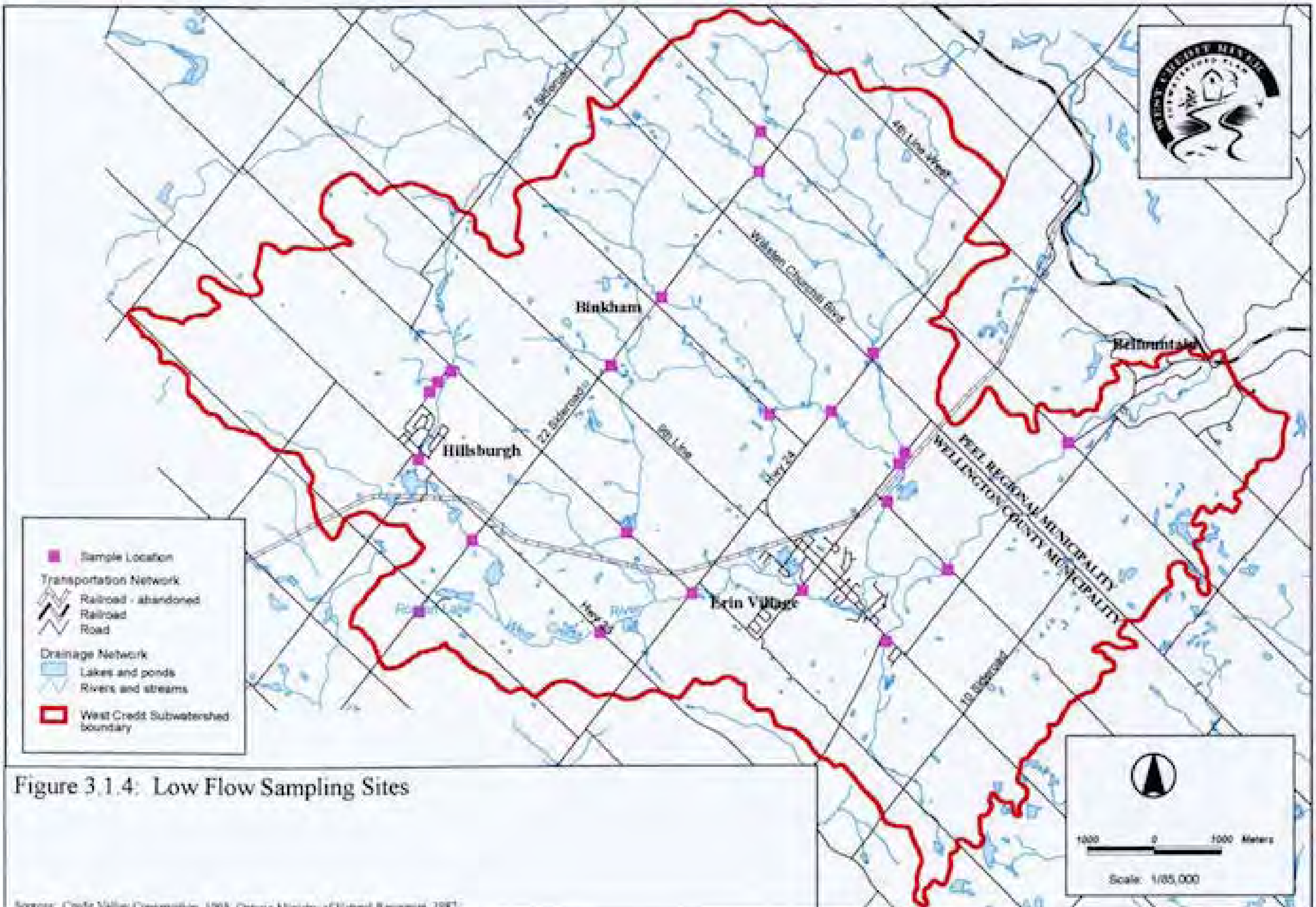

Figure 3.1.4: Low Flow Sampling Sites

Source: Credit Valley Conservation, 1995; Ontario Ministry of Natural Resources, 1982

3.2 Climate and Hydrology

The hydrology component of the subwatershed study focused on defining the precipitation-runoff relationship of the hydrologic cycle. Two approaches were used to study the subwatershed: flow frequency analysis and flow simulation.

When rainfall or snowmelt exceeds the infiltration rate capacity of surface soils, depressions on the ground fill up and overland flow begins. In a natural landscape, this overland flow is concentrated along rivulets and streams. At any point along a stream, flows can be characterized by a hydrograph (a continuous plot of flow rate versus time). Flows rates are generally influenced by physiography, climate and land use. Physiographic factors that influence runoff include:

- size and shape of the drainage area;
- nature of the stream network;
- slope of the land and channel; and
- storage detention in the subwatershed.

Physiographic conditions (geology and soils) have been described in section 3.1. Climatic factors that influence the hydrograph shape and volume of runoff include:

- rainfall intensity and pattern;
- aerial distribution of rainfall over the subwatershed; and
- duration of the storm event.

The climatic conditions of the subwatershed are described below.

Land use can significantly affect surface flows. Removal of trees and vegetation, diversion of channels, and increasing the amount of impervious areas can significantly change the rainfall-surface runoff relationship. These can also change other parts of the hydrologic cycle such as interflow (flow through soil to stream) or deep groundwater flow to aquifers. The impacts of land use in the West Credit Subwatershed is limited due to the small percentage of land (3%) which is characterized as urban.

Table 3.2.1: Climatic Conditions

Mean Daily Temperatures	
January	-8.7^{o}C
July	19^{o}C
Average Annual Precipitation	
Rainfall	665 mm
snowmelt	185 mm
Total	850 mm
Average Annual Number of Days with	
Rainfall	99
Snowfall	52
Precipitation	151
Regional Mean Annual Runoff	350 mm

3.2.1 Streamflow Analysis

Figure 3.2.1 shows how the subwatershed was subdivided into subcatchments to simulate flows. Also shown is the location of the stream gauge where data was collected.

In conducting stream flow analyses, statistical techniques are used to interpret the past record of hydrologic events and predict future probabilities of occurrences. This was done for the West Credit using station data from the Erin stream gauge. Water levels that are translated into stream flow rates have been recorded since 1983. An assessment of the daily stream flow rates between 1983 and 1994 shows that the rates tend to peak in the spring or fall. The higher rates were preceded by rainfall or snow melt conditions.

A combined flow-duration analysis (mean daily flow rate versus the percentage of time exceeded) was also conducted for 1984 to 1994. It showed the following:

- a mean daily flow of 0.3 m^3/s will be exceeded 90 percent of the time; and
- a mean daily flow of 0.8m^3/s will be exceeded 10 percent of the time.

A frequency analysis was conducted for low flow rates as well as for peak flow rates. It is important to understand the full range of flows (low flows and peak flows) in order to characterize the flow regime and explain the types of streams found in the subwatershed, and the types of vegetation and biota that exist within them.

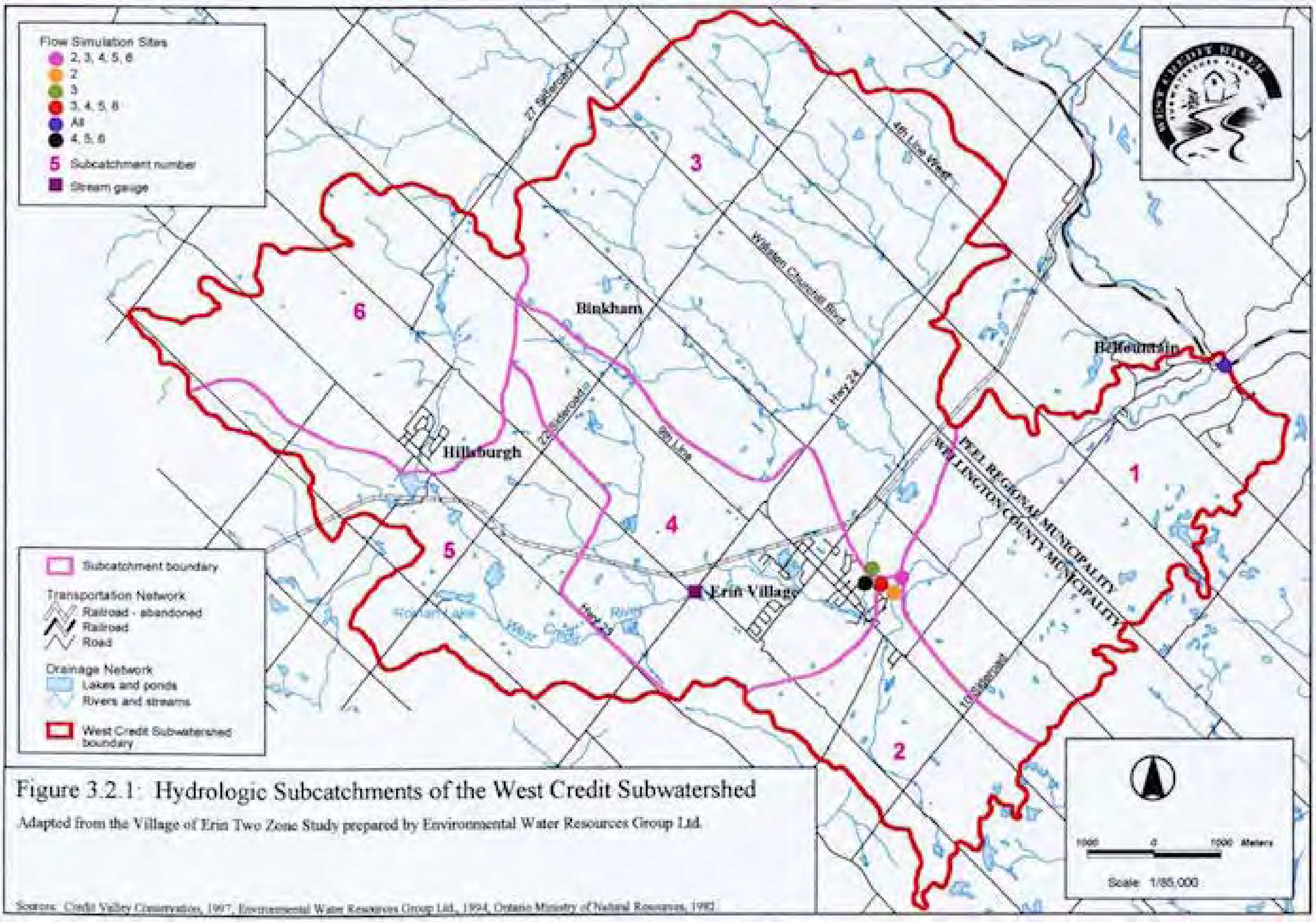

Figure 3.2.1: Hydrologic Subcatchments of the West Credit Subwatershed

Adapted from the Village of Erin Two Zone Study prepared by Environmental Water Resources Group Ltd.

Sources: Credit Valley Conservation, 1997, Environmental Water Resources Group Ltd., 1994, Ontario Ministry of Natural Resources, 1981

Table 3.2.2: Frequency Analysis

Return Period (years)	Average Minimum 7 Day Flow Rate (m^3/s)	Peak Flow Rate (m^3/s)
1.01	0.334	-
2	0.232	3.9
5	0.199	5.3
10	0.184	6.3
20	0.174	7.2
50	0.164	8.4
100	0.159	9.2

The above data is applicable to the West Credit River at the location of the gauge.

3.2.2 Flow Simulation

The objective of flow simulation is to interpret a past record of hydrologic events in terms of future probabilities of occurrence. The result is a flow that occurs on average every so many years. For example, even if you do not have 50 years of data, existing information can be used to model the high flows that would occur on average, once every 50 years. Note that the CVC Regional Storm is based on information gathered during Hurricane Hazel.

During the 1984 Credit River Flood Damage Reduction Study, peak flow rates were simulated for the West Credit Subwatershed. At that time, four flow monitoring stations existed on the Credit River. The study used a simulation model that generated hydrographs for the Regional Storm as well as generating hydrographs with peak flow rates that were very similar to the flood frequency curves for each of the four stations. The model was then used to generate 2 to 100 year return period hydrographs for various points of interest that did not have recording gauges. All peak flows are summarized in the following table.

Table 3.2.3: Flow Simulation

Location	Drainage Area (km^2)	Regional Storm m^3/s	100 year m^3/s	50 year m^3/s	25 year m^3/s	10 year m^3/s	5 year m^3/s
Subwatershed 15 at confluence with Credit River	105	320	170	140	120	90	70
Confluence Subwatershed 15 and Eastern Tributary	90	310	160	130	110	80	60
Confluence Subwatershed 15 and Northern Tributary	75	270	130	110	100	70	55
Subwatershed 15 at Erin	40	155	70	60	50	40	30
Eastern Tributary	13	90	50	45	35	25	20
Northern Tributary	37	120	60	55	45	35	25

See figure 3.2.1 for the location of flow simulation sites.

3.2.3 Hydrology 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 streambank erosion, loss of terrestrial and aquatic biota and loss of recreational resources. Increased urbanization in the West Credit Subwatershed would have the most impact in three areas: flooding, domestic water supply and aquatic habitat.

With respect to flooding, there are three "flood damage centres" (areas susceptible to flooding during storms) located within the subwatershed. These are located at Hillsburgh, the Village of Erin and Belfountain. During the Regulatory Storm (a storm of Hurricane Hazel's magnitude), approximately 28 buildings in Hillsburgh, 38 buildings in the Village of Erin 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. 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 streambank erosion and cover spawning beds. Increased water temperatures caused by on-line ponds have already changed species composition and habitat in the West Credit.

For more information on hydrology in the West Credit Subwatershed see Appendix B.

3.3 Stream Morphology

Stream morphology (or geomorphology) is the study of river forms and processes. It includes the study of how a river reacts over time to changes in the land which it drains. Depending on the type of change, the river will respond in various ways: flooding may increase in frequency, bank erosion and siltation may worsen, streams may become seasonal (i.e. dry up in the summer).

Healthy functioning of a river is dependent on many factors, such as a constant supply of groundwater to keep it flowing in the summer and plentiful vegetation cover along its banks to minimize bank erosion and the effects of flooding. Essentially, a river is in a fine tuned balance with the land around it.

By studying the present forms and functions of a river, and looking at rivers in similar landscapes, we can predict with some confidence both past conditions and responses to future changes. This is important when trying to minimize the effects of land use changes in the future on the river and the surrounding environment. If we have a good idea of how the river is functioning today in current conditions, we can know where to focus our efforts for protection, rehabilitation and enhancement in the future.

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. The main branch can be characterized as having little erosion and stable banks. The permeable nature of the soils deposited during the last glacial epoch have a significant influence on the geomorphic system. The gravely soils in the West Credit 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.

There is little urban activity in the subwatershed, and therefore storm runoff is contained in three nodes — Hillsburgh, the Village of Erin and Belfountain. At present, the runoff is not significant enough to cause increased bank erosion. In the urban areas, encroachment onto the flood plain 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 property.

Vegetation is the strength and weakness of streams in headwater areas and especially “E” type channels. Loss of deeply rooted vegetation along these streams will cause massive bank erosion and channel adjustment, ultimately creating a different type of stream channel. If the process is relatively slow, the channel will adjust to a “C” type channel; if it is fast, the channel will become a “D” or braided channel. “D” channels are highly unstable systems and are extremely poor environments for fish, aquatic invertebrates or people (Rosgen, 1996). Vegetation is also extremely important for the health of big rivers. In larger streams, healthy densely rooted vegetation helps to hold the banks, becomes an important element of flood plains, provides woody material for fish habitat and pool enhancement and provides leaves that are an important food source for aquatic bugs. The elevation of the baseflow channel provides the control on the shallow water table under the banks and riparian zone. This, in turn, ensures the health of the vegetation. All elements of the system therefore rely upon each other. See table 3.3.1 for a generalized description of stream type. Table 3.3.1 lists only the stream types found in the West Credit Subwatershed, see Rosgen (1996) for a complete listing of stream types.

There are some disturbances in the West Credit's morphological regime, especially in areas where beaver activity is common (between the Village of Erin and Hillsburgh). The beaver dams trap water, flooding riparian areas and drowning adjacent trees, causing them to topple. Beaver 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. See figure 3.3.1 for a geomorphological classification of some reaches of the West Credit River, and figures 3.3.2 - 3.3.6 for pictorial examples of the stream types. The locations of figures 3.3.2 - 3.3.6 can be found on figure 3.3.1 as site numbers 1-5 respectively.

Many reaches of the river are influenced by woody debris. For more information on this, see the section on Aquatic Habitat. In some areas of the West Credit, the headwater streams are devoid of riparian cover, as many are in pasture or crop fields. These areas should be considered for rehabilitation. Limiting cattle access, for example, will limit bank erosion caused by cattle and improve water quality.

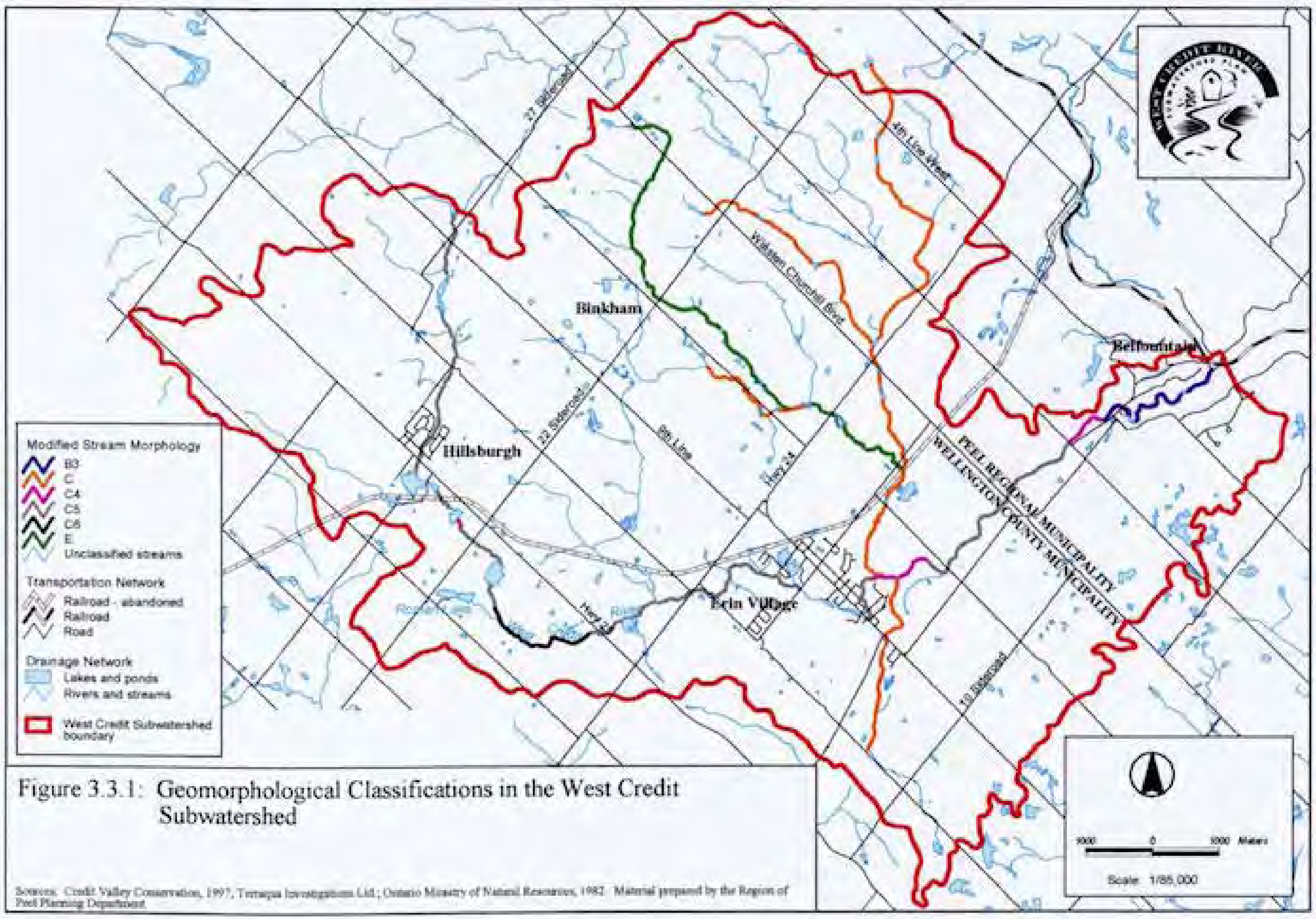

Figure 3.3.1: Geomorphological Classifications in the West Credit Subwatershed

Sources: Credit Valley Conservation, 1997; Terraqua Investigations Ltd.; Ontario Ministry of Natural Resources, 1982. Material prepared by the Region of Peel Planning Department

Table 3.3.1: Stream Types

Stream Type	General Description
B	Moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks.
C	Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined flood plains.
E	Low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander width ratio.

Adapted from Rosgen - 1996

There is the potential for damage to sensitive areas, for example, upwelling areas and fish nursery habitat, if the balance between erosion and sediment transport is altered. This can occur with drastic rapid land use change in the subwatershed. Generally, the river in the subwatershed is very healthy. To keep it healthy, and perhaps improve the environment, tree and shrub plantings should be encouraged adjacent to watercourses both along the main branch and the smaller headwater tributaries. Revegetating can stabilize banks and improve water quality by filtering water before it enters the river.

For more detailed information on the geomorphologic resources of the West Credit Subwatershed, see Appendix C.

Figure 3.3.2: B - Type Channel, looking downstream from the Belfountain Dam*

Figure 3.3.3: C4 Channel, looking downstream from Shaws Creek Road

Figure 3.3.4: C5 Channel, looking upstream from Shaws Creek Road

Figure 3.3.5: C6 Channel, looking upstream from Highway 25

Figure 3.3.6: E Channel, looking upstream from Highway 24.

3.4 Terrestrial Systems

In terms of land use, the West Credit is dominated by agriculture and open space (forests and wetlands). Only 3% of the subwatershed is characterized as "urban". Studies show that in subwatersheds where urban land use is greater than 15%, fisheries are significantly degraded (Klein, 1979).

The terrestrial component of the Phase I West Credit Subwatershed Study focused on the open space areas of the subwatershed: its wetlands, forests and plantations. However, it should be noted that other areas in the subwatershed also provide wildlife habitat. Land use in 68% of the subwatershed is agricultural in nature; this includes pasture lands, row cropping, livestock raising and abandoned fields. These agricultural areas also provide wildlife habitat, but have not been considered in this component of the study.

3.4.1 Forests

Terrestrial features were mapped for the subwatershed (see Figure 3.4.1). These terrestrial habitat units consist of any combination of forest, plantation, and wetland. In many cases, there is overlap between forested habitats and wetlands found in the river and stream valleys.

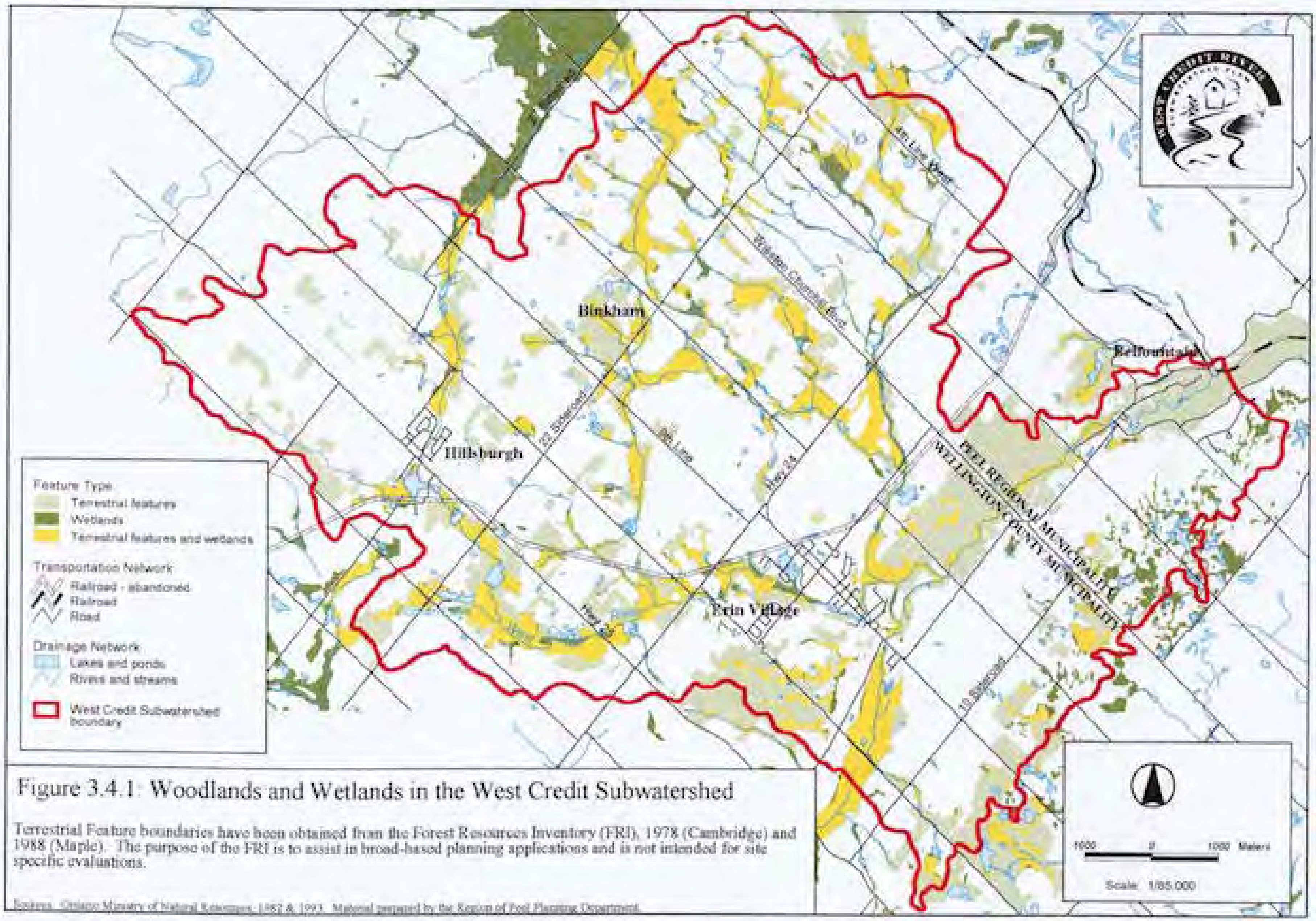

Figure 3.4.1: Woodlands and Wetlands in the West Credit Subwatershed

Terrestrial Feature boundaries have been obtained from the Forest Resources Inventory (FRI), 1978 (Cambridge) and 1988 (Maple). The purpose of the FRI is to assist in broad-based planning applications and is not intended for site specific evaluations.

Sources: Ontario Ministry of Natural Resources, 1987 & 1993. Material prepared by the Region of Peel Planning Department.

About 15% of the West Credit Subwatershed is currently covered with natural forests or tree plantations. This is only half of the goal of 30% forest coverage that has been recommended by the Ministry of Natural Resources and adopted by Credit Valley Conservation to maintain forest interior species and area sensitive species (MNR 1997).

The value of forested lands varies depending on location, size, connectivity and condition. It is important to protect those forested areas in the subwatershed that are of high value. We have recommended that 92% of the forested land in the subwatershed is either a high or medium priority for protection. In addition to protecting the key (high value) forested areas, the connectivity of habitat units needs to be improved. Currently, there are few corridors connecting the blocks of habitat that are scattered throughout the subwatershed. Connecting blocks of habitat is important for wildlife communities. Wildlife need corridors for cover when travelling from one area to another. Without corridors, there is little defence or camouflage offered and animal populations are stressed.

The areas adjacent to the main branch of the West Credit River between Fifth line WHS and 10th line are in excellent health. This coldwater reach of the river is characterized by the presence of abundant fish fry concentrations and significant spring seepage. This is a significant recharge area that contains forests, plantations and wetlands, and a high degree of habitat diversity is found. This reach includes the largest interior habitat block in the subwatershed which we have classified as being the highest priority for protection. Currently, this area is unprotected.

Areas where terrestrial cover is notably lacking include the northwest portion of the subwatershed, west of Hillsburgh. This is also one of the largest recharge areas in the subwatershed. Here, the soils are glacial deposits and exhibit high rates of infiltration. Increased vegetative ground cover in this area would promote groundwater infiltration, especially of snow melt in the spring. This enhanced recharge of aquifers would help sustain groundwater quantities for home, farm and municipal use. Most of the terrestrial units in the northwest part of the subwatershed have been categorized as being a low priority for protection due to their sparse occurrence and small size.

When examined in combination with other features such as proximity to recharge areas, many of the woodlots that were classified as low priority on their own became higher priority with respect to subwatershed function (see section 6.2).

For the most part, the riparian stream corridors throughout the subwatershed are well vegetated (see section 3.5). Maintaining, protecting or improving this cover should be priority for the future. A well-vegetated riparian stream corridor serves many functions including decreasing the impact of a flood by slowing down the flow and allowing dirt and contaminants to settle onto the flood plain. The dense root system in riparian vegetation holds soils in place, resulting in minimal bank erosion. Maintaining vegetative cover near the subwatershed's rivers and streams is fundamental to maintaining a self-sustaining coldwater fishery. Bank side vegetation shades the water from the sun and keeps water temperatures cool in summer. Vegetation that falls in the river provides food and cover for fish and invertebrates. Finally, a well vegetated stream corridor provides shelter and cover for larger mammals that access the river for drinking water.

3.4.2 Wetlands

Wetlands (marshes, swamps and bogs) make up about 14% of the West Credit Subwatershed. Figure 3.4.2 shows their distribution, and classification. Two general patterns emerge: belts running east to west in the headwater areas, and wetlands that follow valley physiography, especially from Hillsburgh to the Village of Erin. In many cases in the river valleys, wetlands overlap forest cover. The distribution of wetlands in the subwatershed reflects the important role and linkages that wetlands perform relative to the hydrology of the West Credit.

Wetlands perform many functions. In terms of hydrology, wetlands play important roles in controlling floods, removing contaminants and nutrients from water, preventing erosion and recharging groundwater in certain geologic settings. The biological values of wetlands are usually assessed with respect to productivity (the amount of plant and animals sustained), biodiversity, system age, size and rarity. Wetlands provide habitat for fish, reptiles, amphibians, invertebrates, birds and mammals. Recreational values include nature appreciation, fishing, hunting, hiking, canoeing, bird watching and aesthetics.

Wetlands are usually classified under a standard assessment methodology developed by the Ontario Ministry of Natural Resources. This ranks Ontario's wetlands on a scale from 1 to 7. Class 1 to 3 wetlands are considered "provincially significant" and are protected under the Wetlands Policy. Class 4 to 7 wetlands, while not being provincially significant, often play important regional roles in terms of hydrology or biology. Many of the wetlands in the West Credit Subwatershed are Class 1 wetlands (see figure 3.4.2).

3.4.3 Environmentally Significant Areas

Environmentally Significant Areas (ESAs) are areas where ecosystem functions or features warrant special protection (Region of Peel, 1996). ESAs were designated by the Conservation Authority in 1984. To be designated, an area would have to meet one or several criteria which reflected its ecological importance within the watershed. Also in 1984, CVC adopted a series of policies to aid in the protection of these features and their associated functions. The Town of Caledon, Wellington County and the Region of Peel have indicated a commitment to the protection of the designated ESAs.

There are 6 ESA's within the boundaries of the West Credit Subwatershed, and 2 ESA's just outside the subwatershed boundary (see figure 3.4.2):

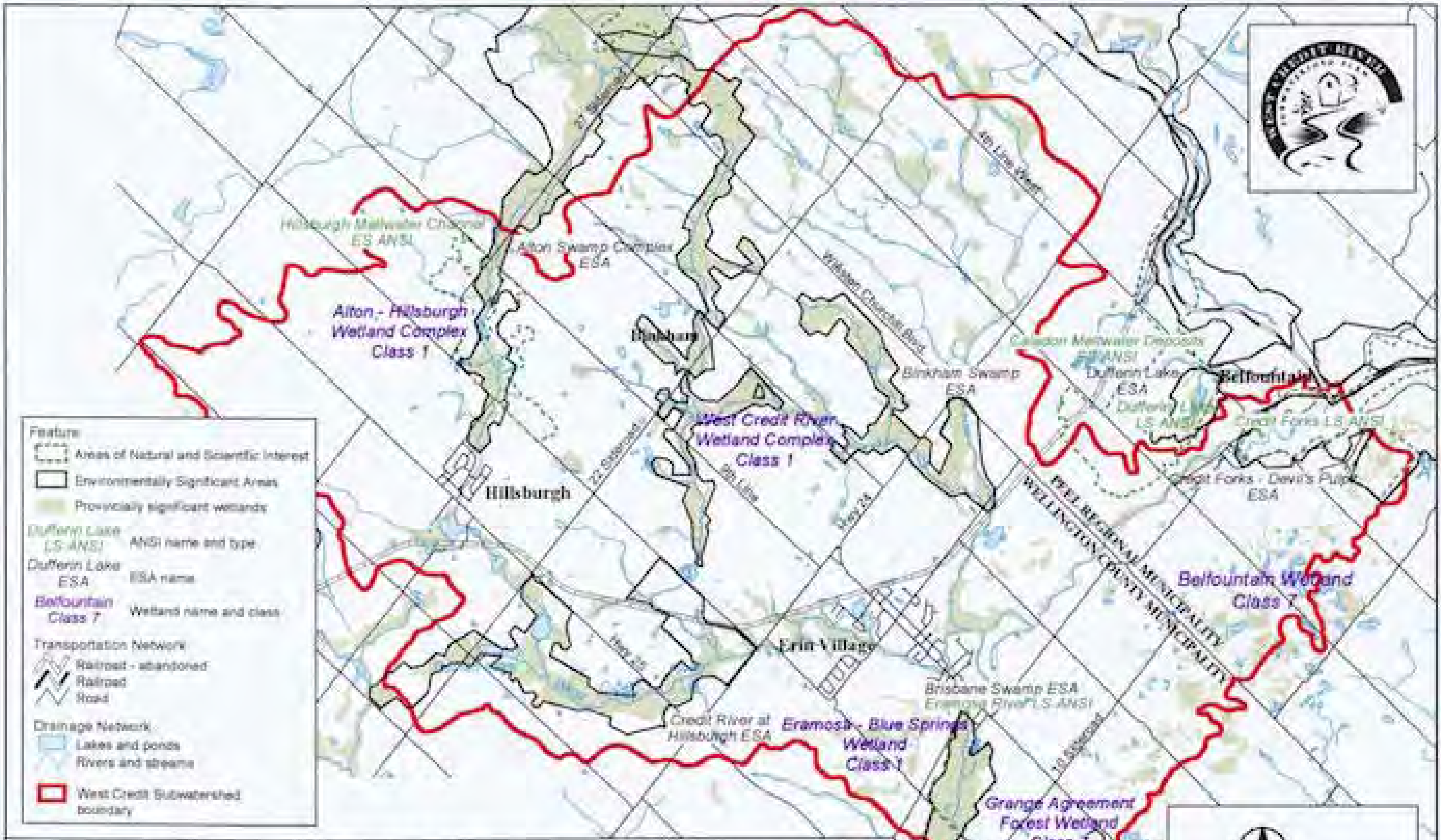

Figure 3.4.2: Wetlands, ESAs and ANSIs in the West Credit Subwatershed

Source: Ontario Ministry of Natural Resources, 1982 & 1993. Material prepared by the Region of Peel Planning Department and Credit Valley Conservation

Credit River at Hillsburgh

This 285 ha ESA lies in the river valley between Erin and Hillsburgh. There is overlap with the West Credit Class 1 Wetland Complex. The area provides habitat for rare, endangered or indigenous species and is hydrologically/hydrogeologically significant.

Alton Branch Swamp

The Alton Branch Swamp ESA is the largest in the Credit River watershed at 890 ha. Overlapping Subwatershed 17 and the West Credit Subwatershed, the ESA is the headwaters of Shaws Creek and the West Credit River. The ESA supports an unusually high diversity of species, including rare, endangered or indigenous species, including class 1 wetland species. The ESA contributes significantly to local hydrogeology/hydrology functioning.

Brisbane Swamp

The 149 ha ESA located in the south-western portion of the subwatershed is the headwater area for tributaries of the West Credit River and the Eramosa River. It is large relatively undisturbed swamp/bog complex with an usually high diversity of species.

Credit Forks - Devil's Pulpit

Credit Forks - Devil's Pulpit ESA, a 287 ha feature at the downstream reach of the West Credit River is composed of one of the most extensive relatively undisturbed forest tracts in Peel Region. The area supports outstanding earth science features, plentiful breeding bird habitat and habitat for rare, endangered or indigenous species.

Brisbane Woods II

Only the northernmost portion of the 318 ha ESA is located within the West Credit Subwatershed. The ESA supports an unusually high diversity species of significant value.

Binkham Swamp

The unusually shaped 192 ha ESA lies in the middle of the subwatershed. There is a lot of class 1 wetland habitat lining the central tributaries of the West Credit River which is of hydrological/ hydrogeological significance.

Dufferin Lake ESA lies just outside the subwatershed to the east, and the Hillsburgh Sandhills ESA lies just outside the subwatershed to the west.

3.4.4 Areas of Natural or Scientific Interest

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

There is one provincially significant Life Science ANSI in the subwatershed, the Credit Forks ANSI. Only part of the 337 ha area lies within the subwatershed, and abuts the Belfountain Conservation Area. It includes forested lands on the foot, slopes, slope terraces and plateau of the Niagara Escarpment on both sides of a re-entrant valley along a section of the West Credit River (MNR, 1990). Terrestrial communities include tableland forest, glaciofluvial slope and talus slope forest. Terrestrial species of local, regional and provincial significance can be found in the area, as well as rare species.

ANSIs were mapped, based on information provided by the Ministry of Natural Resources (figure 3.4.2).

3.4.5 Rehabilitation and Future Conditions

Because there are no major land use changes predicted for the subwatershed in the near future, efforts can be focused on improving current conditions to ensure that the health of the subwatershed is maintained or enhanced.

Future rehabilitation work in the subwatershed should be focused on:

- increasing habitat complexity and diversity;
- improving connectivity between habitats;
- increasing the total amount of forest cover;
- increasing forest patch size;
- increasing forest cover in groundwater recharge areas;
- increasing forest cover in riparian zones, especially in cold water fish habitat reaches, and groundwater discharge zones; and
- increasing the amount of wildlife habitat available on agricultural land.

More field work needs to be completed on soils and slopes before specific rehabilitation strategies can be developed.

In the West Credit Subwatershed, 96.5% of woodlots and wetlands are located on private lands. Only 3.5% are located on public lands, i.e., CVC properties, lands leased to municipalities, and Ontario Heritage Foundation land holdings. As a result, the continued health of the subwatershed depends on co-operation with private landowners through stewardship and education initiatives. In light of current government restructuring and program cuts, relations with private landowners have become increasingly important. CVC can assist landowners with achieving the long term goals for the subwatershed through forestry and wetland advisory programs.

For more information on the terrestrial resources of the West Credit Subwatershed, see Appendix D.

3.5 Riparian Systems

3.5.1 The Riparian Zone

Riparian zones are 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 and trees that can tolerate saturated roots for extended periods. The amount of 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, total sediment eroded into the channel system is low. 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.

In headwater systems such as the West Credit River, the presence of rooted vegetation in the riparian zone is likely the single most important control on shape and pattern of the channel and the quality of fish habitat. Loss of riparian vegetation in headwaters streams (especially E type streams) will cause massive bank erosion and channel adjustment, ultimately creating a different type of stream channel. If the process is relatively slow, the channel will adjust to a "C" type channel; if it is fast, the channel will become a "D" or braided channel (Rosgen, 1996). See table 3.3.1 for further description on general stream type.

Unlike other adjacent subwatersheds, the West Credit River has an almost continuous corridor of diverse bank side vegetation in its riparian zone. Except for the Villages of Erin and Hillsburgh, most of the banks of the West Credit River have stable vegetative communities of grasses, shrubs and trees. There are four major groupings of riparian vegetation along the river. These are described as: (1) urban - manicured grass and some trees; (2) agricultural - mostly pasture, abandoned pasture or orchard; (3) wetlands and or beaver meadows - sedges, grasses, shrubs and some trees; (4a) forests - conifer/deciduous or cedar/poplar and (4b) forest plantations. The most common vegetation types along the West Credit River are conifer/deciduous forests dominated by cedar and balsam poplar, or wetland/beaver meadows. Figure 3.5.1 shows the type and location of riparian vegetation along the main branch of the West Credit River.

The dominance of forest or wetlands along the banks of the West Credit River ensures that bank erosion is held in balance. In addition, these wide riparian zones made up of forests or wetlands act as natural sponges, retaining nutrients that come from adjacent table lands. These zones also moderate flood flows by retaining water and releasing it gradually into the stream after storm events. Functionally, this moderates the severity of floods including reducing impacts on aquatic habitats.

The West Credit's riparian zone is unusual for Southern Ontario because of its contiguous length and its width. These characteristics provide high quality habitat to the stream and buffer it from adjacent land use activities. In this regard, the West Credit River is in a minority of rivers in Southern Ontario.

3.5.2 Aquatic Habitat

Healthy aquatic communities require a channel/valley system and a surrounding subwatershed that are healthy and functional. Characteristically, this means a healthy, stable riparian vegetation, a good tree canopy and a moderate low flow and high flow regime to maintain channel form and type. These basic conditions are found throughout most of the main West Credit River. Notable exceptions to this are the local disruptions that occur within the Villages of Erin and Hillsburgh and immediately adjacent to the several on-stream dams on the main stem of the West Credit River.

Anglers understand the importance of wood in streams. Pieces of tree limbs, branches, trunks and roots provide extremely important shelter areas for fish in streams. Logjams on an outside bend or root wads adjacent to a run spell out "big fish" to canny anglers. Smaller bits of twigs and branches along the margins of riffles are extremely important for small fish and trout fry. Woody debris modifies the characteristics of stream channels by helping to form pools, providing structural escape cover, and providing roughness. Woody debris provides roughness by slowing down flood waters and giving fish a place to stay safely when water velocities are high, and by making river flows more turbulent, and therefore allowing more oxygen to enter the water.

In "C" channels such as along the main West Credit River, moderate amounts of woody debris on the outside bends of channels enhance pool formation and creates better habitat for fish.

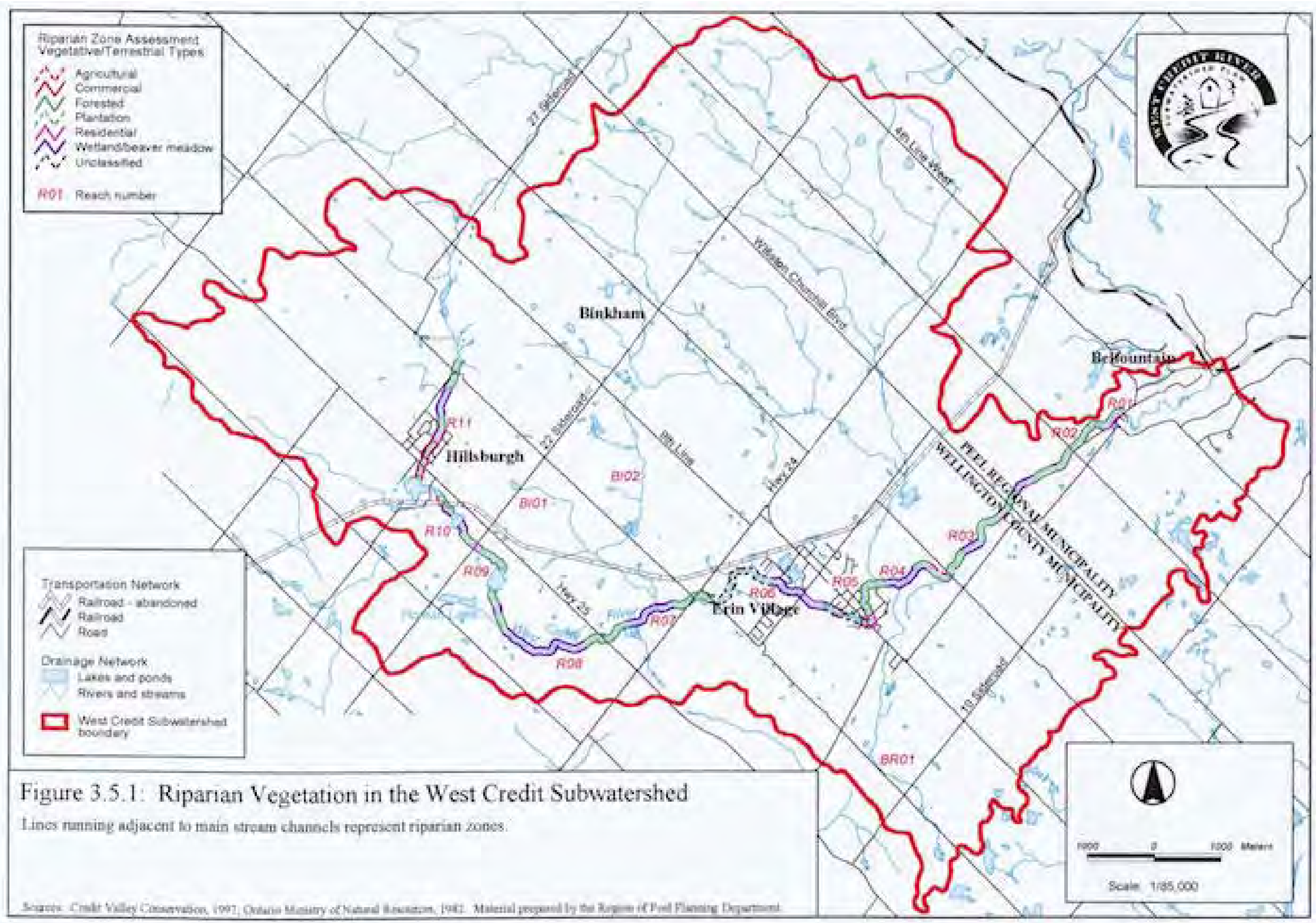

Figure 3.5.1: Riparian Vegetation in the West Credit Subwatershed

Lines running adjacent to main stream channels represent riparian zones.

Sources: Credit Valley Conservation, 1997; Ontario Ministry of Natural Resources, 1982. Material prepared by the Region of Peel Planning Department.

Fine woody debris (branches and twigs) in the margins of the stream creates habitat for fish fry and older juveniles. However, too much wood debris in low gradient "C" type channels can destabilize and degrade a functional channel. Subtle changes in roughness of a channel can have major implications on the ability of a stream to mobilize or transport sediment thereby modifying or altering the habitat of the streambed for bugs and fish reproduction. Too much wood throughout a low gradient channel can actually reduce the streams ability to move its sediment. This can lead to too much sediment storage in the channel and ultimately to accelerated bank erosion which destabilizes the channel and reduces fish habitat. This was not found to be the case along the West Credit except in a few small sections downstream of Townline Road where historic beaver activity has caused large numbers of trees to fall into the stream. In most sections of stream in the West Credit Subwatershed, wood debris constitutes less than 3% of the surface area of the stream. In one or two areas where wood debris approaches 6% of the surface area, habitat appears to be less suitable for fish such as trout, although other species may prefer it. For more information on riparian systems in the West Credit Subwatershed, see Appendix E.

3.6 Fisheries

Subwatersheds such as the West Credit River Subwatershed that have high volumes of gravels and sands characteristically create streams that are fed by the abundant, available groundwater which flows through these soils. In much of the West Credit River, over the course of the year, stream levels are usually the same as the height of the water table at that location. Where steep hills and porous soils are found together, we get shallow water tables (and occasionally regional aquifers) with steep gradients. In such areas, the steep slope of the water table actively pushes groundwater into streams and wetlands. On the main branch of the West Credit River, groundwater discharges directly or almost directly into the stream around Hillsburgh, below the Village of Erin and from Belfountain to the Forks-of-the-Credit. These reaches of stream are also the best coldwater sections for brook trout and, below Belfountain, for brown trout.

The areas of a coldwater stream where groundwater flows upward through the substrate into the stream provide trout with refuge against very high or very low temperatures and provide the location brook trout need for spawning. These areas of coarse sand and gravel where spring water upwellings occur are the waterbeds for trout eggs and recently hatched fish and are likely the most sensitive and rare environments within a brook trout stream. Within the 14 kilometre brook trout zone on the main Credit River, for example, a third (35%) of all brook trout spawning occurs in a section of the river that is only 100 metres long.

3.6.1 The Current Fishery

In order to characterize the fishery, members of the study team collected spawning survey data, identified concentrations of emergent trout fry and spring discharge areas, and walked the entire main branch of the West Credit from Belfountain Conservation Area to Hillsburgh. Areas of significant spring seepage, significant fry concentration and coldwater habitat are shown on Figure 3.6.1. The best areas for brook trout are associated with spring discharge areas. The most critical areas for spring discharge are in the headwaters of the main branch above Hillsburgh at the 22nd Sideroad and downstream from the Village of Erin to the Forks.

Notably, the West Credit contains wild, self-sustaining populations of brook trout. The distribution of this species has decreased over the last 100 years in Southern Ontario as forests were cleared and urbanization took place. While many rivers in Southern Ontario have undergone drastic (in some cases irreversible) changes, much of the West Credit system, and the fishery it supports, have remained unchanged. Localized changes — on-line ponds, dams, villages and other disturbances have reduced the distribution of brook trout in the subwatershed. On-line ponds cause local changes in water temperature and water quality that work against the survival of brook trout. Brook trout (and salmonids in general) are sensitive to increases in water temperature and sediment and impairments in water quality. In addition to cool temperatures, brook trout need coldwater upwellings in streams for spawning and for refuge in the warm summer months. The upwellings provide flowing water in the winter months when parts of the river are frozen. The presence of self-sustaining populations of brook trout is an indicator of a healthy, complex ecosystem with high quality ground and surface waters.

In addition to brook trout, other coldwater fish found in the subwatershed include rainbow trout, brown trout, stocked Atlantic salmon and mottled sculpin. The Atlantic salmon are not self sustaining, and are therefore still experimental. Warmwater fish found include yellow perch and largemouth bass. A complete list of species is presented in Table 3.6.1.

The three types of fish communities in the West Credit Subwatershed are coldwater, potential coldwater and probable coldwater, defined as follows. Table 3.6.2 describes the communities and indicator species used to classify them.

Brook trout, and other salmonids in general are highly sought after by anglers. The Upper Credit River is one of the most popular resident trout fisheries in Southern Ontario. Wild, stream-resident brook trout populations are in relatively short supply in Southern Ontario (especially near large urban centres) and the Credit River and its tributaries provide some of the best angling opportunities for stream-resident brook trout in the southern part of the province. Within the Credit River Watershed, the best populations of brook trout are found in Black Creek from Limehouse to Stewartown, in the Main Credit, and in the West Credit upstream from the Forks.

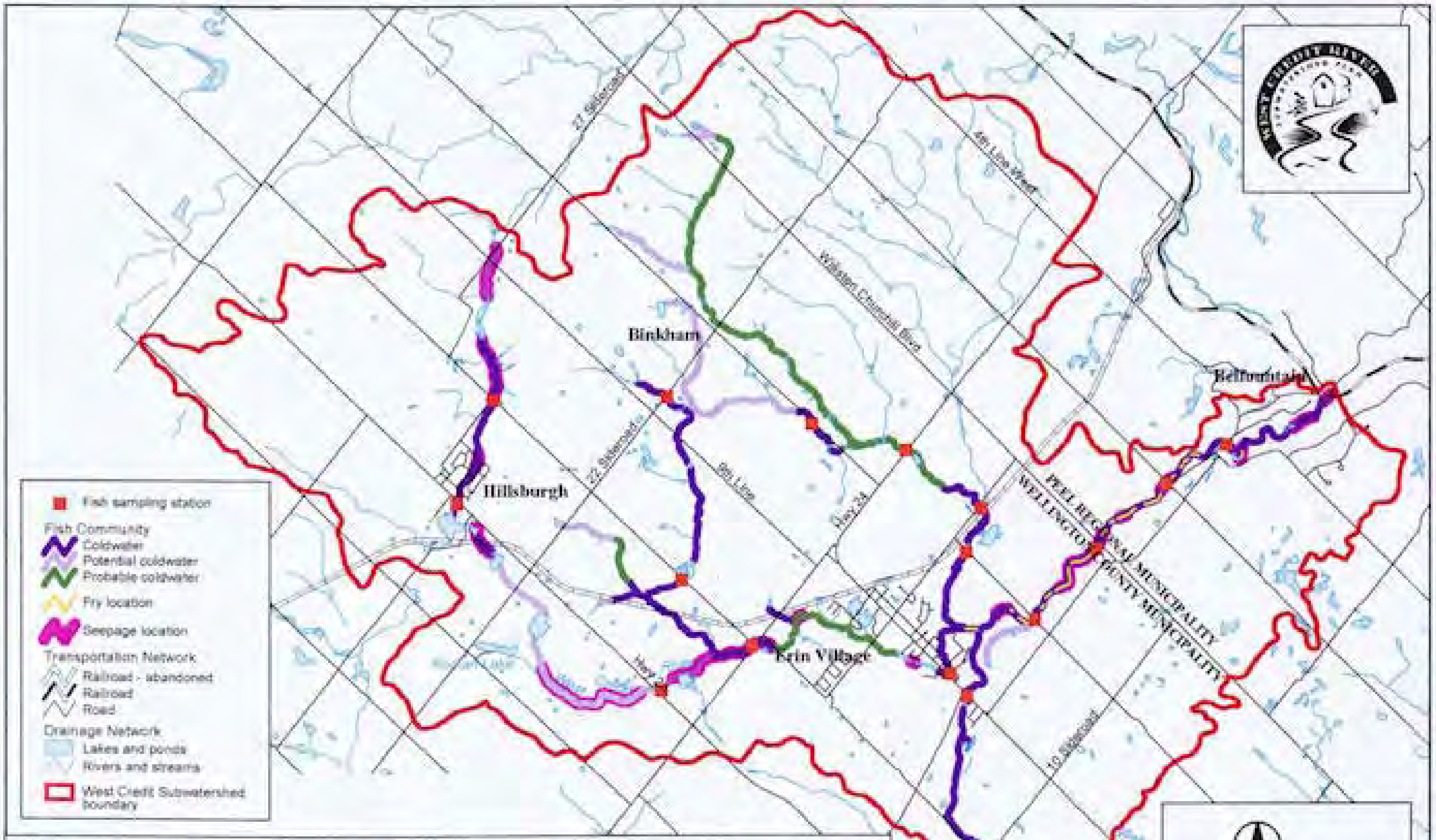

Figure 3.6.1: Fisheries Resources of the West Credit Subwatershed

Information on waterbodies was collected through physical and biological surveys.

Sources: Ontario Ministry of Natural Resources, 1982 & 1993. Material prepared by the Region of Peel Planning Department.

Table 3.6.1: Fish Species in the West Credit

Common Name	Scientific Name
rainbow trout	*Onchorhynchus mykis*
brook trout	*Salvelinus fontinalis*
central mudminnow	*Umbra limi*
white sucker	*Catastoms commersoni*
northern redbelly dace	*Phoxinus eos*
common shiner	*Notropis cornuti*
bluntnose minnow	*Pimephales notatus*
fathead minnow	*Pimephales promelas*
blacknose dace	*Rhinichthys atratulus*
longnose dace	*Rhinihthys cataractae*
creek chub	*Semotilus atromaculatus*
pearl dace	*Semotilus argarita*
brook stickleback	*Culaea inconstans*
pumpkinseed	*Lepomis gibbosus*
yellow perch	*Perca flavescens*
mottled sculpin	*Cottus bairdi*

(Modified from Martin, 1984, Bisset, 1996)

In addition, the following species have also been recorded recently:

Atlantic salmon	*Salmo salar*
brown trout	*Salmo trutta*
largemouth bass	*Micropterus salmoides*
brown bullhead	*Ictaluris nebulosus*
redside dace	*Clinostomus elongatus*

* stocked, as fry spring 1996;

** unconfirmed report of sighting upstream of Belfountain Dam (CVC)

Table 3.6.2: Community Classification

1.	Coldwater	Resident brook and/or brown trout;
2.	Probable Coldwater	Mottled sculpin or likely aces for brook/brown trout with exceptional habitat conditions. Unconfirmed and angling reports may be utilized;
3.	Potential Coldwater	With further investigation, could be classified as probable coldwater, or with rehabilitation efforts could be restored to support trout species;
4.	Migratory Coldwater	Spawning nursery or juvenile habitat for Pacific and Atlantic salmon, rainbow trout (steelhead) or lake-run brown trout. Areas utilized for adult migration only will be noted but not assigned a separate classification;
5.	Coolwater	Fantail and rainbow darter northern hog sucker and/or smallmouth bass;
6.	Warmwater	White sucker, largemouth bass, pumpkinseed sunfish or rock bass;
7.	Tolerant Warmwater	Creek chub blacknose dace, brook stickleback;
8.	Special Status	redside dace

Note: Category 1 in the above table would correspond to Type IA in Table 3.6.3 categories 2, 3 and 4 would correspond to Type IB, categories 5 and 6 would correspond to Types II A and B and category 7 would correspond to Type III.

3.6.2 Characterization of the Fishery

Fish such as trout and the forage fish and invertebrates they feed upon take advantage of the diverse features that characterize healthy, stable stream channels. Various forms and features of channels in different locations within a subwatershed are used by fish for various parts of their life cycles. Riffle pools and step pools are important habitats for shelter, food, space and reproduction. The quality of such pools is a measure of the depth, extent, location, and complexity found. Pools provide shelter, feeding and over wintering for many species of fish including trout, suckers, and minnow species. Riffle areas provide shelter and feeding habitat for species such as sculpins, darters, dace, and northern hog suckers. For other species such as brown trout and Atlantic salmon, riffles provide only feeding and reproductive habitat; pools and runs provide them with refuge and shelter. The use of channels by aquatic invertebrates is similar to that of fish species.

Brown trout require rivers with a coarse substrate, well defined and sequenced riffles and pools or step pools, and low levels of fine silts and sands in the riffle substrate. The West Credit River downstream of Belfountain is well suited for most of the life stage requirements of brown trout, although suitable spawning habitat is somewhat limited to small sections of lower gradient found midway between the Forks-of-the-Credit and Belfountain.

Brook trout are, in fact char and have different spawning requirements than brown trout and other true trouts and salmonids. Brook trout are also found in riffle pool and step pool systems as long as suitable spawning habitat is also available. Suitable spawning habitat for brook trout is found in areas rich in groundwater discharges. Spawning redds (or nests) are located within the channel, usually on top of or adjacent to major groundwater seepages, along the margins of the stream or along the edges of a pool where active groundwater seeps occur. Suitable substrate is variable and can include pea-size gravel which is ideal, as well as mixtures of gravels and sands to sand and fine wood debris. Brook trout spawning does not appear to be successful where the substrate is fine silt or silty clay.

The ideal conditions for brook trout spawning on the main West Credit River appear to occur between the Village of Erin and Belfountain, around the intersection of Road 17 and Concession 8 and immediately upstream and downstream of Hillsburgh.

Specific habitat for trout species such as brook trout and brown trout include pools that are relatively deep for the size of stream, ideally with log jams and/or undercut banks and a complex, shallow edge with a mildly irregular shoreline. Ideally this habitat has small amounts of wood debris for fry. These physical conditions are found throughout the main West Credit River with the exceptions noted above.

The Index of Biological Integrity assessment of the West Credit shows that the health of the stream is good. The biomass of a stream, the total amount of living organisms it contains, is a common indicator of productivity. Studies show that the biomass estimates for the West Credit, while slightly lower that those for Black Creek, are still among the highest in southern Ontario.

The economic value of recreational fisheries has only recently been a subject for study in Canada and Ontario. In Ontario recreational fisheries generate 1.2 billion dollars to the provincial economy in direct benefits, and 3-4 billion dollars in indirect benefits (MNR, 1995). While the popularity and value of resident trout fisheries has increased dramatically in the US, England and New Zealand, in Ontario their value has only recently begun to be appreciated. The brown trout fishery in the Grand River (which is based on stocking) has become internationally renowned in a few short years. The brook trout range in Ontario has been dramatically reduced since the early 1900's. Therefore the intrinsic value of self sustaining brook trout populations is very high.

Fisheries resources are only one component of an aquatic system. They are the product of many physical, chemical and biological processes (as summarized in Table 3.6.2); in conjunction with these parameters, they provide a good indicator of the health of the aquatic system. Table 3.6.2 summarizes the factors that control aquatic systems and lists performance standards for different fish community types. The performance standards were developed by Snodgrass *et al* (1996) based on similar watershed/subwatershed studies across Southern Ontario, and have been adapted for the habitat types found in the West Credit Subwatershed.

The target species for fisheries management in the West Credit should be brook trout. It is a self-sustaining native species, and its habitat requirements are the most stringent of all species found in the subwatershed. Protecting groundwater discharge will be vitally important in order to provide spawning habitat and thermal refuge in the summer and winter months. MOEE stormwater quality targets should be Level 1 for the subwatershed (MOEE, 1994) Level 1 protection is a measure of suspended solid removal performance required for fish habitat protection in areas with Type 1 habitat as defined in MNR's "Fish Habitat Protection Guidelines for Developing Areas (MNR, 1994). The suspended solid removal performance is based on different levels of development imperviousness and different types of stormwater management practices, and a subjective relationship between removal rates and lethal/chronic effects of suspended solids on fish.

In general, aquatic habitat quality is good to very good along the main West Credit River from the Forks of the Credit upstream to above Hillsburgh (with the exception of the disruption of ponds and the two urban areas). Despite the high quality aquatic habitat, there are disruptions in the distribution of brook trout in the main stem, likely as a result of the on-line ponds, the two urban areas and the resulting increases in water temperature from these influences.

Groundwater discharges of cold water appear to moderate these temperature changes along certain sections of the river. For example, water temperatures through the Village of Erin are quite warm in the summer for brook trout, but these high temperatures quickly decrease downstream of the village because of groundwater seepages. We begin to find healthy brook trout communities approximately 1 kilometre downstream of the village core. On the other hand, the portion of the main stem beginning about 1 kilometre downstream of Thompson's Pond (the first pond on the main branch of the West Credit River downstream of Sideroad 22) flows through a large wetland complex in which little of the groundwater entering the wetland appears to reach the stream. In this section, although aquatic habitat is moderate, lack of canopy and minimum groundwater discharge result in water temperatures that are unsuitable to brook trout. These conditions improve downstream of Highway 25. For more information on the fisheries of the West Credit River, see Appendix F.

Table 3.6.3: Performance Standards for Aquatic Ecosystem Objectives in the West Credit Subwatershed*

AQUATIC PERFORMANCE STANDARD	AQUATIC ECOSYSTEM OBJECTIVE		
	TYPE IA	TYPE IB	TYPE III
HYDROLOGY • 7Q2 or 3Q2 flow as a proportion of average daily flow April to September	minimum 30%	minimum 30%	minimum 10%
CHANNEL MORPHOLOGY • channel stability	dynamically stable channels with natural	dynamically stable channels with natural	dynamically stable channels with natural features
AQUATIC PERFORMANCE STANDARD	**AQUATIC ECOSYSTEM OBJECTIVE**		
	TYPE IA	**TYPE IB**	**TYPE III**
 • average pool area as % of total surface area • average riffle area as % of total surface area • average minimum summer pool depth	features > 12% > 12% 0.5 metres	features > 12% > 12% 0.5 metres	 > 4% > 10% 0.3 metres
IN-STREAM COVER	minimum total in-stream cover 30-40% by surface area woody debris present up to 10% of surface area minimum 15% of surface area with overhead cover	minimum total in-stream cover 25- 30% by surface area minimum 5% of surface area with overhead cover	minimum 10% of stream area during low flow 10-20% of bottom of pool/backwater habitats covered by logs, vegetation, woody debris and boulder cover at stream margins critical for juvenile fish
SUBSTRATE	well-sorted riffle zones maximum 25% fines in spawning substrates maximum 30% fines in riffle zones upwelling conditions required minimum 50% of riffles composed of cobble, rubble, small boulder	well-sorted riffle zones maximum 25% fines in spawning substrates no upwelling conditions required minimum 30% of riffle/substrate composed of cobble, rubble, small boulders	D50 in pools generally <80 mm fines in riffle zones moderate to low (<50%)

RIPARIAN HABITAT • shaded during 1000 -1400 hours • woody debris	minimum 35% important component of in stream cover and roughness	minimum 20-30% important for roughness and in stream cover	minimum 0%; maximum 70-75% important for roughness and refuge during peak flows
WATER QUALITY • maximum annual water temperature	22 degrees C	26 degrees C	30 degrees C
AQUATIC PERFORMANCE STANDARD	**AQUATIC ECOSYSTEM OBJECTIVE**		
	TYPE IA	**TYPE IB**	**TYPE III**
• average annual total suspended solids • dissolved oxygen (ppm) • spills	< 20 > 5 none	< 40 > 5 none	< 150 > 3-4 none
BARRIERS	remove as feasible	remove as feasible	minimize as feasible
GEOMORPHIC REACH TYPES	B, C, E types	B, C, E[1] types	virtually any
EXAMPLE	upstream from Belfountain (primarily B, C types)	upstream from the forks of the Credit (B type)	Erin mill pond

* Modified from Snodgrass *et al* (1996)
[1] With C-type in close proximity to provide spawning substrate/form

3.6.3 Aquatic Invertebrates

As part of the Phase 1 West Credit Subwatershed study, aquatic invertebrates were sampled to provide information on the state of the aquatic system.

The term "aquatic invertebrates" is used to describe all forms of animals without backbones that reside under water for at least part of their life cycle. This includes everything from microscopic zooplankton to freshwater scuds, worms, leeches, snails, clams and insects. Most of these aquatic "bugs" either absorb oxygen directly through their outer "skin" or use fish-like gills.

Aquatic bugs are a vital part of the food chain: they take nutrients from the water, combine them with energy from the sun, and pass these nutrients on to animals such as brook trout, cedar waxwings, flycatchers, otters, minks and humans. Streams with abundant aquatic bugs also have good water quality, in part because millions of aquatic bugs capture and use the nutrients that end up in the water column. Healthy communities of aquatic invertebrates therefore contribute to a healthy aquatic community in general, and healthy animals that feed on them.

Most of the aquatic bugs that biologists examine in streams and lakes live in water for the first part of their life cycle (as nymphs or larvae) and live out of the water as adults. Aquatic insects that live their complete lives in the water either breathe air occasionally at the surface (like the giant water bug) or capture bubbles of air and take it down with them under water (like the water boatman). Either way, water-dwelling aquatic insects, like their cousins living on land have various requirements for habitat, food and quality of the air or water that sustains them.

Most aquatic bugs live for a year or less. Because of this relatively short life cycle, bug populations can often respond fairly quickly to changes in the aquatic environment. Accordingly, examining the distribution, numbers and diversity of aquatic bugs in streams can be a useful indicator of the health and quality of different stream sections within a subwatershed. Because different types of aquatic bugs require different environmental conditions, distribution of species can identify where environmental conditions vary throughout a subwatershed. In many studies, aquatic bugs that are highly intolerant of various environmental conditions such as high temperatures, high nutrients, low oxygen and differing types of bottom substrates are used to determine the relative quality of the stream and its water. Aquatic bugs can also be used to determine changes in the environment: habitat types, food sources, and areas of toxic or poor water quality where there are high levels of toxic contaminants or nutrients.

There is a good body of scientific literature on varieties of aquatic invertebrates, their life cycles, distributions, habitat and water quality requirements. This information was used to examine the aquatic bugs that were collected in the West Credit River as part of the CURB (Clean Up Rural Beaches) program of the Ontario Ministry of Environment and Energy and Credit Valley Conservation.

Streams that have a mixture of habitat types generally host a great variety of aquatic invertebrates. Some bugs like to live under or on large rocks and boulders in streams, in the gravel of the stream bed, burrowed into the sand or silt of the bed or banks, or on pieces of wood and tree that become water logged in the stream. Some aquatic bugs also have narrow temperature requirements and are found only where water temperatures are relatively cold such as near the discharges of springs and/or the headwaters of streams. The greatest variety of bugs are often found in stream sections with a gravel and cobble bed because this affords the greatest diversity of habitat.

Some sections of streams with soft beds composed of silts and muds may not have large numbers of species but may contain large numbers of a relatively few types of invertebrates. The ultimate control on numbers of bugs in a stream or lake is its the relative fertility or productivity. Productivity is a function of many factors including physical habitat features, temperature and general water quality. Streams and lakes that are alkaline (pH > 7.0) with high amounts of dissolved mineral salts (e.g. calcium and magnesium) and carrying moderate quantities of nutrients (e.g. phosphorus) are much more productive than waters of low pH and low dissolved mineral salts. The West Credit River is quite alkaline with a pH > 7.7 and contains high levels of dissolved mineral salts due to the limestone geology of the area. It is a fertile river for aquatic bugs and has the capability (all things being equal) of producing large numbers of bugs as well as diverse aquatic invertebrate populations.

A general comparison of the types, varieties and numbers of bugs collected at 9 stations on the main branch of the West Credit River and on the north eastern tributary suggests that the water quality is generally quite good. There are differences in the types of bugs found throughout the subwatershed, but part of this is due to the manner of sampling, the types of habitats sampled, the time of year and the consistency of the collection approach. See figure 3.6.2 for a map of the sampling sites.

In general, the types of aquatic bugs that are relatively intolerant of poor water quality (i.e. high temperatures, high nutrient loadings or toxic chemicals) were found at all the stations sampled, although in varying numbers. However, only a few stations appeared to have bugs that indicate exceptional water quality. These stations were located near the Townline Road 1.5 kilometres downstream of the Village of Erin, upstream of the village at Sideroad 17 and 8th line, at the Highway 25 crossing near Sideroad 17 and at Wellington Road 22, and on the Little West Credit Tributary 1.5 kilometre upstream from its confluence with the main branch. The only location where the predatory caddisfly *Rhyacophilia* sp. (representing very good water quality) was found was in the urban part of Hillsburgh upstream of Highway 25. Other aquatic invertebrates indicative of well-oxygenated water such as the stoneflies, freshwater scuds, and native mussels were present throughout the system, even in the stream portion downstream of Highway 24 in the Village of Erin. However, although present, these invertebrates were found in low numbers indicating some form of control on the productivity of this portion of the river for these bugs. This situation was also found in the main branch in Belfountain at the Conservation Area.

Several types of aquatic bugs derive their food by filtering suspended solids out of the water column. These solids can be other small organisms such as zooplankton, early larvae of other bugs and small amounts of particulate organic matter. High loads of suspended solids can come from sources such as ponds, reservoirs or areas of a stream where water is somewhat slow and exposed to sunlight. Net-spinning caddis and blackflies are two species that derive their food in streams by filtering suspended material from the water column. Blackfly larvae are relatively intolerant to organic pollution so that the presence of these bugs in the stream indicates relatively good water quality. Net-spinning caddis can cope with poorer water quality and these bugs are found in good numbers beginning at Townline Road and occurring at every station upstream. The numbers appear exceptionally good in the Village of Erin downstream of Highway 24 and above. The high numbers of net-spinning caddis upstream of the Village of Erin upstream and not below may be due to the large ponds and wetland sections on the West Credit River from Townline Road upstream. Below Townline Road, the stream gains more groundwater, has no more major riverine wetlands and no on-line ponds until it reaches the dam in the Belfountain Conservation Area.

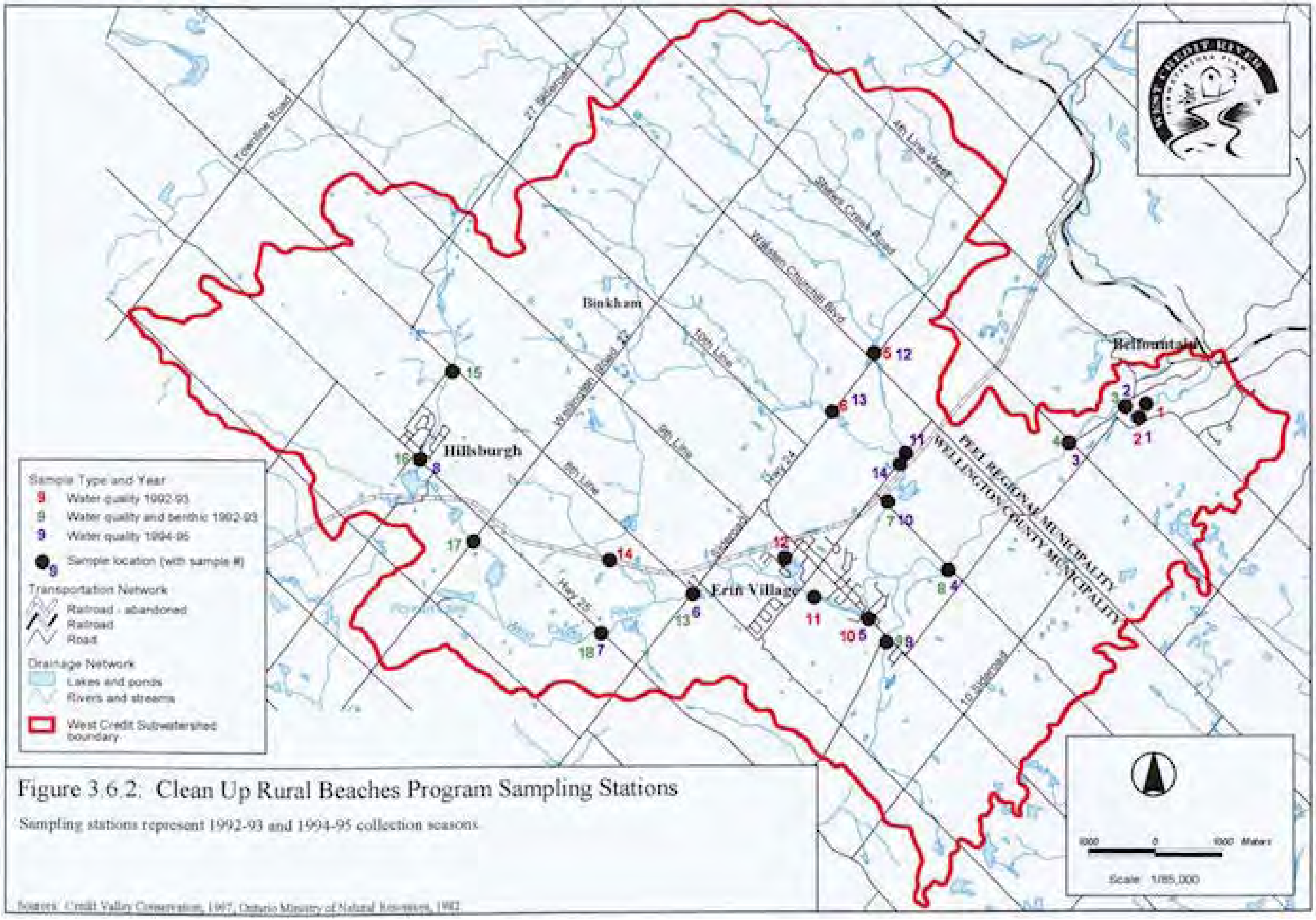

Figure 3.6.2: Clean Up Rural Beaches Program Sampling Stations

Sampling stations represent 1992-93 and 1994-95 collection seasons.

Sources: Credit Valley Conservation, 1997; Ontario Ministry of Natural Resources, 1982

The variety of aquatic bugs throughout the subwatershed suggests that the river is generally healthy and is not over-enriched or suffering from bad water quality. However, the limited numbers of individuals in any particular invertebrate group found in some sections of the river (such as in Belfountain, in the Village of Erin and upstream of Hillsburgh) suggests that habitat and/or possibly temperature stresses are limiting the potential numbers of aquatic bugs that the river can sustain.

3.7 Water Quality

The water quality of West Credit Subwatershed is good in comparison to the main Credit River system. Within the Credit River Watershed, the West Credit Subwatershed has the lowest values of total phosphorus, chlorides and has some of the coldest temperature regimes. This is a function of limited urbanization, hydrology, and the extensive riparian vegetation in stream corridors. Bacterial levels are high in the West Credit Subwatershed relative to the remainder of the Credit River Watershed, which led to the initiation of a recent CURB (Clean Up Rural Beaches) study to identify causes and potential solutions.

The water quality analysis carried out as part of the West Credit Subwatershed Plan identified a few specific problem areas, particularly related to microbiological parameters. Densities of the microbiological water quality parameter *E. coli* are elevated throughout the subwatershed, and a particular problem at the Belfountain Conservation Area where swimming has been prohibited on a frequent basis and in the Village of Erin area where septic tank and leaching bed failures were perceived to be a problem. It is suggested that the chloride budget can be a useful tool for checking a water quality model for the subwatershed.

3.7.1 Implications of Basin Hydrology

Basin hydrology is important in the evaluation of surface water quality because it defines the flow pathways from various human activities to receiving waters. Significant aspects of basin hydrology include the following:

1. Baseflow is estimated to constitute 45-50% of the total volume of runoff from the subwatershed. This means that rainfall and snow infiltration into aquifers and aquifer recharge of baseflow is as dominant an element in basin hydrology as is overland flow.

2. As a hydrological indicator for fish habitat, the ratio of baseflow to average annual flow volumes indicates that habitat is appropriate for cold water communities since its value is 45- 50%.

3. Infiltration and baseflow recharge can be a dominant pathway for directing and influencing surface water quality. This pathway is significant in modelling the relationships between land management practices and human activities and the concentrations for

nitrates and chlorides in receiving waters. The actual magnitude of overland transport versus infiltration/ baseflow transport of these substances is not known because modelling of these substances has not been carried out to the extent necessary to confirm this premise.

3.7.2 Bacteria

Bacteria or microbiological parameters describe whether the receiving water is swimmable and/or potable without disinfection. The key water quality measure for swimming is the level of one type of bacteria, *E. coli*. Key points relating to bacterial contamination are listed below:

1. There is evidence that the West Credit is polluted with *E. coli* during the swimming season. The bacterial densities are generally above swimming guidelines in dry weather, and substantially above guidelines during wet weather.

2. A mathematical model was developed during the CURB study to determine the relative significance of sources of bacteria, but the model calibration is suspect. Accordingly, inferences concerning the relative magnitude of sources can be drawn only from a review of existing monitoring data. The spatial data suggest that the major source during wet weather is diffuse overland flow from rural areas, in addition to urban areas (Soucek, 1994).

3. Significant contamination of the West Credit by private sewage systems appears to be mainly centred below the Village of Erin, and only during wet weather conditions. The flow pathway is probably from septic systems through saturated near surface soils to the stormwater systems which drain the streets of specific subdivisions. There is no apparent contamination of the Regional aquifer by septic systems in the Village of Erin area.

4. Best Management Practices are being applied to high profile sources of *E. coli* in a gradual fashion. It is unclear whether these measures will have a significant effect upon bacterial densities in the receiving waters.

3.7.3 Stream Temperature

One of the issues raised by the public and stakeholders was a concern that stream temperatures are increasing. Recent data shows average temperatures of 19.5°C, which is above the target temperature of 18°C for healthy coldwater communities temperature. Temperature impacts are attributed to ponds, groundwater impacts, land use impacts and loss of riparian cover. Note that the watershed plan for the Credit River set the target temperature for the West Credit Subwatershed at 20°C. The target has been redefined to address the most sensitive trout species in the subwatershed, brook trout. If exposed to temperatures above 18°C on a regular basis, brook trout populations can become stressed.

The large portion of baseflow is a critical element in providing adequate habitat for cold water fish species and determining whether ecological objectives such as brook trout can be maintained. Adequate cold baseflow and adequate riparian cover can be used as a planning tool for predicting whether stream temperatures are likely to be appropriate for resident coldwater communities such as brook trout, or whether the community will shift to cool water communities. It is the hypothesis of this report that stream temperature is likely the key water quality parameter with power for predicting the presence of coldwater communities.

Where water temperature is the dominant habitat issue, different models can be used to establish design objectives in order to achieve a cold water community objective (such as Barton *et al* 1983).

3.7.4 Chlorides

Chlorides are used in this report in three ways:

- as a long-term indicator of the effects of anthropogenic sources and changes in the magnitude of these sources;
- as a parameter for checking on flow models; and
- as a tracer of specific contaminant sources (i.e., the role of urban hamlets on subwatershed water quality).

1. The chloride concentrations in the subwatershed are 15-40 mg/L which is well below the Provincial Water Quality Objectives. The Water Quality Objectives are aesthetically based, which means that at the threshold of 250 mg/L as chlorides, some people can characterize the water as tasting salty.

2. Chloride concentrations in the subwatershed have approximately doubled over the past two decades.

3. Chloride concentrations in the subwatershed increase from the order of 15 mg/L in headwater tributaries, the north-east tributary and upstream of Hillsburgh, to the order of 35 to 45 mg/L at the mouth station. There are increased concentrations measurable through Hillsburgh and the Village of Erin but not through Belfountain. The consistently measured increase of chlorides between CURB stations 5 and 4 (see figure 3.6.2, 1994 - 95 sampling sites) does not appear to be explained by locations of the town centres.

4. There is no significant seasonal trend in concentration evident from the 28 year provincial monitoring record. This indicates that the effects of road salt on chloride concentrations in receiving waters are not discernible.

5. The provincial monitoring station, located where Winston Churchill Boulevard crosses the

main West Credit, measures most of the longitudinal increase in chlorides in the subwatershed. Hence, its continued existence provides a reasonable monitoring point for auditing the success of the subwatershed plan, and can continue to be used as a benchmark for examining the effects of any future development upon subwatershed water quality as measured by chlorides.

6. An estimate of the significance of different chloride sources are as follows:

Background (5 mg/L)	12%
Road salt from infiltration	23%
Rural animals - infiltration	15%
Rural septic systems	0.2%
Rural softeners	10%
Rural animals - overland	0.8%
Urban septic systems	0.5%
Urban water softeners	22%
Urban stormwater	14%
Total	100% (147,000 kg/month)

(Murphy, 1995; Burnside, 1996)

This estimate should be used with caution until further data evaluation validates some of the key assumptions (such as the number of water softeners in the subwatershed and the amount and frequency of road salt applied in the winter).

The following points can be made about the chloride budget:

- Infiltration is the dominant way that salt reaches the West Credit (septic systems and softeners essentially discharge to shallow groundwater sources).

- Approximately 36% of the loadings are from urban human activities, 11% from rural human activities, 16% from rural animals, and 25% from road salt.

- Sodium chloride (used for softeners and road salt) constitutes close to 60% of the total loadings.

- Farm animals are the dominant source of the mammalian population. Humans as mammals discharge less than 1% through septic systems in both rural and urban areas. No estimate has been made for the contribution from wildlife and farm pets.

3.7.5 Eutrophication

Eutrophication is the process of nutrient enrichment in aquatic systems. Eutrophication occurs naturally over geologic time but can be dramatically accelerated by human inputs of two key nutrients - phosphorus and nitrogen. In the West Credit, phosphorus is likely the limiting nutrient.

Based on concentrations of total phosphorus and invertebrate species present, the West Credit's streams can be classified as being in the oligotrophic - mesotrophic range. This means that the water quality in the streams is good. However some ponds in the lower West Credit appear to be well-nourished based upon the presence of algae in the summer time. Overall, good water quality is maintained because of present agricultural practices, the extensive amount of riparian vegetation, and the large amount of base flow.

3.7.6 Total Nitrogen

The total nitrogen (TN) concentrations average approximately 1.6 mg/L in dry weather (75 to 80% is nitrate) and 1.9 to 2 mg/L in wet weather (57 to 80% is nitrate). There are no water quality objectives for TN. Most of the TKN (Total Kjeldahl Nitrogen) is organic nitrogen, as the ammonia concentrations are approximately 0.02 mg/L. The nitrate concentrations of 1.2 to 1.4 mg/L in surface waters are an order of magnitude below the drinking water limit for humans of 10 mg/L which is based upon human health considerations.

There is no significant seasonality apparent in TKN levels. There is a small seasonal effect in nitrate concentrations ranging from median concentrations of 2.4 mg/L in February to 1.3 to 1.6 mg/L from March to October.

The creeks of the subwatershed have essentially the same concentrations of nitrate, TKN, and total phosphorus, indicating the dominant influence of rural land uses (farming) on these parameters. This is also reflected in the estimated sources of total nitrogen uses and loadings (5,100 kg/month)in the subwatershed of:

Rural areas (farming, woodlots etc.)	68%
Rural septic tanks	7%
Urban hamlets septics and storm water runoff	25%

(Murphy, 1995; Burnside, 1996)

There is one exception: two stations (11 and 12) located on the northerly stream of the north east tributary, have close to zero nitrate concentrations, large TKN concentrations and elevated TP concentrations (see figure 3.6.2, 1994 - 95 sampling sites). This suggests that the nitrogen dynamics are mainly influenced by decomposition and release of nitrogen from wetland and other vegetation in this tributary.

3.7.7 Total Phosphorus

Measurement of total phosphorus (TP) at the provincial water quality monitoring station over the last 18 years showed concentrations on the order of 0.02 mg/L. A median concentration of 0.019 mg/L was found for the recent 5 year period. There is little apparent seasonality in the data. These values are below the Provincial Water Quality Objectives of 0.03 mg/L for flowing waters, a target which is based upon eutrophication objectives. Spatially, the CURB data indicate larger TP concentrations in the upper subwatershed and lower concentrations below Hillsburgh during dry weather conditions.

These total phosphorus concentrations are much lower than many other streams in Southern Ontario dominated by farming activities. The nitrate concentrations of 1 to 2 mg/L are similar to those observed in streams dominated by agriculture. The lower TP concentrations may reflect the presence of a well-buffered vegetated strip along the streams which minimizes phosphorus inputs into the stream.

The estimated significance of different sources of phosphorus is:

Rural areas (farming, woodlots etc.)	90%
Rural septic tanks	3%
Urban hamlets septics and storm water runoff	7%

(Murphy, 1995; Burnside, 1996)

This reflects the dominance of agricultural practices in the subwatershed TP budget. The estimated application of total phosphorus to the lands is 1200 kg/month.

3.7.8 Great Lakes Issues

Watershed management objectives have also been set at the Great Lakes Basin scale with respect to eutrophication, toxic chemicals, water levels, exotic species, contaminant levels in fish and other issues. The most significant achievement at the Lake Ontario scale in the past twenty years has been the reduction of total phosphorus loading to meet eutrophication objectives. For the Credit River Watershed, this means that the total phosphorus goal is no net increase in loadings to Lake Ontario as future land development occurs.

The allocation of the goal of no net increase in phosphorus loadings among the subwatersheds was not definitively established in the Credit River Water Management Strategy. However since urbanization of pasture and wooded areas will increase the nutrient concentrations in stormwater runoff, and since the increase in volumes of runoff associated with impervious cover of urbanization would increase loadings, it is probable that we will need an objective of no net increase in loadings for each subwatershed to achieve the overall goal. This will mean an objective of no net increase in total phosphorus loadings for the West Credit Subwatershed.

It is recommended that any future development in the subwatershed, including the potential installation of a wastewater treatment plant at the Village of Erin, address this criteria.

3.7.9 Recommendations for the Future

Future Development Applications

1. Any future development in the subwatershed, including the potential installation of a wastewater treatment plant at the Village of Erin, should address the criteria of no net increase in total phosphorus loadings to the Lower Great Lakes.

2. The unit yield approach provides a reasonable method for modelling flow at different locations in the subwatershed, and for evaluating the impact of development activities upon stream water quality.

3. A chloride budget provides a tool for checking a water quality model. It is concluded that (i) the source budget developed in this study is reasonable and that (ii) the calculation framework, when distributed according to the spatial location of rural residents, village residents, and farm animals, provides a reasonable basis for understanding relationships between land-use/human activities and stream water quality. Hence, the modelling framework can be used for future extrapolation and impact assessment purposes.

   Prior to using these assumptions for extrapolation purposes, an effort to re-calibrate the assumptions with the observed concentrations in the West Credit should be undertaken as a further check on the assumptions. The checking process would also be strengthened if population estimates in the subwatershed, water softener use, road salt applications for the past 50 years, and well water concentrations were reviewed.

4. Future impact assessment models should partition the hydrological model into groundwater and overland hydrological pathways. Such a partitioning provides estimates of loadings through groundwater pathways for substances such as nitrates and chlorides - substances which are highly soluble and whose loadings are significantly influenced by memory (inputs into the subwatershed several months to years ago). Introducing hydrological partitioning in the model would improve the predictive capability of the mass balance approach for chlorides and nitrates.

   The hydrological partitioning approach was used for the Credit River Water Management Strategy. However, the assumption of conservative behaviour for nitrates on a watershed scale can be challenged due to denitrification reactions as groundwater moves from aquifers through wetlands to become baseflow in streams. To complete a calibration for the partitioning of hydrological pathways, ambient chemical data for springs and aquifers should be assessed.

5. Criteria concerning the limitations of this study for considering development applications should be developed by the CVC and partners.

Further Data Synthesis

1. Data for a variety of other water quality parameters (major cations, anions etc.) have been gathered but not analyzed. They provide a basis for looking for markers for the influences of groundwater and soils on major ion chemistry. It would be useful to address these deficiencies in the information base to complete integration activities, and for future development considerations

Hydrology

1. Present hydrological data and models have not been summarized sufficiently to establish the ratio of baseflow to average annual volumes for stations on the West Credit other than at the Water Survey Gauge. The ratio of baseflow to average annual volumes is a hydrological indicator of fish habitat for cold water communities, and the likely dominance of infiltration and stream recharge as the pathway for substances such as chlorides and nitrates. It would be useful to know this.

2. Additional hydrological synthesis is needed as a future integration activity to establish quantitative relationships between basin hydrology, flow pathways, stream geomorphology, aquifer sizes and locations, riparian canopy and stream water quality. This synthesis is needed to provide a quantitative integrative framework for the subwatershed for impact prediction purposes. This activity has not been carried out because it was beyond the scope of Phase 1 of the West Credit Subwatershed Study.

Microbiological Contaminants

1. Current models which were calibrated to estimate the relative significance of different sources were critically reviewed and concluded to have been miscalibrated because the significance of sources is inappropriate. Re-calibration studies should be undertaken before this model can be used to estimate the relative significance of sources and for assessing impact. Re-calibration would involve critically evaluating the original calibration from MTRCA and other data sets, spatially laying out the sources of *E. coli* by sub-basin within the West Credit, and examining the spatial distribution of density data.

2. Present management efforts should be systematically documented and their effects evaluated for the subwatershed scale.

3. Additional biotracer tests should be undertaken for Hillsburgh to confirm or reject the premise that the Village of Erin subdivisions are the major source of private septic

pollution in the lower West Credit.

Temperature and Baseflow

1. For rehabilitation schemes, the empirical models of Barton *et al* (1983) can be used to evaluate the potential effectiveness of the scheme in terms of stream temperature.

2. For evaluating the impact of a proposed development upon stream temperature, a mathematical temperature model, based upon the principles of heat balance, coupled with a landscape architect-vegetation canopy model are the appropriate tools.

3. The empirical models of Barton do address the combined effect of baseflow and canopy on stream cooling. However in terms of management, it is unclear the degree to which the cooling rate in the streams studied by Barton was provided by cold groundwater recharge waters, versus that provided by shading of the riparian canopy. It is recommended that a future study go back to those streams and measure both temperature and baseflow.

For more information on water quality in the West Credit Subwatershed, see Appendix G.

3.8 Recreation and Conservation Lands

3.8.1 Current Situation

Public ownership of conservation lands occurs for a variety of reasons and meets the needs of many interests. Conservation land in public ownership in the West Credit Subwatershed has been acquired for the following reasons:

- **Protection:** The primary reason for public ownership of conservation lands is to protect significant and/or representative natural areas of importance to the community. Land types falling into this category can include: lands to be stabilized, restored or enhanced; undisturbed natural communities; significant wildlife and fisheries habitat; flood plain and stream corridors; wetlands and ponds; and sites of high groundwater discharge.

- **Appreciation:** Conservation lands are often in public ownership to provide opportunities to understand natural features and functions. Appreciation opportunities are created by providing access to and information about an area. Program orientation is often (but not always) directed at the impacts human activity have on natural processes.

- **Recreation:** As "protected" natural areas, public conservation lands can be suitable for selective outdoor recreation activities requiring high quality natural environments. Currently, the dominant recreation activities taking place in the subwatershed's conservation lands are trail activities, fishing, bird watching and picnicking.

Figure 3.8.1 illustrates the publicly-owned conservation lands and recreational trails in the subwatershed. The public conservation lands are listed below.

Willoughby Estate

Designated through the Niagara Escarpment Plan as largely Escarpment Natural Area and classified as a Natural Environment Park, the Willoughby Estate is owned by the Ontario Heritage Foundation and managed by CVC. The Willoughby Estate is dominated by upland deciduous, mixed slope and lowland coniferous forest communities. The upland portion of the property is an Escarpment promontory providing a scenic vista of the Forks of the Credit and Devil's Pulpit area. The steep slope and lowland areas have been formed by the West Credit River as it cuts its way down the Escarpment. The land was acquired to provide protection to the natural features of the area and in recognition of its natural and cultural interpretive values. No formal access facilities are presently provided on site. In 1990, an Interpretive Trail Plan was prepared based on cultural and natural data collected in the 1980s. This plan includes trails planned for the Cox Property.

Belfountain Conservation Area

Designated through the Niagara Escarpment Plan as an Escarpment Natural and Protection Area and classified as a Recreation Park, Belfountain Conservation Area is owned and managed by CVC. Adjacent to the Willoughby Estate, the conservation area is an upstream extension of the valley corridor created by the West Credit River described in the Willoughby Estate lands. The core of the conservation area is an active day use park with picnic grounds, manicured gardens, stone works, dam and head pond, beach, loop trail, parking lot and washroom facility. Dominant activities include scenic viewing, picnicking, fishing and walking. Water quality in the river fluctuates and as a result the beach facility is frequently closed. Last revised in 1984, the Belfountain Conservation Area Management Plan is dated and should be integrated with the newer Willoughby Estate lands.

Credit River Pine Estate Park

This forested wetland and river corridor includes the confluence of the main branch of the West Credit and the eastern tributaries. This property was dedicated to CVC by the developer of the estate subdivision that borders the property. Located in Erin Township and adjacent to Erin, the property was acquired as a natural area to be protected through public ownership. At present no formalized recreation or appreciation activities occur, however the site is valued locally as a site for passive leisure activities. There is no management plan at present for the site.

Woollen Mills Conservation Area

Located upstream of Credit River Pine Estate Park and on the main branch of the West Credit River in the Village of Erin, the 8 acre Woollen Mills Conservation Area is owned by CVC and leased to the village for use as municipal parkland. The conservation area contains the limestone ruins of the Woollen Mill (1840), a modestly forested flood plain and the McMillan's Mills Trail created as part of the Village of Erin's extensive walking trail system. While trail location and mill ruin studies have been recently been completed for Woollen Mill, no formal management plan has been prepared for this small conservation area.

Alton Forest (Forest Conservation Area #1)

Straddling the West Credit Subwatershed and Subwatershed 18, the portion of the Alton Forest within the West Credit Subwatershed contains about 30 acres of white and Norway spruce, red and white pine, and red oak plantation. The remaining forest (another 30 acres) is upland deciduous. These forest communities provide a direct linkage to forest communities in the adjacent subwatershed. No formalized recreation or appreciation activities presently occur on site. The Alton forest management plan was last revised in 1989. The remaining 40 acres of the Alton Forest lies in an adjacent subwatershed.

Elora Cataract Trailway

The Elora Cataract Trailway is a 47 kilometre recreational trail established on the former Canadian Pacific Railway branch line that serviced the rural communities of north Wellington, south Dufferin and west Caledon. The character of the Trailway is strongly influenced by the earth science features it travels over and the life science communities it passes through. As one might expect with a built facility such as an abandoned rail line, the features found within the corridor are often not as significant as the features just beyond it. One of the greatest strengths of rail lines that have been converted to trails is that they create new opportunities to view and access natural and cultural areas. This is certainly the case with the Elora to Cataract Trailway. Approximately 11 kilometres of the Trailway passes through the subwatershed. A management plan was prepared in 1995 to guide development and use of the Trailway. In addition to its recreational benefits, the plan recognizes that the Trailway must serve as a linear greenway providing linkages between larger natural areas. As such, the plan contains a long term objective of enhancing vegetative cover along its length through the establishment of native plant communities.

The Elora Cataract Trailway is an important recreational corridor as it is linked to other recreational trailways that run through or adjacent to the subwatershed such as the Alton Side Trail, the Grand Valley Trail and the Forks of the Credit/Bruce Trail system.

3.8.2 Planning for the Future

Once the location, extent, significance and sensitivities of natural systems in the subwatershed have been documented through the West Credit Subwatershed Plan, there will be a need to develop strategies for public access to environmental resources. As people become more aware of the natural landscape of the subwatershed, it is anticipated that pressure will increase for access to natural areas for recreation and appreciation. If properly managed, increased public access to the subwatershed's natural areas is a good thing. It will foster a greater understanding of natural area form, function and value, and will engender a greater commitment to protection of resources. Increased opportunities for outdoor recreation and nature appreciation will contribute to individual and community health.

However, there must be recognition that there are limits to how much human interaction a natural system can sustain. It is well understood that unmanaged or inadequately planned development can negatively impact on the quality and quantity of environmental resources. Less recognized is the potential for unmanaged recreation and leisure activities to cause adverse impacts on the form, function and linkages of natural systems.

It is recommended that a management planning process be undertaken for activities proposed on existing or future conservation lands. This process should measure the overall benefit of an activity to the community and consider its impact on the natural area. In addition, there should be an analysis of the effect of proposed activities on the subwatershed and watershed as a whole. Through this process, it may be determined that in some instances activities of a more active nature are appropriate.

There has been some discussion of a West Credit Trail being established. This raises many issues. The most prominent of these is the sensitive nature and high protection priority placed on most of the valley land in the subwatershed. The valley land functions as one of subwatershed's major habitat linkages. A trail through the length of the main West Credit may impair this function. In addition, the lack of public ownership of this corridor makes the development of a trail difficult. An acceptable alternative would be to use the Elora Cataract Trailway as the main trail route and create side trails to loop through selected natural areas. This would provide recreation and appreciation activities while protecting natural corridor functions of the West Credit River. The location and extent of this trail network would require further research, planning and consultation.

As noted in section 3.4 (Terrestrial Systems), the West Credit Subwatershed currently has a combined forest, plantation and wetland coverage of 29.1% (15.4% forest and 13.7% wetland). Over the long term, this forest coverage is to be increased through restoration efforts to 30% of the subwatershed. Public conservation lands are located in approximately 3.1% of these natural areas: in total less than 1% of the subwatershed is public conservation land. This measure is quite low when compared to other subwatersheds.

The "Conservation Areas Strategy for the Credit River Watershed" recommends a target for public conservation land of 9% for the Credit River Watershed (all the land and tributaries that drain into the Credit River). The strategy recognizes that ownership (including the process of acquiring land) is a broad term that is meant to include such mechanisms as conservation easements, donations, dedications, land acquisition and stewardship agreements. The strategy also recognizes that ownership of public conservation lands falls to a range of agencies and levels of government. There is a great opportunity to not only improve the quantity and quality of resources in the West Credit Subwatershed through a public conservation land program, but to contribute to the overall target set for the entire watershed.

The terrestrial component of the West Credit Subwatershed Plan recommends that 92% of the natural areas in the subwatershed be designated as medium to high priority for protection. Given the importance being placed on these areas, it is recommended that appreciation and recreation activities be passive in nature in them. Passive activities are those that do not require the support of built infrastructure such as buildings, roads and servicing in natural areas. Hiking or walking on trails, fishing, photography, bird watching and other activities with an element of appreciation to them are considered to be passive in nature. Even some of these activities, if pursued by large numbers of people or in highly sensitive areas, can be a concern for the integrity of natural areas.

3.9 Mapping and Data Management

In carrying out Phase I of the West Credit Subwatershed Study, a number of spatial data sets were collected from various government bodies, municipalities, private sector firms and individuals. Data collected included the geographic location of: land uses, wetlands, woodlands, ESAs, ANSIs, potential sand and gravel sources, licensed pits and quarries, contours, fish and water quality sampling locations, fry locations, physiography, soils, trails, rivers, streams and ponds, lot and concession lines, roads, railways and publicly owned land. A complete list of data sources and data types can be found in Appendix H.

Collection of this data allowed the study team to map the following:

- land use;
- elevation contours;
- soils;
- physiography;
- recreation and public conservation lands
- resources (potential sand and gravel resources, licensed pits and quarries, fisheries, and publicly owned land and trails); and
- terrestrial habitat (including natural forests, plantations, wetlands, ESAs, ANSIs, habitat units, connectivity, and potential rehabilitation areas).

These maps were used across disciplines and are used in this report and in its Appendices.

3.10 Public Involvement

The study was kicked off with a Subwatershed Partners Workshop that was held in June 1993. The councils of the three participating municipalities participated in this Workshop, and agreed that a subwatershed study was necessary and agreed to pursue funding. The Phase I study was initiated in the Fall of 1994.

The goal of the public consultation process during Phase I of the West Credit Subwatershed Study was to encourage the public to provide guidance for the study. Involving the public from the outset of the study was extremely beneficial. The important issues in the subwatershed were readily identified by people at the first public meeting: this gave the study a slightly new direction. Members of the public also provided pertinent information on how environmental conditions have changed in the subwatershed, for example, how levels in wells have dropped and how the fishery has changed.

3.10.1 Public Meetings

Three public meetings were held during Phase I of the Subwatershed Study. The first public meeting was held on June 11, 1995 at the Erin Community Centre in the Village of Erin. A slide show tour of the subwatershed was presented. Art on the theme of the local environment prepared by the children of Erin Public School was also on display. This encouraged parents to attend. After presentations by CVC staff, residents asked questions about the study and raised concerns about the water resources of the subwatershed. To elicit more detailed information, a questionnaire was mailed to all those who attended the meeting or expressed interest in the study. Recommendations from the public allowed the study team to identify the top ten public issues, develop a vision for the subwatershed, and address public concerns in the study.

A second public meeting was held on August 3, 1995 at the Township of Erin offices in Hillsburgh. This meeting used a workshop format, and those attended worked in small groups aided by facilitators. The topics discussed included water quality, aggregates, recreation, groundwater and a vision for the subwatershed. Participants' comments on the various issues in the subwatershed were recorded.

A third public meeting was held on June 27, 1996 at the Erin Municipal Office in the Village of Erin. An open house format was used, with many displays set up. On a drop-in basis, participants could look at maps of the subwatershed that provided information on physiography, soils fisheries, flood lines, terrestrial resources, public land and trails, and a 3-dimensional topographic map of the subwatershed. Visitors could also take a "video flight" over it, connect to the CVC Web Page on the internet, view an aquarium of fish from the river, and join in on a hands-on children's display. A working groundwater model was on display to help explain how groundwater flows to the river and how wells affect the groundwater system. Again, children's art on an environmental theme decorated the walls.

A fourth public meeting was held on June 4, 1997 to present the results of the Study. After the presentation there was an open house where the public could view the maps from the study, and visit many of the interactive displays such as examining insects gathered in the area and view 3- D air photos of the subwatershed.

3.10.2 Other Activities

During Phase I of the subwatershed study, many other activities took place to promote awareness and encourage participation. Three newsletters were published that provided information on the study, the history of the area, study findings and related information. Articles on the study accompanied the ads that were used to promote public meetings. This helped to generate interest in the meetings. Copies of the newspaper ads were posted in municipal offices, libraries, arenas and community centres.

In addition to preparing art on an environmental theme, a class of grade ⅔ students at Erin Public School were given a presentation on water and rivers and asked to design the cover of this report, as well as the covers of the appendices.

4.0 INTEGRATING THE STUDY COMPONENTS

4.1 Characterizing the Subwatershed

The characteristics of subwatersheds are created by the interplay of physical and chemical processes such as precipitation, weathering, and erosion. The form of a subwatershed is created by the earth's climate interacting over time with the geology of the landscape. Geology provides the type of rock and topography; climate provides the precipitation and conditions over time that modify the landscape so that soils are built up, glaciers form and melt, and rivers and lakes are created. Vegetation is influenced by an area's topography, soils and climate.

A subwatershed ecosystem is therefore an interplay between the non-living materials (bedrock, soils and water) and the living organisms that exploit and modify the processes and forms of the non-living components. An understanding of how water moves over and through the West Credit Subwatershed, the functions it performs, and the materials it carries is fundamental to understanding the past, present and possible future states of the subwatershed.

4.1.1 The Water Cycle

The geology and topography of the West Credit Subwatershed in association with its climate have created an ecosystem in which large amounts of precipitation infiltrate soils and aquifers, yielding a subwatershed with very active and abundant groundwater resources. The areas of major infiltration, called recharge zones, are locations where the surficial geology is comprised of materials such as gravels and sands into which water can readily soak. Over 50% of the subwatershed area has this function (See Figures 4.1.1 and 4.1.2). These infiltration areas are linked to specific surficial features such as gravel moraines; they recharge water both to local water tables and to the regional aquifer. The remainder of the subwatershed is comprised of soils that do not infiltrate water very readily. These areas are associated with fine soils of tills, clays and silts. Here precipitation moves off the land primarily as surface run-off.

In addition to recharge areas and surface runoff areas, there are discrete locations within the subwatershed which function as major groundwater discharge zones. These locations exist where there is an intersection between the appropriate geologies and either local or regional water tables. Some of these discharge zones have created riparian wetlands such as the wetlands found upstream and downstream of the Village of Erin, while other discharge zones lie within streams themselves (e.g. downstream of Belfountain). Discharge areas in streams (upwellings) add to the flow volume which in turn provides living space for aquatic animals. Much of the infiltration of precipitation that occurs in the West Credit Subwatershed serves to replenish the more extensive regional groundwater system. This does not mean that groundwater from local recharge areas is not available to the subwatershed but rather that a larger proportion of water moves through the regional system contributing to an area larger than the West Credit River alone.

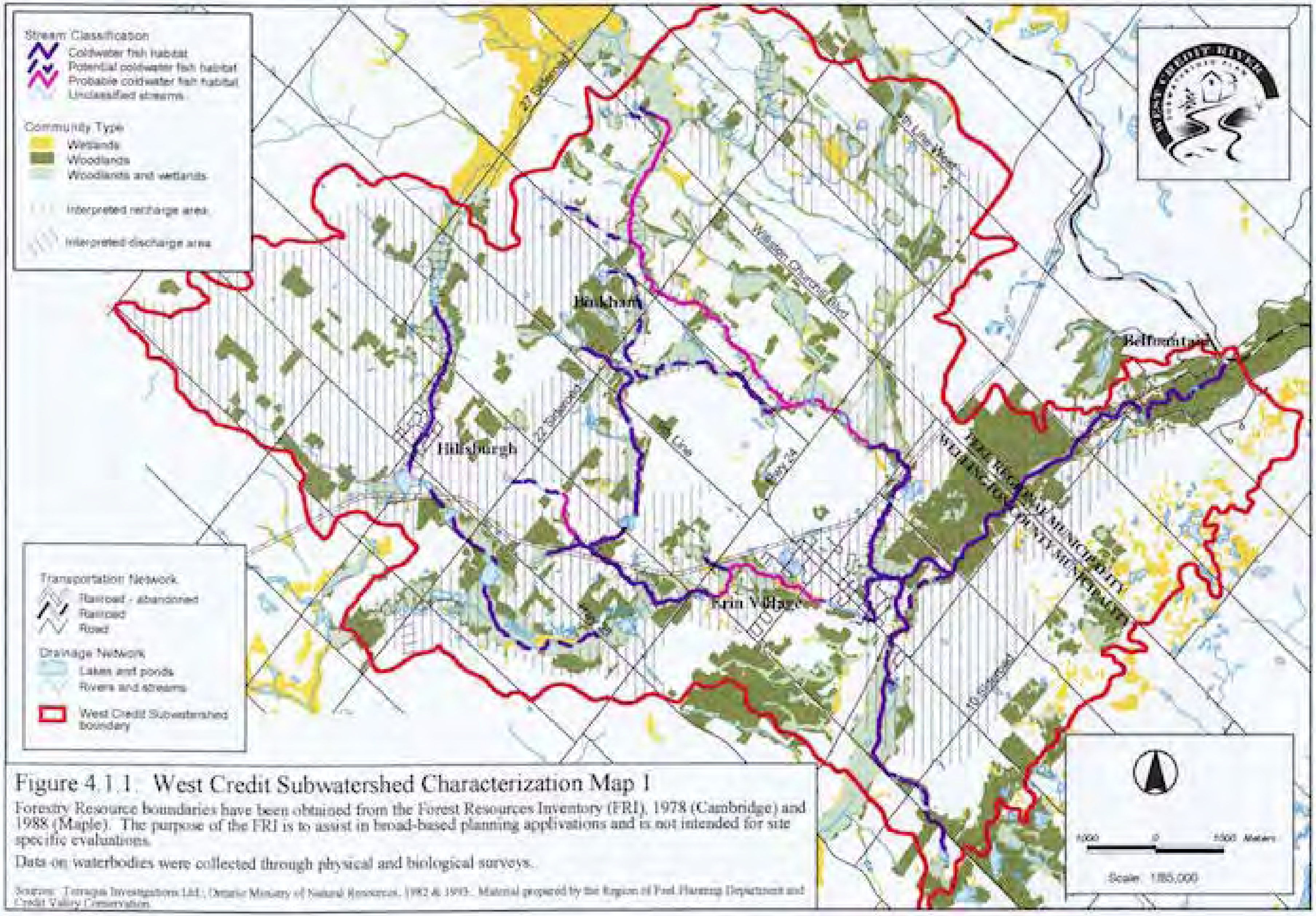

Figure 4.1.1: West Credit Subwatershed Characterization Map 1

Forestry Resource boundaries have been obtained from the Forest Resources Inventory (FRI), 1978 (Cambridge) and 1988 (Maple). The purpose of the FRI is to assist in broad-based planning applivations and is not intended for site specific evaluations.

Data on waterbodies were collected through physical and biological surveys.

Sources: Terraqua Investigations Ltd.; Ontario Ministry of Natural Resources, 1982 & 1993; Material prepared by the Region of Peel Planning Department and Credit Valley Conservation.

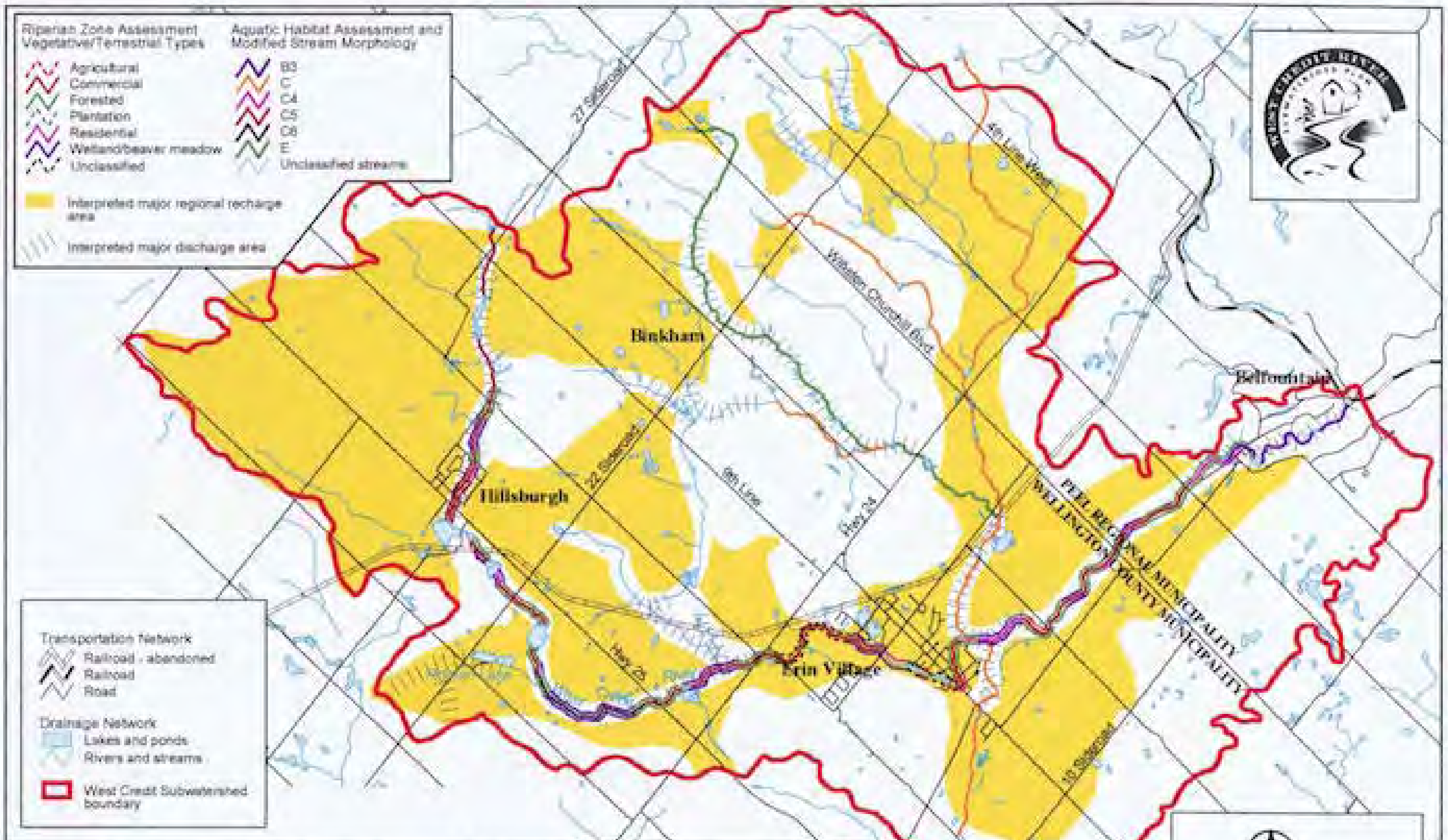

Figure 4.1.2: West Credit Subwatershed Characterization Map 2

Data on waterbodies were collected through physical and biological surveys.

Regional recharge areas may also contribute to local groundwater systems.

Lines running adjacent to main stream channels represent riparian zones.

Sources: Credit Valley Conservation, 1997; Terraqua Investigations Ltd.; Ontario Ministry of Natural Resources, 1982 & 1993. Material prepared by the Region of Peel Planning Department and Credit Valley Conservation.

Because of the extensive amount of porous soils within the subwatershed, the West Credit River has relatively moderate flooding on an annual basis. As well, because of the porous soils and nature of the topography, the West Credit River has a significant amount of groundwater contributing to its low flow volumes. Baseflow in the West Credit River is estimated to constitute 45-50% of the total flow volume of runoff from the subwatershed which is 10 - 50 times higher than watercourses such as Cooksville Creek in Mississauga (City of Mississauga, 1996). This relatively high percentage of flow from groundwater creates a stream system that is very stable with moderate bank erosion and channel change. Streams of this kind are also characterized as having moderate flood potential, relatively long higher flow periods, slower response time to sudden severe storm events and relatively consistent low flow volumes. All these characteristics create very good conditions for aquatic animal populations.

The volume of groundwater discharge dictates the extent of the benefit to the local ecosystems whereas the distribution of discharge controls the type of ecosystem that will benefit. For example, local groundwater flow into the main West Credit River and the lower portion of the Binkham tributary occurs through seepage into the base of the valley slopes approximately 50-100m from the streams. The groundwater discharging at the base of the valley slopes moves through and over the saturated soils of the flat valley bottom, providing the ideal opportunity for the development of a wetland system adjacent to the stream. However, because of the wetland vegetation, most of this cool groundwater is used up and transpired by the vegetation before reaching the stream or warms up as it passes through the wetland soils. Low flow measurements indicate that portions of this reach only receive an average of approximately 1.7 litres of water per square kilometre of contributing subwatershed. In this case, the form of the valley and the location and volume of discharge enhances the quality and extent of the wetlands in this location but provide little benefit to the coldwater community of the West Credit River directly through contributions to water temperature or baseflow. Examination of the fisheries and temperature data for reach 7 (see figure 4.1.3) show that this portion of the system has moderate to low potential for coldwater communities due in part to high temperatures. In contrast, in reaches where groundwater flows directly into the stream channel, a healthy coldwater community exists.

Groundwater discharges are also very active downstream of the Village of Erin. In the Village, water temperatures can exceed 24°C in summer which is inappropriate for coldwater fish such as brook trout. However, major regional groundwater discharges occur in the West Credit downstream of the Village of Erin. This area also supports a wetland fed by groundwater flows. Both the volumes and distribution of the groundwater are such that both the wetland system and stream benefit. This occurs because the discharge zone is extensive and includes discharges directly into the streambed, thereby avoiding capture and warming by wetland vegetation. This portion of the system gains over 26 litres of water per square kilometre of contributing subwatershed. Examination of the fisheries and temperature data indicate that the brook trout population suddenly reappears within reaches 4/5 (see figure 4.1.3) and temperatures drop from a maximum of 24°C in the Village of Erin to a maximum of 19.6°C at

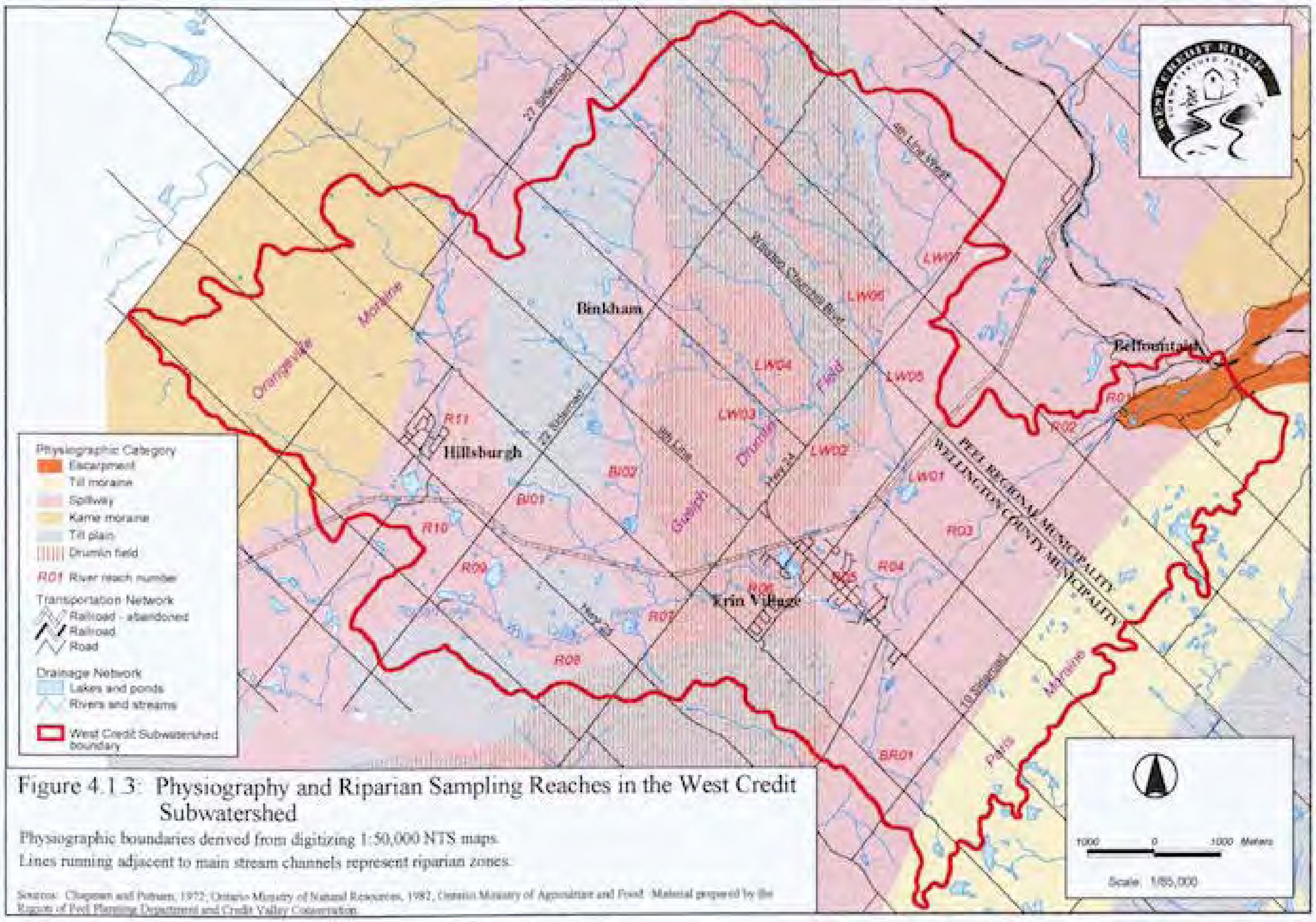

Figure 4.1.3: Physiography and Riparian Sampling Reaches in the West Credit Subwatershed

Physiographic boundaries derived from digitizing 1:50,000 NTS maps.

Lines running adjacent to main stream channels represent riparian zones.

Sources: Chapman and Putnam, 1972; Ontario Ministry of Natural Resources, 1982; Ontario Ministry of Agriculture and Food. Material prepared by the Region of Peel Planning Department and Credit Valley Conservation.

the bottom of this reach. This discharge zone is likely responsible for the maintenance of the coldwater fishery all the way to Belfountain.

Groundwater may generate the potential to enhance wetland or streams but human activities as well as distributional characteristics of groundwater can modify the subwatershed's potential for various ecosystems. The temperature-moderating influence of groundwater can be negated by dams, and the baseflow to wetlands and streams can be reduced by land use activities both within the valley and on the uplands. For example, despite the significant amounts of groundwater discharges in Reach 11, upstream of Hillsburgh, the series of dams below Hillsburgh causes increased temperatures and creates migration and movement barriers for coldwater fish. The potential for a highly productive coldwater brook trout community is impaired by these structures, despite the local benefits derived from the ponds by local residents. The groundwater flows upstream of Hillsburgh also provide the potential for coldwater fisheries, but the habitat quality of the channel in this reach is impaired by a combination of cattle access, historical beaver dam building, residential development and stormwater inputs. All these constraints on the system's potential can be rectified or moderated to allow for the restoration of the abundant coldwater fishery that was there historically.

It has been found that several tributary sections within the subwatershed also appear to have the potential for coldwater fisheries upon examining groundwater discharge capability and recorded low flow discharge information. In these reaches, the limiting factor is physical habitat which is impaired by adjacent land uses. Reaches BI02, LW03 and LW04 have a high potential for restoration (see figure 4.1.3).

Depending upon the type of groundwater system present in an area, human uses of groundwater for water supply can affect the volume and distribution of groundwater moving to natural areas such as wetlands and streams. It is possible to exceed the available supply of groundwater, based on the type and size of an aquifer and the geologic conditions. This occurs when the extraction of water exceeds the recharge volume of the system. A number of areas were delineated in the subwatershed based on the geologic conditions and assessed in terms of potential impacts to water quantity from water takings. Another aspect of water supply is water quality. With a few localized exceptions, the quality of the water from groundwater sources in the subwatershed is very good. As the water that feeds the regional aquifer in the area is likely recharged within the West Credit River basin, the people of the subwatershed have the ability to control and ensure the quality of the water they use.

Land use activities such as urban development and aggregate extraction have the potential to affect groundwater resources as well, although given the size of most urban areas and individual aggregate areas, the effects are usually felt on local water tables rather than regional aquifers. In the West Credit subwatershed, this may not be a concern for water supply, as the supply is from the regional system, but it is a concern for local water tables that play an important part in the ecology of subwatershed wetlands and streams. Upon recognizing that a large portion of the subwatershed is comprised of gravels and sand moraines, it is not surprising that the subwatershed supports an active aggregate industry. Under some conditions, aggregate extraction can have an impact on the infiltration, movement and discharge characteristics of groundwater systems. Some of the major criteria that need to be considered in order to determine the potential impacts of aggregate extraction on groundwater discharge areas include: size of the extraction area, proximity of the extraction site to the discharge area, depth of the aggregate material, and depth of pit in relation to the water table. Some of the potential impacts of an aggregate extraction site may be: increased water temperature of the discharging groundwater, reduction or loss of discharge areas, reduced discharge volumes, loss of spawning areas of fish such as brook trout, loss of refuge areas, reductions in baseflow volumes of a stream, reduction in size and quality of wetlands. Specific studies may be required to determine the potential impact of localized aggregate extraction on the wetlands and stream.

4.1.2 Water Quality

In comparison to the Credit River Watershed, the water quality of West Credit Subwatershed is good. Within the Credit River system, the West Credit has the lowest values of total phosphorus, chlorides and has some of the coldest temperature regimes. This is a function of limited urbanization, hydrology, and the extensive riparian vegetation in stream corridors. The presence of invertebrates that are intolerant of pollution and the existence of self-sustaining populations of brook trout are biological indicators of the health of the system.

The water quality analysis carried out as part of the West Credit Subwatershed Study identified a few specific problem areas, particularly related to microbiological parameters. *E. coli* densities are high throughout the subwatershed, at the Belfountain Conservation Area where swimming has been prohibited on a frequent basis and in the Village of Erin area where septic tank failures were perceived to be a problem. The chloride budget can be a useful tool for checking a water quality model for the subwatershed.

4.1.3 Channel Form, Fish and Habitat

The form of stream channels results from the interplay of surficial geology with climate, topography and vegetation. Surficial geology and its topography provide the type of soils and relief while climate provides precipitation patterns and volumes. The channels themselves — their forms, widths, depths and slopes — are a response to the flow patterns of the subwatershed as they try to convey water efficiently and with minimal energy.

In the West Credit Subwatershed, this interplay of physical forces and an overall healthy and contiguous riparian zone has generated several major channel forms within the subwatershed. These channel forms include high sloped, "B" type channels (downstream of Belfountain), moderate to low sloped "C" type channels and highly meandering, narrow and deep "E" type channels (Table 3.3. 1) (Rosgen, 1996). In addition, given the mixture and spatial distribution of coarse and fine soils, these channel forms have four major bed structures: cobble bed channels in Belfountain downstream to the Forks; gravel bed channels in three reaches along the main branch and five reaches in the tributaries; sand beds in seven reaches of the main branch and three reaches of the tributaries; and silt/clay bed in one reach of the main branch. Given that field measurements were only conducted along the main branch, it is possible that many of the gravel bed reaches are sand bed channels and that several of the sand bed channels are silt/clay bed systems, especially in reaches LW06 and LW07 which flow through tills (see figure 4.1.3).

As should be expected, gravel bed channels are located adjacent to or immediately downstream of gravel moraine deposits, sand bed channels are found adjacent to or immediately downstream of sand moraine or spillway deposits, and silt/clay bed channels are adjacent to till and clay plain deposits.

The physical structure of the channels within the West Credit River is generally stable. There is some variability in channel form and complexity based upon whether the stream flows through well-wooded riparian zones or not. Where the streams flow through well-vegetated reaches, wood debris is present in the channel and provides important habitat for the fish and aquatic bugs. Nowhere in the subwatershed has wood debris been found to be so excessive that it has severely threatened the stability of the channel, although in some areas it has created over widened portions in which the quality of habitat for fish has been somewhat reduced. In addition, in some reaches, especially R003, historic beaver damming activity has widened the stream such that it is poor habitat for fish although the channel form is still stable. The higher gradient "B" channel from Belfountain to the Forks of the Credit does have good supplies of wood debris, but because of the high energy of this section of the river, the debris is usually along the margins of the channel. Habitat in "B" channels consists of boulders and deep runs.

In "C" type channels, large wood debris comprising from 1.5 to 3.0% of the surface area of the high flow channel appears to provide excellent habitat for fish such as trout and suckers. Lower wood debris volumes in "C" type channels reduce the potential living space for adult members of these species because it exposes them to predation. There are a number of reaches within the subwatershed where historical removal of riparian forests (e.g. through Hillsburgh and the Village of Erin) has reduced wood debris volumes to 1.0% or less. This reduces channel complexity for fish populations and makes these sections less productive. Of course, the loss of wooded riparian areas in these locations also enhances temperature warming of the stream. Some reaches of the subwatershed have naturally low woody riparian zones. These reaches are adjacent to some of the riparian wetland complexes.

The distribution of fish communities within the West Credit Subwatershed is influenced by both natural and human factors. Of these factors, water temperature is likely the most important variable controlling the distribution of fish communities. Coldwater fish communities dominated by brook trout are extremely sensitive to water temperatures. Where water temperatures exceed 22°C for more than several days over the summer, brook trout populations usually disappear. Cool to cold water temperatures are a product of the amount of groundwater entering the system and the amount of shading or canopy coverage in a stream. Although there may be a lot of groundwater entering a stream, the distribution of groundwater discharges is spotty. Where there are no active groundwater discharges in a portion of a stream, a good riparian canopy will help to insulate the stream and keep water temperatures cool. In reaches where these riparian canopies are removed by land clearing, water temperatures increase and brook trout can be lost. Refer to figure 4.1.4 for a visual representation of the above described system along the main branch of the West Credit River.

Historically, the subwatershed was dominated by a coldwater community made up of native brook trout along with other typical species such as white sucker and mottled sculpin. There is little doubt that some portions of the subwatershed, such as reaches LW06 and LW07, likely had a coolwater community with few, or no, coldwater species because of surficial geology and a lack of groundwater discharge areas, despite having once had a good riparian canopy (see figure 4.1.2).

Human activities such as land clearing, agriculture, dam building and urban development have created and exacerbated physical and thermal breaks in the stream channel. This has resulted in different fish community structures within the subwatershed. Clearing and farming the land in some reaches that may have had marginal coldwater communities warmed these reaches shifting them to coolwater communities. Dams create numerous changes in a system: they prevent movement of fish to important reproductive zones, warm downstream waters, trap silt, change channel forms and provide opportunities for the colonization and development of warmwater fish communities. As a result, several locations on the West Credit River now contain warmwater communities and fish such as largemouth bass and sunfish.

4.1.4 Terrestrial Features

Terrestrial features include the vegetative systems which are important both in terms of biological function (i.e. wildlife and aquatic habitat) and physical/chemical function (e.g. water, nutrient and carbon cycling). Within any subwatershed there are two major environmental zones: upland and lowland or valley. The distribution of terrestrial features within the West Credit Subwatershed has been modified by past and current land use practices.

At present, about 15% of the West Credit Subwatershed is covered by forest or plantation cover. In many cases, the forested habitat units overlap with wetlands, although this is not always the case (see Figure 3.4.1). Generally, the terrestrial habitat units can consist of any combination of forest, plantation, swamp, and wetland.

Examination of habitat quality of the subwatershed's forested lands indicates that 92% of this should be considered to be medium to high priority for protection. We can assume, therefore,

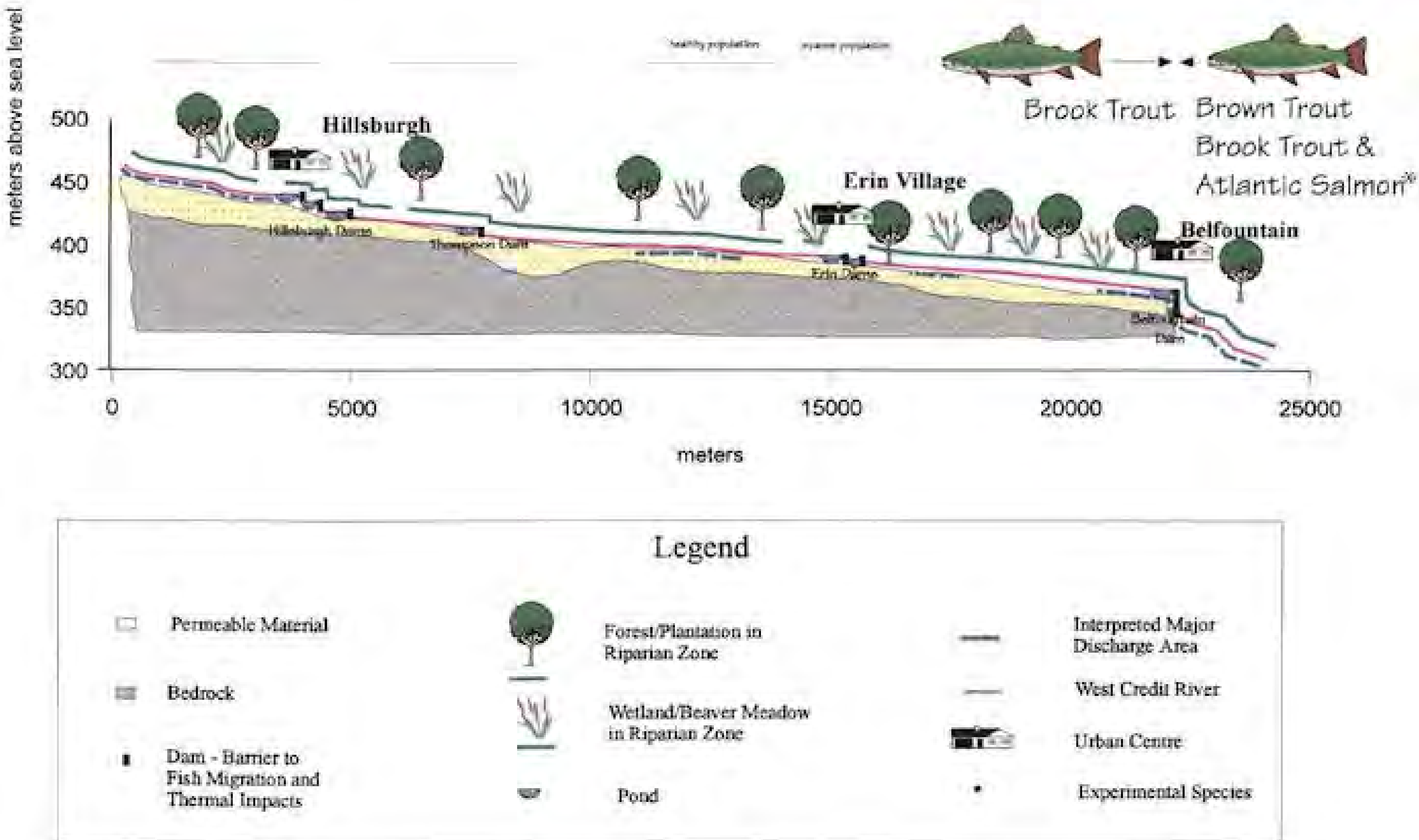

Figure 4.1.4: Cross Section of the Main Branch of the West Credit River - Riverine Characteristics

that what coverage remains is healthy and very important to the terrestrial values of the subwatershed. Unfortunately, the forested and plantation lands that do exist are patchy and often isolated from other patches. Therefore, there is a need to improve the connectivity of the habitat units to maintain and improve habitat for many of the species of animals found in forested systems. Wildlife need corridors for cover when travelling from one area to another. Without the cover, there is little defence or camouflage offered, and therefore self sustaining populations will be stressed.

Although much of the major vegetative cover is found in upland woodlots, the valley bottoms contain many terrestrial habitat units are found that are a combination of forest, plantation, swamp and wetland. The forested valley bottoms and wetland complexes comprise a significant portion of the subwatershed natural features. Valley bottoms and their associated riparian lands also provide similar wildlife functions to upland areas.

Upland and bottomland terrestrial features affect different components and therefore different functions of the water cycle. Recharge areas that are forested are able to infiltrate more precipitation than recharge areas lacking forest cover. Therefore a healthy riparian forest growing over top of major recharge zones can further enhance infiltration, and both reduce and further moderate surface runoff. A variety of benefits can accrue from this: improved water supply for shallow and deep wells, more stable channel form with less erosion, more productive fish communities, further moderation in frequently-occurring flood flows. Large portions of the upland subwatershed that have been identified as major recharge areas lack the forest cover that could enhance infiltration and therefore these areas should be considered targeted areas for increasing forested areas from 15% to 30%.

Valley bottom riparian forests and wetlands serve a slightly different function than upland forested areas. Riparian forests and wetlands provide sinks, retention and transformation areas for nutrients, carbon, and sediments from upland and upstream sources. The wood material and leafy materials generated in these valley bottom riparian zones also contribute to bank stability of the stream, energy sources for the bugs and other animals in the stream, shading and wood debris that can function as cover and habitat for aquatic animals such as fish. In addition, a well vegetated valley corridor provides shelter and cover for larger mammals who use the river for a source of water, and shelter.

4.1.5 Overall Health of the System

The subwatershed is composed of two major functional areas, the upland recharge areas that have the potential to moderate surface flows and recharge both local and the regional aquifers, and the bottomland riparian zone of the subwatershed that performs various functions including groundwater discharge, flood flow buffering and nutrient assimilation.

Despite human activities, the West Credit Subwatershed remains in relatively good health. The broad-scale processes of surface hydrology, groundwater infiltration and discharge are still functional although in some cases impaired or modified by loss of upland forest cover. There are problems in some reaches with water quality impairment due to high coliform counts although the evidence suggests that this problem can be addressed through improved cattle fencing and spot checks of urban septic bed or septic tank leaks.

In Southern Ontario, the West Credit Subwatershed is somewhat unusual in having an almost contiguous stable riparian zone along its banks from mouth to headwaters. These riparian zones are made up of two major vegetative forms: forests and wetland/beaver meadows. (Other riparian forms include manicured lawns, residential properties and farm fields). Fortunately for the health of the stream and its valley, the forest and wetland zones are extensive with only small breaks in continuity. These breaks, caused by the three urban areas and several dams, have altered the movement and distribution of wildlife species and of fish communities. Wildlife species have been affected by the reduction of critical forest patch sizes, loss of volume and fragmentation; fish communities have been affected by changes in water temperatures, modifications in channel structure, impacts on water quality and in construction of dams.

Riparian zones perform numerous functions. Well-vegetated, productive riparian zones improve water quality in their adjacent streams by capturing silt from the stream during high flows and filtering out nutrients and contaminants from floodwater. When water from upland areas flows through healthy riparian zones, the vegetation and roots of the riparian vegetation capture water bearing nutrients, sediments and bacteria before the water reaches the streams and wetlands in the bottomland. Studies in the United States have demonstrated significant improvements in water quality in watersheds having healthy riparian zones (Hunsaker and Levine, 1995, Osborne and Kovacic, 1993).

In addition to water quality improvements, healthy riparian zones can also moderate flood flow intensity by slowing the water down, reduce its erosion potential by lengthening the duration of high water, and reducing the magnitude of flood velocities. These functions translate into streams with stable channels, little extensive erosion, good quality habitat for fish that inhabit the stream and additional improvements in water quality.

Agriculture comprises approximately 68% of the subwatershed, yet despite this, nutrient loadings are moderate, water quality is generally good and the fish communities and productivity of the stream are relatively good compared to other subwatersheds with this level of agriculture and urbanization. The overall good health of the subwatershed is attributable to two interrelated factors: the large amount of the subwatershed that captures and recharges water, and the healthy, almost-contiguous riparian canopy. Recharge areas can reduce the potential of nutrients and other materials from entering the surface water system. Some of the nutrients and materials that are carried away by rainwater from agricultural areas are captured in part by the healthy riparian zone while the remainder are assimilated by the productive invertebrate and fish communities residing in the stream system of the subwatershed. These functions could be further improved through additional forest development on upland sites.

There are two variables that are affecting the health of the aquatic system within the subwatershed: water temperature and coliform bacteria. Water temperature problems occur in several locations because of dams and lack of a healthy riparian zone. Coliform bacteria levels are attributed to two major sources: cattle pasturing in specific areas of the subwatershed and septic leakage.

Despite specific locations where environmental quality is impaired, in large sections of the subwatershed, aquatic habitats are very good because of groundwater discharges and the productive riparian forests and wetlands. The fish community distribution mirrors the temperature, channel and riparian characteristics of the subwatershed, demonstrating how closely they interact. Additional benefits could be derived from further stream channel and riparian zone restoration in some locations of the subwatershed and its tributaries in conjunction with upland forest regeneration.

An additional concern is the present fragmentation of the Terrestrial features and fish community types within the subwatershed. This fragmentation prevents linkages and movement of animals through the system, thereby reducing the overall resiliency to disturbances. Much of these concerns can be addressed through specific and strategic restoration and rehabilitation programs that: increase patch size, increase the diversity and complexity of forested habitat that already exists, re-establish forested areas on major recharge zones, and create linkages along valley corridors and into the uplands.

Much of the continuing health of the riparian and aquatic environments of the subwatershed is due to the groundwater discharge patterns found within the subwatershed. Groundwater discharge zones provide clean, cold water that can improve water quality in streams (through dilution), reduce high summer temperatures for coldwater fish, improve low flow volumes in streams thereby increasing living space for fish and aquatic bugs, and also provide reproduction zones for sensitive fish such as brook trout. These discharge areas and their associated recharge areas are highly sensitive to change and must be recognized as important to the overall health of the subwatershed. They can also play an important role as key "stepping stones" or "lynch pins" in any restoration or rehabilitation programs aimed at reconnecting and linking degraded reaches of the subwatershed with healthy, productive reaches.

When discussing terrestrial and aquatic health in the West Credit Subwatershed, the land adjacent to the main branch of the West Credit River between Fifth line WHS and 10th line is of notable significance. This reach of the river is home to abundant fish fry concentrations, significant spring seepage and has been classified as cold water fish habitat. The terrestrial resources in this area, a significant recharge area, are composed of forests, plantations and wetlands, and therefore offers habitat diversity. This reach hosts the largest interior habitat area in the subwatershed, and is the largest area classified as highest priority for protection. The area is currently unprotected.

Areas where terrestrial cover is notably lacking include the northwest portion of the subwatershed, west of Hillsburgh. This is also one of the largest recharge areas in the subwatershed. The surficial geology in this area is comprised mainly of gravels which have high rates of infiltration. Most of the terrestrial units in this area of the subwatershed have been categorized as being a low priority for protection because of their sparse occurrence and small size. Increased ground cover in this area would promote groundwater infiltration, especially of snow melt in the spring. It is important to encourage infiltration and aquifer recharge in areas dependent on groundwater for municipal use.

5.0 IMPLEMENTATION

5.1 Implementation Framework

The need to carry out subwatershed plans was highlighted as key in the implementation plan for the Credit River Water Management Strategy (CRWMS). The CRWMS provides important background information on which to build in order to define the scope of work to be carried out for each subwatershed.

The West Credit Subwatershed can be described as being healthy with localized areas of impairment. The work required to be carried out in support of the subwatershed study findings can be broken down into the following categories:

- Land use Planning and Policy
- Stewardship and Education
- Rehabilitation and Retrofitting
- Monitoring
- Research and Development

Due to the nature of this work, successful implementation will require the co-operation of agencies, municipalities and the community in meaningful partnerships.

5.2 Land use Planning and Policy

The land use planning tools currently available to assist in the development of the implementation strategy include official plans, zoning by-laws, site plan control, community improvement plans and approvals of subdivision plans and land severances.

The policies suggested should be noted as being interim measures pending the completion of subsequent phases. An impact analysis has not been carried out yet, particularly related to aggregates, ponds and bacteria.

As land use changes occur, it will be imperative that those areas classified as protection area 1 and level 1 be protected in order to ensure the continued health of the West Credit River. In addition, as proposed development progresses through the planning process, appropriate policies and guidelines should be in place to provide upfront direction that reflects the sensitivity of the lands being developed. It should be noted that this study did not carry out an impact assessment of future land use changes and therefore will not provide detailed guidance for such activities. However, sufficient information is provided to highlight sensitive areas and develop appropriate policies. In the event of an official plan update which expands the current urban boundaries, an impact assessment should be carried out that builds on this work and further develops appropriate guidelines. The impact assessment would also require an analysis on a subcatchment level which would lead to a refinement of the development guidelines and requirements. Refer to section 6.2.1 for further explanation on protection areas.

Broad planning documents, such as the official plan, allow for the environmental system to be protected in a comprehensive manner, reflecting the goal of a healthy, functioning ecosystem. An opportunity exists through an official plan review to designate areas where development would not be permitted. The official plan includes policies which address adequate protection and possible accessory uses or minor expansions for existing developments. Areas where conflicts arise will are examined on a site specific basis.

Protection area 2 lands should be protected through stewardship programs, particularly when adjacent to level 1 stream and valley corridors. If land use changes are proposed, these areas should be protected or replaced with equivalent features.. Subject to an environmental impact statement, some level of development may be permitted to alter the size or physical form of protection area 2 lands provided that ecological functions are protected and maintained.

Protection area 3 lands represent priorities for revegetation and rehabilitation. These works may be achieved through proposed developments or in a rehabilitation context.

Level 2 and 3 stream valley corridors are to be protected and maintained and should be considered for rehabilitation and restoration potential.

The official plan should provide policies which support the preparation of guidelines and development control techniques, such as site plan control and zoning, to allow for implementation of the study as land use changes and development occurs.

The official plan should also provide policies which support the stewardship and education, rehabilitation and retrofitting, and monitoring components of the implementation strategy. It is recommended that each municipality within the West Credit Subwatershed consider amending their official plan within six months of council endorsement of this document, in order to incorporate the findings and recommendations of the strategy into a legal framework.

Until such time as official plans are amended, development guidelines should be in place to provide developers with upfront and clear direction that reflects the sensitivity of the lands and the surrounding environment. The guidelines would be applied to all development applications including plans of subdivision/condominium, consents, site specific official plan and zoning bylaw amendments, and site plans.

Within the West Credit Subwatershed there are some licensed pits and quarries that have been identified as lying partially within the recommended protection area 1. These pits and quarries obtained their licenses prior to the initiation of the subwatershed study. However, every effort should be made to mitigate/minimize/compensate environmental impacts in these areas and to recognize features and functions in the restoration plan if required under the license.

5.3 Stewardship and Education

5.3.1 Stewardship

Subwatershed stewardship is caring for the land, water, plants and animals in order to sustain the environment. There are many ways in which residents can become involved as stewards of the West Credit Subwatershed.

CVC is willing to provide property owners with advice, and in some cases assistance, to improve environmental quality and diversity. CVC's forester can provide information to property owners on woodlot management (including thinning), planting of trees, and planting of riparian vegetation. The planting of riparian vegetation is especially important in terms of improving the health of the West Credit River. CVC has a specific riparian revegetation program of which property owners with streams can take advantage. The only prerequisite is that participants must purchase a minimum of 100 shrubs. A planting plan is drawn up to meet the needs of the property owner and the site: this considers soil type, other types of cover present, and the animals the property owner would like to attract.

Key recharge areas of the subwatershed are shown on maps in this report. Recharge areas are places where rain water and snow melt percolate into the ground and reach the aquifers which are the sources for municipal and private wells in the subwatershed. Some landowners in the area have complained that well levels have dropped in the last few decades, suggesting that more infiltration of groundwater is needed. This can be encouraged by planting trees in recharge areas. Residents or groups interested in reforestation in recharge areas, or who would like advice on which trees to plant on private property should contact the CVC forester, who can provide advice on where to obtain native stock - trees that grow naturally in the area. CVC strongly encourages the selection of native stock for reforestation as these species are adapted to our climate and provide the most suitable habitat for animals in the area.

Residents wishing to be more actively involved in stewardship activities on their land should contact CVC. CVC is also interested in hearing from residents who have tried innovative stewardship projects.

5.3.2 Education

The protection of the features and functions of the natural ecosystem of the West Credit relies heavily on the residents and private landowners of the subwatershed. It is imperative that residents have access to information in order to understand, appreciate and participate in stewardship activities. While the most effective way to educate landowners, address specific issues and encourage restoration is through site visits and related stewardship services provided by CVC, broader education programs are also needed to deal with a wider range of issues involving the whole community.

The CVC Community Relations Program provides information on specific issues to individuals and the media through press releases, newsletters, displays and other means. It should continue to perform this role.

Interpretive trails and signage throughout the subwatershed could be better implemented to identify and educate residents by example in their own "backyards". The focus should be on major features such as recreational river corridors, wetlands, forests, conservation areas and past restoration projects such as those implemented through the Clean Up Rural Beaches Program.

Packaged educational programs including guest speakers from the CVC and hands-on projects are ideal for school and community groups. A focus on youth is extremely important since many solutions and restoration programs are long-term in nature and may require a difference in thinking and lifestyle changes. In addition, children can be very influential on the attitudes and actions taken by their parents. Modules for an educational program on the West Credit could include the hydrological cycle and subwatershed concepts, water conservation, stream dynamics and habitat features, the brook trout as an indicator of subwatershed health, aquatic insect collections and identification as water quality indicators, participation in the Peel Children’s Groundwater Festival, Yellow Fish Road Storm Drain Marking Program, stream clean-ups and rehabilitation projects such as soil bioengineering and tree planting. Many related ideas are also packaged together in a more comprehensive way in the Watershed Report Card (Fishermen Involved In Saving Habitat, 1995).

Other programs such as in-home audits related to energy consumption and water conservation (e.g. Elora Centre for Environmental Excellence) could be adopted by the municipalities in the subwatershed. Discussions should also be held with local community groups such as Save Erin's Environment to see how they can most effectively work in co-operation with other groups and agencies to better define their role not only with respect to education but other proactive activities.

5.4 Rehabilitation and Retrofitting

The objective of stream rehabilitation projects is to contribute to the goal of restoring stability (including flood and erosion protection) to stream systems while also contributing to habitat, biodiversity and productivity. Instream projects must be integrated with protection and restoration activities at the subwatershed scale such as the protection of wetlands, the protection of groundwater recharge/discharge areas and stormwater management. Stream reach manipulation then uses natural channel principles to improve the health of the stream and address the factors that limit biological productivity. Tables 5.4.1 and 5.4.2 contain lists of typical problems and stream rehabilitation projects. A review of existing conditions as documented in the subwatershed plan will help to identify key problems on stream reaches and set priorities so that the greatest benefits are achieved within the context of the subwatershed and entire Credit ecosystem.

Table 5.4.1: Typical Problems in the West Credit Subwatershed

- high water temperatures or lack of thermal refugia
- high width/depth ratios or low flows
- excess silt or unstable sand substrates
- poor riparian vegetation buffers
- cattle access
- lack of woody debris
- excess woody debris
- lack of morphological diversity / thalweg meandering
- unstable banks and erosion
- migration barriers (dams and culverts)
- beaver dams (in certain locations only)
- on-line ponds
- direct alterations (hardened banks, diversions and channelization)
- excess nutrients (algae) and toxins from point and non-point sources
- garbage

Table 5.4.2: Typical In Stream Rehabilitation Projects

- buffer plantings
- channel narrowing/low flow definition with deflectors or brush bundling
- silt traps (brush bundles, wetland creation)
- addition of woody cover (brush bundles, sweepers and log jam construction)
- artificial undercut banks (lunker structures)
- soil bioengineering (live stakes, fascines and live crib walls)
- barrier removal, fish ladders or plunge pool creation
- beaver dam removal or baffle installation (certain locations only)
- "Natural Channel" recreation or relocation
- on-line pond removal or bottom draw installation
- selective debris removal
- riffle creation, boulder placement and vortex weirs
- cattle fencing
- promotion of catch and release fishing

Such projects have been traditionally identified and planned by CVC and MNR biologists and are often implemented by volunteer groups. Volunteer labour and funding from organizations such as Trout Unlimited Canada and the Izaak Walton Fly Fishing Club now plays a major role in stream rehabilitation on the Upper Credit. With the aid of comprehensive data bases and community objectives provided by the West Credit Subwatershed Plan, these resources can be applied more effectively. In co-operation with CVC, Trout Unlimited has completed a *Rehabilitation Strategy For the Coldwater Fishery of the Upper Credit* (Grewal and Trembley, 1997). The Strategy assessed three study areas, or reaches, in the West Credit Subwatershed and compared them with 16 other reaches on the Upper Credit River in terms of priority for funding, labour, data collection an education or advocacy roles. The upper, lower and eastern tributaries of the West Credit River were ranked as 10th, 9th and 15th respectively as areas of somewhat medium to low priority for Trout Unlimited to apply their resources. The assessments for each reach were based on existing data, existing impacts and development pressures, public access, stream health, rehabilitation potential and implementation feasibility of identified rehabilitation projects. These priorities will vary as changes occur in the subwatershed and opportunities for stream rehabilitation arise. A similar range of potential rehabilitation projects have been identified by Trout Unlimited, CVC and in the subwatershed plan, including agricultural remedial projects and addressing the impacts of large impoundments in Hillsburgh and the Village of Erin. Other reach level concerns identified relate to woody debris management and sandy substrates.

5.4.1 Pond and Wetland Restoration

Natural wetlands that have been altered by farming practices, drainage or livestock access are best restored by removing the impact and allowing vegetation to re-establish itself. In some cases drainage into or out of the wetland may have to be manipulated. Such cases require site specific assessments and plans that can be pursued in co-operation with CVC staff. In the cases of wooded swamps, advice and programs offered by the CVC forester on management techniques are applicable.

CVC and other agencies have successfully completed wetland creation projects to enhance fish and wildlife habitat and improve water quality. Many stormwater facilities are also incorporating wetland features during or after construction.

Most restoration opportunities arise from landowners seeking advice on the management of private ponds; commonly information is sought on unwanted algae growth or the desire to stock fish. Historically, ponds were constructed for water supply purposes and aesthetics without broader ecological considerations. With education, most landowners begin to understand the impacts of excess manicured landscaping around their ponds or the advantages of raising native self-sustaining populations of fish better adapted to naturalized ponds. Attracting wildlife to these features is now becoming a prime consideration for most landowners. Many landowners are interested in planting emergent and submergent wetland plants. Plant growth in many ponds is limited by the lack of shallow littoral zones and poor ratios of shoreline length to pond surface. The addition of features such as sunken reefs, woody debris in the shallows and emergent and floating timber can enrich habitat for aquatic life, increase nutrient cycling, increase species diversity and complexity and reduce numbers of nuisance species.

Removing ponds that are on-line are a top priority given their impacts on streams and rivers (i.e. warming) and the impacts of streams on the ponds themselves (i.e. siltation and nutrient enrichment). Such situations usually require permits. In contrast, off-line pond restoration projects require less intervention and can more easily be implemented by the landowner. In either situation, more detailed assessments and can be provided by CVC.

5.4.2 Retrofit of Dams

The West Credit River flows through a variety of on-line ponds, some of them quite large. Two such ponds are those upstream of the Charles and Church Street Dams in the Village of Erin (see figure 5.4.1). A large amount of sediment is currently stored behind the dams: this has the potential to escape downstream and damage fish habitat, should the dams breach. As the water pools behind the dams, it slows down, and sediment settles out to the bed of the river, trapping contaminants which become resuspended during storm events and can re-inoculate the river. The potential result is continuous long term sporadic contamination.

The structural integrity of the dams has been assessed and is summarized below.

- Some of the future rehabilitation costs and potential flood damages resulting from over topping may be avoided under various dam removal options.

- The dams' discharge and reservoir storage capacities are small. There is a significant risk that over topping could lead to an embankment failure. The resultant flood wave could increase the risk to life and property damages, as well as have detrimental environmental impacts.

- From a geotechnical perspective, the embankment dams do not meet contemporary standards for stability of water-retaining structures. Deficiencies that could develop during runoff events may lead to embankment failure and increase the risk to life and downstream property damage, as well as have detrimental environmental impacts.

- Interference with the embankment dam material may enlarge current seepage pathways. This may result in embankment failure and consequential flood waves that may increase the risk to life and downstream property damage as well as have detrimental impacts on the aquatic resource.

For more information on the effects of the dams and ponds on the river, and options for rehabilitation, see Appendix C.

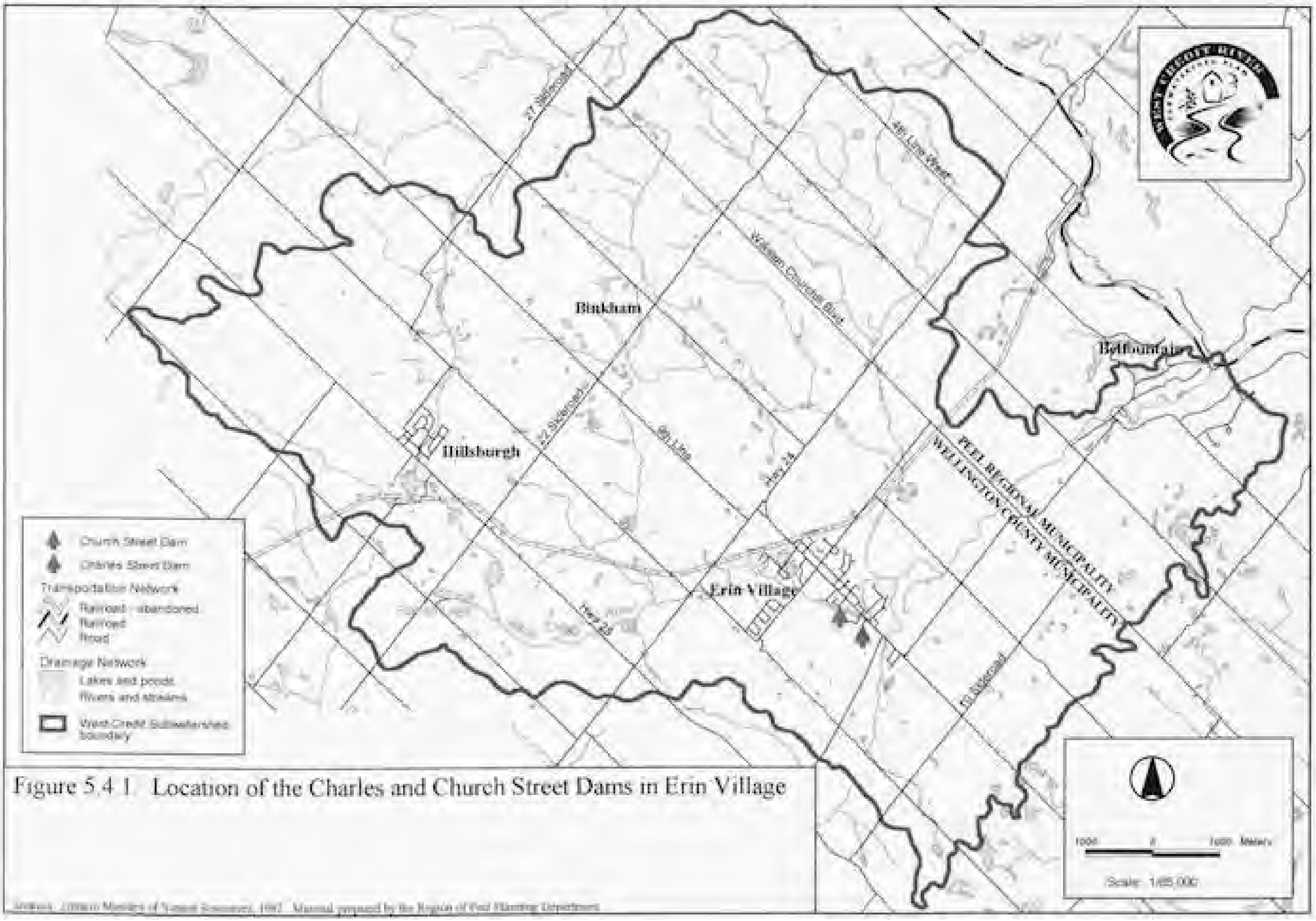

Figure 5.4 1 Location of the Charles and Church Street Dams in Erin Village

5.5 Monitoring

Environmental monitoring is the collection of data and information that allows conclusions to be drawn about environmental quality. Are things getting better? Are things getting worse? Are we meeting the targets we set for ourselves? Monitoring can include water quality, water quantity, flows, weather, air quality, and species and numbers of plants and animals. Some types of environmental monitoring (such as basic water quality and fish surveys) have been taking place in the subwatershed for decades; some types of monitoring (especially plants and animals other than fish) need to be improved.

5.5.1 Water Quality

Water quality data has been collected in the subwatershed since 1965. Water sampling occurs at one site in the subwatershed once a month, in accordance with the Provincial Water Quality Network program managed by the Ministry of Environment and Energy (MOEE). Many parameters sampled including: acidity, nickel, nitrates, lead, phosphorus, fecal coliform and arsenic. Fecal coliform counts (which measure bacteria) have historically been a problem in the subwatershed, and have increased since water quality sampling began in 1965. Run-off from barnyards, manure storage areas and milk houses can be a major contributor to bacterial contamination if managed improperly. Farmers wanting to know more about how to improve the water quality of the creeks running through their farms, can get information from CVC or the Ontario Ministry of Agriculture Food and Rural Affairs (OMAFRA).

MOEE's Clean Up Rural Beaches (CURB) program focused on the West Credit Subwatershed between 1990 and 1994. One aim of the program was to improve the water quality in the West Credit by limiting livestock access to creeks and upgrading manure storage practices. The program offered a grant to farmers who wanted to alter their farming practices, as well as persons in the area who wanted assistance repairing or upgrading their septic system. During the course of the program, water quality samples were taken on the tributaries in the subwatershed to determine the potential sources of contaminants of the West Credit River. The data are available to anyone wanting information on a specific tributary. Unfortunately, the program was cancelled in 1994, and there are no further plans to continue a formal water quality sampling program on the tributary creeks.

There are many other methods of monitoring water quality. Some of them require that access to materials that would be found in a science lab; some of them can be done by homeowners.

Identifying indicator insect species and plotting their presence, absence and numbers over time will give an excellent idea of how water quality is changing. For example, the presence of mayfly and stonefly nymphs indicates excellent water quality; the presence of leeches and sludgeworms in the absence of other insects indicates poor water quality. There are specific methods that must be followed when sampling for insects, and those interested should speak to an experienced biologist before beginning.

One such example of a program that has been set up to monitor water quality using insect indicator species is the BioMap program developed by MOEE. Insects are collected from various areas of the river, out of pools and riffles, around areas with vegetation and with no vegetation, and then the species and amount of insects in each sample are analyzed. Minimal equipment is needed: forceps, dissecting trays and a magnifying glass. The methods used are easy, repeatable, and can be completed by children in the middle school grades and older.

Water fleas (*Daphnia magna*) are excellent indicators of water quality. A culture of water fleas can be used to monitor water quality over time. A population can be maintained in an aquarium in controlled conditions, and fed a few times a week. By placing them in a water sample from the river, and monitoring how many fleas expire, water quality can be assessed and monitored over time if the test is repeated.

Total Dissolved Solids (TDS) indicate the amount of potential food in the water in the form of small particles. A normal range of TDS is 150 to 500 milligrams per litre. In heavily industrialized areas, the amount can exceed 2000 milligrams per litre. An excess of TDS can be detrimental to aquatic life. To measure TDS, water is sampled from the middle of a running stream. The water is filtered to remove the particulate matter and the particulate matter is weighed to the nearest 1000^{th} of a milligram. The amount of TDS per litre can then be calculated, recorded and checked over time.

The amount of phosphorus and nitrogen in water can be determined with more specific tests. Excess phosphorus can lead to excessive algae growth. Decay of algae uses up oxygen in the water column, leaving less for fish and other aquatic animals. To minimize weed growth, water should generally contain 10 parts per billion of phosphorus or less. The test for phosphorus concentration is a complicated one, and should be guided by an experienced scientist.

One vital parameter that is easy to monitor is temperature. Temperature measurements are taken at noon, in a shaded area, by lowering a thermometer into the water about 10 centimetres and waiting two minutes. Records should be made of the temperature, weather, location and date. The same methodology and site should be used every time.

The acidity or alkalinity of water — pH — can be measured using litmus paper which is available from science supply stores. Litmus paper is dipped into the water sample and the colour is then compared to a chart that is provided with the paper to determine the pH.

For further information on water quality sampling, or to become involved in gathering water quality data in the subwatershed, CVC should be contacted. For more information on how to become involved in environmental monitoring in your subwatershed, see Appendix J.

5.5.2 Water Flows

Since April 1983, flow measurements have been taken on a regular basis in the West Credit Subwatershed by CVC and Water Survey Canada at a structure called a gauging station. The gauge records water levels in the river 12 times a day, 365 days a year. At any instant, the levels can be accessed from the CVC flood forecasting station. If the water level is known, a chart, called a rating curve is used to determine the "discharge" — the amount of water flowing in the river at that spot and at that time. The main purpose of the gauge station is to provide instantaneous levels when water levels are high. If water levels are extremely high and fast, there is potential hazard to human life and property.

River velocity can be measured by anyone with as little as an orange peel and a tape measure. The orange peel is dropped into the fast moving part of a river and a measurement is made of how long it takes to travel a specific distance. Velocity is then calculated by dividing the length travelled by the time taken, and is recorded in metres per second. *Sampling should never be done in or near fast, dangerous or icy water.*

Other data obtained from the flow gauge can be used to monitor low flows. Fish need a certain amount of flow during the dry summer months to survive. One measure that can be used to determine if there is enough water in a watercourse during dry summer months to support fish populations is to calculate the 7Q10 flow. This refers to the flow after the driest seven days in a ten year period. There is enough water in the main branch of the West Credit River to support fish year round, but some of the tributaries dry up in the summer months.

Low flows are also used when determining if there will be enough water in the river in dry summer months to dilute effluent from sewage treatment plants. Because of importance of low flows, CVC will continue to monitor this parameter in the West Credit in the future.

5.5.3 Weather

There is no weather station in the subwatershed, but there is a rain gauge located on the gauge station. The rain gauge monitors the rate of rainfall: this, combined with other environmental conditions, such as how wet the soil already is, can be used to infer potential flooding hazards.

Monitoring the weather can be a good classroom activity for younger children, as temperature can be taken from inside a classroom if a thermometer is mounted outside. Air pollutants can be examined by placing a glass slide with petroleum jelly outside the classroom for a while. After a period of time, the slide is brought inside and observed with a magnifying glass to identify what has settled on the slide and what the sources might be.

5.5.4 Fish

Spawning surveys have been conducted by MNR and CVC since 1979, and have generally been carried out on the reach downstream of Belfountain. However, the main branch of the West Credit upstream of Belfountain was surveyed in fall of 1996.

Electrofishing has been conducted in the subwatershed at various sites. In 1995, many sites were re-sampled. When a section of the river is "electrofished", the fish are temporarily stunned with an electric charge. They are then counted, undergo species identification, have their age determined, are measured, and then released. Over the years there have been no drastic changes in the fish population; for more information see Section 3.6 or Appendix F.

Regular inventories of fish allow for accurate records to be kept and comparisons made with historic data. Any significant changes will indicate that there is a stressor in the environment, one which may do long term damage to the fishery. If changes are noticed early enough, there is opportunity to take action to mitigate the stress on the fishery. Both electrofishing and spawning surveys should continue in the future, as there is a lot of baseline data for comparison, and the fishery is a healthy resource that should be maintained for future generations.

To better understand the fishery, biomass stations should be set up in the subwatershed. When gathering information for biomass, the fish are weighed, and the productivity of a river reach is calculated, which provides a quantitative measure of the health of an area. Currently, the presence/absence methods (e.g. presence of brook trout) are used to provide a qualitative measure of the area's health.

Anglers interested in helping to monitor the fishery can forward information on fish caught to CVC. This should include the date, time, weather conditions, water conditions, specific location, species, numbers, size and any other points of interest. An official Credit Valley Conservation fishing log is available from CVC for this purpose. The fishing log is also posted on the CVC web site (http://www.mississauga.com/conservation.html).

5.5.5 Other Animals

Subwatershed residents can play a vital role in monitoring by watching for and recording animals. These can include birds, mammals, reptiles and amphibians, and butterflies. Logs should be kept of dates, weather, location and species seen. Generally, the only equipment that is needed is binoculars, and a guidebook, for example Peterson's *A Field Guide to Birds,* or Peterson's *A Field Guide to the Butterflies of Eastern North America*. Canadian Wildlife Service has developed protocols for monitoring forest birds, marsh birds, and amphibians. These are available and can be useful for community-based monitoring activities. Please call the CVC biologist if you are interested in monitoring other animals.

Any sightings of rare, threatened or endangered species should be reported to the CVC biologist, and the Ministry of Natural Resources.

5.5.6 Plants

Monitoring of the terrestrial component of the subwatershed can include making inventories of woodlot and wetland plant species, and monitoring them as land use changes around the area.

Species that do not belong in an area and came from other parts of the world are called non-native invasive species. The most notorious plant example is purple loosestrife which invades wetlands, reduces diversity and chokes out natural species that provide habitat to the animals that have adapted to them. Those interested in becoming part of a community program to eradicate or control the spread of purple loosestrife should contact the CVC biologist.

5.6 Research and Development

The following is a list of topics to consider in the future should the opportunity for further research in the subwatershed arise. Presently there is no schedule to investigate any of the following topics further:

1. Relationship between high flow characteristics, woody debris and channel stability and complexity.

    - Wood debris is a very important component of aquatic habitat and channel complexity.

    - Most channel systems in Southern Ontario are wood debris poor and therefore habitat complexity and health is low.

    - The West Credit has many reaches with high woody debris volumes, yet the channel is extremely stable. Similar reaches of the main Credit River could not support these volumes and still maintain stable channel features.

    - What are the conditions necessary to maintain a stable channel with these volumes of wood debris, and what are the conditions that control the maximum volumes of wood debris.

2. How wide and continuous must a vegetated, woody riparian zone be in order to offset intensive, adjacent agricultural or urban conditions?

- The riparian zone on the West Credit appears to protect the channel structure and the water quality of the river from intensive agriculture in the uplands adjacent to the river.

- Compare and contrast the West Credit River's riparian zone characteristics, land use patterns, geology and topography with other similar subwatersheds containing less woody riparian zones (e.g. Carroll Creek in the Grand River Watershed).

- This information can be used for planning to protect and information for restoration of water quality and physical stream health.

3. What can we infer from the West Credit River relating to the variables controlling and explaining the distribution of trout populations and coldwater communities in streams?

   - There appears to be an interactive relationship between channel type, riparian zone quality, groundwater discharge and wood debris.

   - Which are the state variables and which are the modifying variables?

   - This information is important towards the development of classification systems for predicting response of fish communities and species to change and for determining subwatershed priorities for restoration.

4. What are the variables that should be used to develop a functional classification system for watersheds?

   - Nested classification systems can be used to predict functional and descriptive characteristics of a system so that models can be used to determine expected conditions and responses to change or disturbance.

   - Develop a descriptive model for the West Credit River and then develop a classification system to be tested on other subwatersheds within southern Ontario.

   - This would provide a valuable tool for land use and resource management.

5. Selection of indicators.

   - Compliance indicators used to judge the attainment of ecosystem objectives.

- Diagnostic indicators used to judge the cause of ecosystem deterioration, where the cause is not obvious or simple to determine.

- Early warning indicators, as the previous two indicators are reactive indicators. The authors advocate the development of early warning ecosystem indicators, analogous to 'leading economic indicators' to allow for the implementation of management actions before conditions have deteriorated to the point where compliance indicators are too late.

6. Issues of Scale

- The physical and temporal response of streams to development and to protective measures such as BMP's and channel protection measures are the key aspect of fluvial geomorphology and in stream habitat central to any analysis of stream channel dynamics. Its importance is usually understood intuitively, but is often understated and is treated implicitly rather than explicitly. Further development of monitoring and management programs as a function of scale is suggested by this activity.

- The key research and development activity is to appropriately develop a conceptual model for relating spatial scales to the ecosystem niche of interest. Once this scale has been established, then defining the response time frames for each spatial scale is the next needed activity to develop a cost effective field measurement and monitoring program.

7. Impact Prediction for Stream Issues

- Design can be based upon empirical relationships which have limited extrapolation capability from one site to another or predictive tools based upon fundamental principles such as water balance and mass conservation. The type of tools available are one of the key issues in Impact Prediction Methodologies for Watershed Scale Development.

- In the *Watershed Planning Initiative Science and Technology Task Force Report*, (1995) the major question addressed was: "what analytical structure will provide quantitative data for relating the stresses of urbanization to impacts on aquatic ecosystems". It was suggested that predictions of changes due to subwatershed development are possible for hydrology, but that predictions, based upon a quantitative impact assessment methodology, are not presently possible for biological entities such as benthos and fish. However, the general direction of response can be estimated. How large a change is necessary to quantify an impact since the major uncertainty is a large variance structure in environmental data.

- The development of applicable tools for the different issues of stream hydrology, fluvial geomorphology, water quality, In Stream habitat, and aquatic ecosystems is suggested as an approach for future subwatershed plan development and to assist future reviews of development applications.

8. Concept of a Threshold

   - The concept of a threshold effect between percent impervious and aquatic system response has evolved and is in widespread use in the field. The concept has evolved in the recent decade for urban land uses where distance relationships can be observed. Its applicability to the West Credit needs further exploration.

9. Relationships Between Land Use and Aquatic Ecosystems

   - The business objective of this research and development activity is to develop a practical set of scientifically defendable relationships which can be used to review development applications in the absence of a subwatershed study in the West Credit Subwatershed, or to increase the level of Science and Technology beyond simply expert judgement for implementation of subwatershed studies elsewhere in the Credit River Watershed. The two proposed approaches are relationships from other like subwatersheds such as the Maitland Watershed Health Study.

10. Chloride and Nitrate Pathways Modelling Through Overland and Subsurface Pathways

    - The objective of this activity is to confirm the relative importance of overland and subsurface flow pathways to the water budget for the subwatershed, and to the transport of chlorides and nitrogen fertilizers to the receiving streams.

11. Sedimentation

    - Is fine sediment from agriculture and unpaved roads impacting on the aquatic system?

    - What are sediment loadings in the subwatershed?

5.7 Individual Actions

Residents do not have to be rural land-owners to practice environmental stewardship. Each of us can make significant differences every day, through changing the way we do things. Collectively, we can make a significant difference. Here are some examples:

- Take paint, used motor oil, used antifreeze or any chemical to your local hazardous waste depot. A couple of litres of used motor oil can contaminate thousands of litres of groundwater (and your drinking water), and find its way into the river. Contaminants can take hundreds of years to work their way out of a groundwater system.

- Do not over-water your lawn or plants. This will result in nutrients being leached from the soil.

- Limit (hopefully eliminate) the amount of fertilizer and weed killer you use. It will eventually find its way into the groundwater, the river, Lake Ontario, then ultimately the ocean.

- Respect fishing regulations and limits.

- Participate in local river clean up days organized by the Village of Erin.

- Volunteer your time with local tree planting programs.

- Plant native species on your land and in your garden.

- Plant species that do not require a lot of water.

Appendix J contains a list of people who can provide additional information on monitoring and stewardship activities in the West Credit Subwatershed.

5.7.1 The Elora Centre for Environmental Excellence

The West Credit Subwatershed Study was tied in with a program run by the Elora Centre for Environmental Excellence(ECEE). The House Doctor project was designed to inform Village of Erin residents about how to conserve water, electricity and other resources, and how to produce less garbage. As the house doctors made their rounds to homes in the village, they distributed a pamphlet that described the subwatershed study and explained how it is linked to the House Doctor program in terms of sustainable use of natural resources (see Appendix J).

ECEE BACKGROUND

The Elora Centre of Environmental Excellence (ECEE) is a non-profit corporation dedicated to bringing innovative environmental solutions to communities. Focusing on water, waste and energy issues, the ECEE has worked with dozens of organizations and municipalities to improve operating efficiency and deliver comprehensive community education programs.

A keystone of the ECEE approach is building community partnerships in several sectors. Project partners have included the Town of Fergus, the Village of Erin, the Township of West Garafraxa, Credit Valley Conservation, Grand River Conservation Authority, Consumers Gas, Union/Centra Gas, Ontario Hydro, Wellington Board of Education, Wellington-Dufferin-Guelph Health Unit, Environment Canada, Health Canada, the Ministry of Environment and Energy, the Ministry of Agriculture, Food and Rural Affairs, Ontario Soil and Crop Improvement Association as well as a variety of local businesses.

The ECEE was founded in 1993 and is governed by a seven member volunteer Board of Directors. Programs include comprehensive water, waste and energy efficient projects, greening your schools, greenspace activities from tree planting to trail building, and the coordination of community animation projects.

The key delivery vehicle of all municipal projects is the “Green Home Visit”, an in home educational session conducted by highly trained assessors. Assessors review the home’s energy and water use and waste output, and prepare a list of prioritized recommendations on how the homeowner can improve their home’s efficiency. The visit may also include specific conservation retrofits such as 6 litre toilets, composters and water heater blankets, to ensure community wide conservation goals are met.

ECEE programs have proven effective for the following reasons:

a) *Efficiency pays for itself*

The municipal efficiency program is structured on a <u>zero net cost</u> basis. Programs are paid for out of the savings realized through more efficient delivery of services combined with deferral of capital expansion or upgrade costs. Arrangements are made with a local financing company that will match projected savings with financed expenditures over periods of one to five years, allowing municipalities to integrate program costs into their operating budgets.

For example, a recent ECEE waste reduction program in the Town of Fergus involved community wide door to door distribution of free composters and recycling information. Combined with an ECEE recommended move to a user pay waste system, the Town is expected to save 30 percent of its waste disposal costs annually, covering the cost of the project in less than three years.

b) *One on one contact*

The “kitchen table” approach results in significant homeowner follow up activity. Six month follow up surveys for Green Home Visit programs have shown that 100 percent of homeowners plan to act on the recommendations given, and 92 percent have already acted. Homeowners spend an average of $1,400 per home on conservation retrofits after the Green Home Visit, proving that this approach achieves impressive results.

c) *Partnership leveraging*

The partnership approach to the municipal programs spreads the project costs among many beneficiaries. Integrating water, waste and energy into a single program allows the partners to achieve their environmental goals at a lower cost, while providing the homeowner with a single vehicle to encourage change. Usual partners in municipal projects include the municipalities, local utility providers, gas companies, banks, schools, local retailers and service clubs.

d) *Environmental leveraging*

A complete water, waste and energy program has a synergistic effect that produces better results than programs that focus on a single issue. Environmental activity in one area will complement and reinforce activity in other areas. For example: installing a composter is primarily a waste reduction activity, but it is also a useful step to reducing chemical use in lawn and garden care.

e) *Community based flexibility and animation*

The ECEE’s municipal programs are effective because they are tailored to serve each community’s conservation priorities, focusing on issues of concern to the community and program partners. Over 7000 volunteer hours were logged in 1996 during the project, indicating the level of community support and interest gained by the approach.

f) *Established expertise*

The ECEE has highly trained staff with expertise in all aspects of program development, project management, residential systems and greenspace protection. Because there are scores of successful completed programs in many municipalities, the start up and training time for new municipal programs is minimal.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This portion of the study covers Phase I of the subwatershed planning process. Further refinements and additions should be made once Phase II is completed.

1) The Vision and Goals

VISION

The terrestrial and aquatic systems in the West Credit Subwatershed will be protected, restored and enhanced through the conservation and management of important features.

The **goals** are to provide a framework to achieve:

- a clean healthy environment with a balance of areas where people can work, live and play;
- areas of natural systems or process including viable habitat of wildlife and fish;
- opportunities for rural, urban and resource use that are compatible within a clean healthy environment;
- areas where recreation will be available including access to public natural areas for passive uses and nature interpretation;
- active areas for swimming and fishing; and
- a ground water resource that is managed to ensure that it is clean and available for use.

2) The overall health of the West Credit Subwatershed has been defined as good, despite human activities. The broad-scale processes of surface hydrology, groundwater infiltration and discharge are still functional although in some cases impaired or modified by loss of upland forest cover. There are problems in some reaches with water quality impairment due to high coliform counts although the evidence suggests that this problem can be addressed through improved cattle fencing and spot checks of urban septic bed or septic tank leaks.

In Southern Ontario, the West Credit Subwatershed is somewhat unusual in having an almost contiguous stable riparian zone along its banks from mouth to headwaters.

However, some headwater sections have been impacted upon significantly by agriculture resulting in degradation to aquatic habitat. These riparian zones are made up of two major vegetative forms: forests and wetland/beaver meadows. (Other riparian forms include manicured lawns, residential properties and farm fields). Fortunately for the health of the stream and its valley, the forest and wetland zones are extensive with only small breaks in continuity. These breaks, caused by the three urban areas and several dams, have altered the movement and distribution of wildlife species and of fish communities. Wildlife species have been affected by the reduction of critical forest patch sizes, loss of volume and fragmentation; fish communities have been affected by changes in water temperatures, modifications in channel structure, impacts on water quality and in construction of dams.

3) Not all the recharge to the subwatershed discharges to the West Credit River. The average annual precipitation within the subwatershed is 850 mm per year, and average infiltration within the subwatershed is estimated to be 338 mm per year. The average infiltration contributing to baseflow is estimated to be 294 mm per year. The difference is approximately 13%, meaning that this water would discharge outside the West Credit Subwatershed to the main Credit River, within Subwatershed 18. Based on permitted water taking (actual water taking may be less than the permitted water taking) approximately 79 mm per year could be utilized for water consumption. Much of this water is discharged back to the shallow groundwater or to the surface water and is therefore not “lost” from the system.

4) Based on analysis of data from the stream gauge upstream of the Village of Erin, the peak flow rate associated with the two year storm is 3.9 m^3/s and for the 100 year storm is 9.2 m^3/s. Increased urbanization in the West Credit Subwatershed would increase the level of flooding particularly in the identified flood damage centres of Hillsburgh, Village of Erin and Belfountain.

5) The main branch of the West Credit River is perennial, which means it flows all year. Many of the smaller first order streams that feed into the main branch only convey water for a few weeks of the year. The main branch can be characterized as having little erosion and stable banks.

6) Two dams located on the West Credit at Church Street and Charles Street in the Village of Erin have been found to be structurally inadequate by current standards.

7) Approximately 15 % of the West Credit Subwatershed is currently covered with natural forests or tree plantations. It is important to protect those forested areas in the subwatershed that are of high value. Approximately 92% of the forested land in the subwatershed is either a high or medium priority for protection based on value (location, size, connectivity and condition, enhancing recharge to groundwater).

8) Wetlands currently make up about 14% of the subwatershed. They play an important role in controlling floods, removing contaminants and nutrients from overland and stream flows, and prevent erosion and facilitate recharge to groundwater in certain geologic settings.

9) The West Credit's riparian zone is unusual for Southern Ontario because of its contiguous length and width. The dominance of forests or wetlands along the banks ensures that bank erosion is held in check. In addition these wide riparian zones act as natural sponges, retaining nutrients that come from adjacent table lands. These zones also moderate flood flows by retaining water and releasing it gradually into the stream. This moderates the severity of floods including reducing impacts on aquatic habitats.

10) Notably, the West Credit contains wild self sustaining populations of brook trout. While many rivers in Southern Ontario have undergone drastic changes, much of the West Credit system and the coldwater fishery it supports have remained relatively unchanged. The presence of self sustaining populations of brook trout is an indicator of a healthy complex ecosystem with high quality ground and surface waters.

11) Limited sampling of aquatic invertebrates (water bugs) on the main branch of the West Credit and analysis of the types, varieties and numbers collected suggests that water quality is generally quite good.

12) There is evidence that the West Credit is polluted during the swimming season with *E. coli* which indicate high levels of fecal source pollution.

13) Recent data shows average stream temperatures of 19.5°C in the main branch of the West Credit, which is above the target of 18°C for healthy coldwater communities. Temperature impacts are attributed to ponds, groundwater impacts, land use impacts and loss of riparian cover.

14) The chloride concentrations in the subwatershed are 15-40 mg/L which is well below the provincial water quality objectives. However chloride concentrations have doubled over the past two decades.

15) Based on concentrations of total phosphorus and invertebrate species present, the West Credit Subwatershed can be classified as having good water quality. However some ponds in the lower West Credit appear to be well nourished based upon the presence of algae in the summer months.

16) Overall good water quality is maintained because of the extensive riparian vegetation and large amount of baseflow contributed by groundwater.

6.2 Recommendations

The following recommendations are made to support the Vision and goal statements established for the West Credit Subwatershed.

1) Establish an Implementation Committee to follow up on the implementation in the following areas:

- Land use Planning and Policy
- Stewardship and Education
- Rehabilitation and Retrofitting
- Monitoring
- Research and Development

The composition of the committee should include representation from the municipalities, CVC, special interest groups and members of the public.

2) The additional work and measures outlined in Chapters 3 and 5 should be implemented. A working group or subcommittee of the Implementation Committee with the necessary expertise, should be initiated in order to assess financial as well as technical needs and priorities over the long and short term. The following classification system of features, based on significant function, offers protection, enhancement and restoration opportunities for the West Credit Subwatershed:

6.2.1 Terrestrial, Riparian and Aquatic Systems

PROTECTION AREA 1 lands provide core natural areas and contribute to biodiversity and environmental integrity within the subwatershed. They also have a significant hydrologic and hydrogeologic function. Protection area 1 lands are important to maintain surface water and groundwater quality and quantities within the subwatershed. These areas also perform important ecological processes and protect biological diversity and life supporting systems that would be lost or degraded if such areas were permanently disturbed in any way. These areas must be protected from land use impacts. Protection area 1 lands include all wetlands, forested areas in or adjacent to wetlands, connecting corridors, areas with interior habitat, woodlots in Areas of Natural or Scientific Interest and in Environmentally Sensitive Areas, and forested land on recharge areas.

PROTECTION AREA 2 lands provide important secondary benefits in terms of wildlife habitat linkages to the Protection area 1 lands, and act as seed sources or nuclei from which revegetation efforts can build upon. Protection area 2 lands should be protected through stewardship programs, particularly where they are adjacent to streamland and valley corridor level 1 areas. However if land use change is proposed, these areas should be protected or replaced with equivalent features depending on the results of more detailed evaluation. These areas provide important ecological functions to the subwatershed and allow for the creation of new ecological features such as vegetative buffers, wetlands and linkages between vegetated areas and watercourses. If land use changes are proposed, subject to detailed studies in the form of an Environmental Impact Statement, some level of development may be permitted to alter the size and physical form of protection area 2 lands provided that ecological functions including hydrologic and hydrogeologic functions are protected and maintained. Protection area 2 lands include wooded areas with very little interior habitat and no corridor connectivity, and all unforested land with a high potential for recharge.

PROTECTION AREA 3 lands represent priorities for revegetation in a stewardship or rehabilitation context. Protection area 3 lands that are targeted for revegetation should be replanted with native species appropriate for the area and conditions. Degraded streams should be enhanced to buffer the effects of potential land use change. Protection area 3 lands include small unconnected pockets of woodlot with no interior habitat.

Upon considering the information provided by the other technical components in the study, and for the purposes of implementation, the riparian and aquatic system was prioritized into three categories based on the following criteria where information was available:

LEVEL 1 includes areas of coldwater fish habitat, probable coldwater fish habitat and wetlands adjacent to watercourses. Level 1 areas provide critical life support functions, such as spawning areas, discharge areas, special status habitat, nursery habitat, and the areas just upstream or downstream of such habitats. Flood plains adjacent to watercourses supporting coldwater fisheries are also assigned level 1 protection. Furthermore areas with solid riparian cover that provide shade to the river, and also provide corridors for terrestrial animals will be assigned level 1 protection. These areas must be protected from land use impacts.

LEVEL 2 includes all potential coldwater fish habitat and on line ponds. Level 2 areas provide habitat for various life stages and functions. Some of these areas could be upgraded to level 1 with rehabilitation and restoration. Maintaining the stability of these reaches is important in maintaining critical habitats in the long term.

LEVEL 3 areas include areas that provide fish passage, water passage and runoff conveyance. Intermittent streams are included in this classification. Level 3 areas help maintain water quality and have limited food production and provide little to no critical habitat for life supporting functions.

UNCLASSIFIED These areas have not yet been studied. If there are proposed land use changes adjacent or in these areas, further research would have to be conducted on fisheries and terrestrial habitat unless they are assumed or treated as level 1.

These areas have been shown on Figure 6.2.1. Various ways of protecting, enhancing and rehabilitating these areas have been discussed in Chapter 5.

An environmental monitoring program should be carried out that recognizes the principles of Adaptive Environmental Assessment Management. The major elements of this concept recognize the uncertainty when dealing with the natural environment and include the need to explicitly recognize uncertainty, be explicit in prediction techniques and most importantly learn from the management approach utilized. This concept supports the need to monitor appropriately, carry out evaluations and make changes accordingly. Monitoring techniques must recognize the importance of indicator and surrogates of environmental health as well as the need to utilize simple, repeatable procedures that can be carried out by a variety of persons (students, interest groups, residents, etc.) when appropriate.

Initiation of Phase II (impact analysis) should be considered if a certain proposed land use or land use management action is judged to be threatening to subwatershed functioning. Depending on the magnitude of the change, assessment could occur on a subcatchment basis. It should also be noted that not all tributaries have been assessed within this document due to lack of existing information. As a result, information must first be collected to characterize these tributaries before any impact analysis is carried out. In the event that development is proposed a review procedure should be jointly developed by the reviewer agencies.

6.3 Answers to the Questions Raised by the Public

The issues raised by the public and professionals lead to important questions that needed to be answered in the subwatershed plan study. These include:

1. What is the overall groundwater/surface water process and how do activities such as aggregate extraction or water taking affect water balance?

The overall groundwater/surface water process is characterized by the hydrologic cycle (see figure 2.3.1). Not all the recharge to the subwatershed discharges to the West Credit River. The average annual precipitation within the subwatershed is 850 mm per year, and average infiltration within the subwatershed is estimated to be 338 mm per year. The average infiltration contributing to baseflow is estimated to be 294 mm per year. The difference is approximately 13%, meaning that this water would discharge outside the West Credit Subwatershed to the main Credit River, within Subwatershed 18. Based on permitted water taking (actual water taking may be less than the permitted water taking) approximately 79 mm per year could be utilized for water consumption. Much of this water is discharged back to the shallow groundwater or to the surface water and is therefore not “lost” from the system.

The amount of aggregate extraction in the subwatershed will not have a significant impact on the water balance. In extraction operations above the water table, recharge is often enhanced since the water typically cannot "run-off" the site. In extraction operations below the water table the net difference between evaporation from the pond and evapotranspiration of the pre extraction vegetation is usually small. The only typical impacts are:

- During extraction when water must enter the excavation to replace the aggregate removed. This is the equivalent of pumping water out of the excavation and varies with the rate of extraction.

- If de-watering is conducted during extraction, which is unusual under current practices, there may be a significant impact.

- If the size of the post extraction pond was large enough to "flatten" the water table, causing localized impacts in water levels.

- Water taking in the subwatershed will have minimal impact on the water balance as basically all of the water goes back into the ground However care should be taken to locate wells so that local flow paths to sensitive streams are not disturbed.

1. How susceptible are groundwater supplies to water quality impacts and what protection is required?

Much of the groundwater recharge area is susceptible to water quality impacts, especially the shallower water table aquifer. The most susceptible areas are where the water table is shallow and the sand and gravel aquifer is exposed at ground surface.

Areas most susceptible will be shallow wells with any extensive pumping as this will more rapidly "pull down" surficial contaminants to the wells. Probably the wells most susceptible to contamination are the shallow wells in the southern portion of the Village of Erin where bedrock is near ground surface and any contaminants will migrate rapidly through the ground.

The key to protection is probably the following:

- characterize the resource, i.e. where does the water recharge and, how are the aquifers connected to the recharge areas

- develop capture zones for larger wells or well fields

- assess local and regional recharge areas

- inventory contaminant sources to identify what may be in capture zones and recharge areas

- develop guidelines / strategies for protection of groundwater and educate industries, general public, etc. as education likely works better than legislation initially.

1. What are the important environmental features and how can we protect them? (e.g. discharge and recharge areas, terrestrial habitats, aquatic habitats)

The important environmental features have been classified in the following manner:

An assessment of the terrestrial riparian and aquatic system in the West Credit Subwatershed can be found in Appendices D, E and F respectively. Upon considering the information provided by the other technical components in the study, and for the purposes of implementation, the terrestrial system was prioritized into three categories based on the following criteria:

PROTECTION AREA 1 lands provide core natural areas and contribute to biodiversity and environmental integrity within the subwatershed. They also have a significant hydrologic and hydrogeologic function. Protection area 1 lands are important to maintain surface water and groundwater quality and quantities within the subwatershed. These areas also perform important ecological processes and protect biological diversity and life supporting systems that would be lost or degraded if such areas were permanently disturbed in any way. These areas must be protected from land use impacts. Protection area 1 lands include all wetlands, forested areas in or adjacent to wetlands, connecting corridors, areas with interior habitat, woodlots in Areas of Natural or Scientific Interest and in Environmentally Sensitive Areas, and forested land on recharge areas.

PROTECTION AREA 2 lands provide important secondary benefits in terms of wildlife habitat linkages to the Protection area 1 lands, and act as seed sources or nuclei from which revegetation efforts can build upon. Protection area 2 lands should be protected through stewardship programs, particularly where they are adjacent to streamland and valley corridor level 1 areas. However if land use change is proposed, these areas should be protected or replaced with equivalent features depending on the results of more detailed evaluation. These areas provide important ecological functions to the subwatershed and allow for the creation of new ecological features such as vegetative buffers, wetlands and linkages between vegetated areas and watercourses. If land use changes are proposed, subject to detailed studies in the form of an Environmental Impact Statement, some level of development may be permitted to alter the size and physical form of protection area 2 lands provided that ecological functions including hydrologic and hydrogeologic functions are protected and maintained. Protection area 2 lands include wooded areas with very little interior habitat and no corridor connectivity, and all unforested land with a high potential for recharge.

PROTECTION AREA 3 lands represent priorities for revegetation in a stewardship or rehabilitation context. Protection area 3 lands that are targeted for revegetation should be replanted with native species appropriate for the area and conditions. Degraded streams should be enhanced to buffer the effects of potential land use change. Protection area 3 lands include small unconnected pockets of woodlot with no interior habitat.

Upon considering the information provided by the other technical components in the study, and for the purposes of implementation, the riparian and aquatic system was prioritized into three categories based on the following criteria where information was available:

LEVEL 1 includes areas of coldwater fish habitat, probable coldwater fish habitat and wetlands adjacent to watercourses. Level 1 areas provide critical life support functions, such as spawning areas, discharge areas, special status habitat, nursery habitat, and the areas just upstream or downstream of such habitats. Flood plains adjacent to watercourses supporting coldwater fisheries are also assigned level 1 protection. Furthermore areas with solid riparian cover that provide shade to the river, and also provide corridors for terrestrial animals will be assigned level 1 protection. These areas must be protected from land use impacts.

LEVEL 2 includes all potential coldwater fish habitat and on line ponds. Level 2 areas provide habitat for various life stages and functions. Some of these areas could be upgraded to level 1 with rehabilitation and restoration. Maintaining the stability of these reaches is important in maintaining critical habitats in the long term.

LEVEL 3 areas include areas that provide fish passage, water passage and runoff conveyance. Intermittent streams are included in this category. Level 3 areas help maintain water quality and have limited food production and provide little to no critical habitat for life supporting functions.

UNCLASSIFIED These areas have not yet been studied. If there are proposed land use changes adjacent or in these areas, further research would have to be conducted on fisheries and terrestrial habitat unless they are assumed or treated as level 1.

These areas have been shown on Figure 6.2.1. Various ways of protecting, enhancing and rehabilitating these areas have been discussed in chapter 5.

4. How is subwatershed health (particularly flows, erosion and habitats) linked to terrestrial resources (woodlands, wetlands and riparian vegetation) and what protection is needed?

The dominance of forest or wetlands along the banks of the West Credit River ensures that bank erosion is held in check. In addition, these wide riparian zones made up of forests or wetlands act as sponges, retaining nutrients that come from adjacent table lands. These zones also moderate flood flow by retaining water and releasing it gradually into the stream after storm events. Functionally this moderates the severity of floods including reducing impacts on aquatic habitats.

The value of forested lands varies depending on location, size, connectivity and condition. Approximately 92% of the forested land has been designated high or medium priority for protection. These areas which are located on groundwater recharge areas contribute significantly to the overall health of the subwatershed due to the baseflow contribution to local tributaries as well as the West Credit River. The high base flow quantities have been shown to contribute significantly to lower stream temperatures, improving assimilative capacity as well as maintaining riparian vegetation.

5) *How healthy is the fishery and how can we maintain or improve it?*

The West Credit River contains wild, self-sustaining populations of brook trout. While many rivers in southern Ontario have undergone drastic changes, much of the West Credit system, and the fishery it supports have remained unchanged. Localized changes such as on-line ponds, dams, urbanization and other disturbances have reduced the distribution of brook trout. Other coldwater fish found in the subwatershed include rainbow trout brown trout, and mottled sculpin. Warmwater fish found include yellow perch and largemouth bass.

Biomass studies (total amount of living organisms in a stream) show that the biomass estimates are among the highest in southern Ontario. The target species for fisheries management in the subwatershed should be the brook trout. It is a self sustaining native species, and its habitat requirements are the most stringent of all species found in the subwatershed. Protecting groundwater discharge to streams will be vital for their survival. For other protection, enhancement and restoration opportunities, see chapter 5.

6) *What impact do existing ponds have on water quality processes in the streams?*

Existing on-line ponds that are not equipped with bottom draw outlets, have contributed to elevated water temperatures. In addition, they act as sediment traps and as such can capture any contaminants that are attached to the sediment particles. This, together with the flow modification caused by the control outlets, have resulted in sediment imbalances and precipitated erosion downstream which can affect overall water quality.

Eutrophication is the process of nutrient enrichment in aquatic systems. Based on concentrations of total phosphorus and invertebrate species present, the West Credit's streams can be classified as having good water quality. However, some on-line ponds in the lower portion of the subwatershed appear to be high in nutrients based on the presence of algae in summer months.

7) *What is the most effective approach to control coliform counts to an acceptable level and is it feasible?*

Significant contamination of the West Credit by private sewage systems appears to be mainly centred below the Village of Erin, and only during wet weather conditions. This would suggest that the flow pathway is probably from septic systems close to the river or other drainage systems such as roadside ditches which would convey runoff to the West Credit River during rainstorms. There is no evidence in the work done to date that would suggest that the regional aquifer has been contaminated. Further investigation is warranted in order to identify those septic systems which need to be dealt with to correct this problem.

8). *What is the long term potential impact of aggregate extraction on flow regimes and water quality?*

It is anticipated that the impacts will be minimal given the extent of extraction in the subwatershed to data and general impacts seen elsewhere, where areas of extensive aggregate extraction are not present. Should additional areas of extraction be identified then the subwatershed planning process should continue into Phase II (Impact Assessment). There is little documented evidence of significant changes in water quality, such as temperature at any distance from extraction operation.

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GLOSSARY

7Q2 - The 7 day average low flow that recurs on average every 2 years. It represents a period of stress on the system that causes some reduction of populations, and thus loss of some productive and reproductive capacity.

3Q2 - The 3 day lowest flow over a two year period. It represents a period that causes minor stress on the system.

AEAM - Adaptive Environmental Assessment Management - an approach to environmental management aimed at improving understanding of the ecosystems being managed, the institutions charged with their management, and the coupling of the two.

ANSI - Area of Natural and Scientific Interest

Char - A fish belonging to the family *salmonidae* which also includes trouts and salmons.

Cumulative Impacts - The sum of all individual impacts occurring over space and time including those of the foreseeable future.

D^{50} - The average size of sediment in a stream bed.

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

ESA - Environmentally Sensitive Area

Ecosystem - Systems of plants, animals and micro-organisms together with the no living components of their environment, related ecological process and humans.

Fascine - A wired bundle of live twigs planted strategically to help check an erosion problem. Can also provide as fishery habitat if planted adjacent to a watercourse.

Fluvial - Relating to a stream or river.

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

Hydrogeology - The scientific study of groundwater.

Hydrology - The scientific study of surface water.

IBI - Index of Biological Integrity - Mathematical formula using the number of fish caught and species diversity to give an indication of the health of the fish community.

Lunker - A structure secured to a river bank which overhangs the water and hence offers protective cover for fish.

Mitigation - Includes prevention, modification or alleviation of impacts on the natural environment. Also includes any action with the intent to enhance beneficial effects.

Morphology - see geomorphology

Physiography - Study or description of landforms

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

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

Rehabilitation - To restore the ecosystem to a higher functioning condition.

Seepage - Slow oozing of groundwater onto the earth's surface, as distinct from the more pronounced flow of a spring.

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

Thalweg - The line joining the deepest points along a river.

Terrestrial - Living on or growing on land.

Vortex Weir - Stratigically placed rocks set in a watercourse whose purpose can include, but is not limited to, taking erosion stress off banks, increasing sediment transport capacity, and providing grade control in a watercourse.

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